ELECTRONIC NOSE: FOR SPOILT MILK DETECTION

By

MUHAMMAD AIMAN BIN JAMALUDDIN

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfillment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
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Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved:

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Your Supervisor's Name
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

December 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Muhammad Aiman Bin Jamaluddin

ABSTRACT

The main objective of this project is to build an electronic nose and implement it for desired application. This report is about the study of an electronic nose and its application to differentiate between the spoiled milk with fresh milk. Electronic nose is an electronic instrument that imitates the function of human nose to detect the smell, odors and flavor. Electronic nose has a wide range of applications where one of them is to discriminate foods by their quality. By using an electronic nose, it is possible to differentiate between fresh milk and spoiled milk without even have to risk our health to taste it by ourselves. The milk where it contains certain type of micro bacteria undergoes certain chemical processes which cause it to spoil and release certain gas as results of the process. The scope of this project is to do research about electronic nose, building an electronic nose for our application and perform a data analysis. The method is explained further inside this report and experiment were done to validate the findings in literature review. The experimental results are presented.

ACKNOWLEDGEMENT

The author would like to take this opportunity to express his utmost gratitude for the individual that have been putting so much effort to help author to finish this project.

First and foremost, the author would like to thank to AP. DR. Tang Tong Boon for his work on doing his job to supervise the author. The author also would like to share gratitude with those who was involved directly or indirectly during this project.

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INTRODUCTION

PROJECT BACKGROUND

Imagine a world where everything is done electronically, a world where people living their life with easy helps from computer, robot and machine. Over these past few years, many scientist, researchers and engineers have been trying to build a sensing system by applying the same concept of human senses like touch, see, hear, taste and smell. Usually, the devices developed by them are named after the part of human body that acts theoretically the same as their application with the addition of the word 'electronic' in front. For example, electronic nose (E-nose) use the same concept of nose which is smelling or electronic tongue (E-tongue) that work as a taste sensor. These sensors function is basically not as realistic as the real human body part functions; it is just that they detect chemicals or organic compound by different method such as sensing a gas, sensing a pH value, sensing a light and a lot of other methods. By sensing these kinds of elements, the sensor will produce the data and this is where data analysis plays a main part to classify, distinguish and discriminate the sensed objects.

For our project, what the author focus is to build an E-nose sensor and test it to detect the spoiled milk. By detecting a specific gases coming out from spoiled milk, it is possible to have our E-nose to differentiate between the fresh milk and spoiled milk.

PROBLEM STATEMENT

A lot of complains have been issued by customers around the world about spoiled food, contaminated drinks, food poisoning due to the incorrect expired date shown on the packages or affected by bacteria. Most of the cases are when the customer eats or drinks without noticing the food and drink was spoiled before. Expired date play a very important role in this scenario and the only thing customer could do is to trust on that date. But the author might found a several cases where even before the expired date the food is spoiled already. It is not about not trusting the expired date but to be more cautious, the author is thinking of inventing a system to detect the spoiled food. This system applies the same concept of nose and tongue, where the detection of the spoil by sensing the food or drink with precise data analysis to determine whether the food is spoils or not could be performed. The author calls it E-nose and E-tongue.

OBJECTIVES

The author's main objective is to study about electronic nose, build it and implement it for our desired application. To achieve that there are sub-objectives that need to be considered to be achieved one by one before achieving the main objective.

- To do literature review about E-nose
- To design and implement an E-nose
- To integrate the E-nose with data acquisition system
- To analyze the data and make a conclusion

SCOPE OF STUDY

Author's project does cover on a very wide range of applications. The focus is only on certain things to make sure our goal is achievable. Below are the scopes of the project.

- Do research about E-nose that focused more on detecting spoiled milk
- Research for a suitable sensor
- Develop a simple E-nose with appropriate function for this project
- Data analysis

RELEVENCY OF THE PROJECT

Food industries have specific influences to health care of every household. Their product quality is very crucial at the moment where it could cause food poisoning and unhealthy life style for the customers if it is bad. A lot of researches have been done to have a system where it could control this quality. It includes a lot of sensors and data analysis. So, this project is relevant in a way that we develop a sensor that act as a nose to detect the spoil milk without even having human being to risk their health to taste it themselves.

FEASIBILITY OF THE PROJECT

The project is feasible where the author could refer to a lot of researches done before this about an E-nose. To be more specific, chemically, the spoiled milk has some characteristic that cause it to release gas when it is spoiled. So this gas is the important factor to have the sensor to detect and produce some data to be analyzed in computer. The main challenge is to build the sensor and to transfer the data from the sensor into the computer.

LITERATURE REVIEW

Talking about E-Nose, there a lot of researches done to fabricate, study, applies and analyses the data from the E-nose itself. There a lot of applications of E-nose such as quality control of foods, volatile organic compounds detector and many others. A review done by Amalia Berna under the topic of “Metal Oxide Sensors for Electronic Noses and Their Application to Food Analysis” states that the E-nose is an electrical sensor that consist of arrays of metal oxide semiconductor (MOS) sensors [1]. It is a system where these MOS arrays are sensitive toward specific compounds depends on what substance they were fabricated. This E-nose is very sensitive and applicable to detect the freshness of the meat, fish, alcoholic drink, milk and dairy products. She also reviewed that most of the data obtained from the commercial sensors which she focused on, were usually plotted and been analyzed on principal-component analysis (PCA) plot.

In a literature wrote by Martyna Kuske et al. [2] stated that the E-nose can be used to detect microbial volatile organic compound (MVOC). He also stated that the E-nose is sensible to nearly all compound and are already in used in food industry such as to discriminate different coffee, detect spoil fish and classifying cheese. Other than E-nose, E-tongue also plays a very important role in food industry. Usually, most of the researches done before were using both E-tongue and E-nose to analyze the foods. F Winquist et al. [3] in his researches under the topic of “Combination of an Electronic Tongue and Electronic Nose” used both of these sensors to improve the classification properties between experimental samples. He added more that it is possible just by having E-nose or E-tongue alone is enough to discriminate the samples but combining both of these sensors would take a lot of effort to have a data analysis together.

The E-nose has a very wide application. The most common application of E-nose that is commonly used to be heard and observed is usually to identify the adulteration of foods, discriminate different type of foods, detecting bacteria produced from foods, detecting volatile organic compound, determining the aging of foods and a lot more. For example, from an article written by Yu H.C et al [4], under the topic of "Identification of Adulterated Milk Using Electronic Nose", by using E-nose (PEN2) which contains 10 different MOS sensor, a certain amount and type of milk which stored for 7 days and adulterated with different volume of water were examined. The result is plot on principal-component analysis (PCA), linear-discriminant analysis (LDA) and probabilistic neuronal network (PNN). By these plots, the E-nose has a capacity to discriminate the purity of milk and also determined the aging of the milk.

The important part of the E-nose application is the data analysis. There are a lot of methods to do data analysis; principal-component analysis (PCA), linear-discriminant analysis (LDA) and differential pulse-voltammograms (DPVs). Inside a literature of "Discrimination among milks and cultured dairy products using screen-printed electrochemical arrays and an electronic nose" written by W.A Collier, D.B Baird, they generate the data to do the analysis by using differential pulse voltammetry [5] and by this method it is possible to discriminate among dairy products, milks and yogurt. Not only for dairy products, milks and yogurt, an E-nose also has a capability to discriminate among wine. M. Garcia et al, use an electronic nose based on metal oxide semiconductor thin-film sensors to characterize and classify several type of wines which come from variety of grapes and from the same cellar [6] by using specific method. The E-nose responded to the presence of the volatile compound in the wine. To achieve their objective, two method of recognition were performed to analyze the data; PCA and probabilistic neuronal network (PNN). There are also studies about how E-nose could assess the quality of a beer [7] which prove to us that E-nose has a wide application in foods industries.

Another famous application of an E-nose is it has the capability to monitor the aging of milk and beer by detecting its volatile compound. S. Lebrache et al, determined the shelf life of a milk by using and E-nose [8] where they analyze the the milk which was stored at an ambient temperature and at constant 5°C temperature at different time. By performing some mathematical method that represents a milk-shelf life, the aging of the milk were determined. Different method were done by S. Capone et al [9] using an electronic nose to determined the aging of the milk.

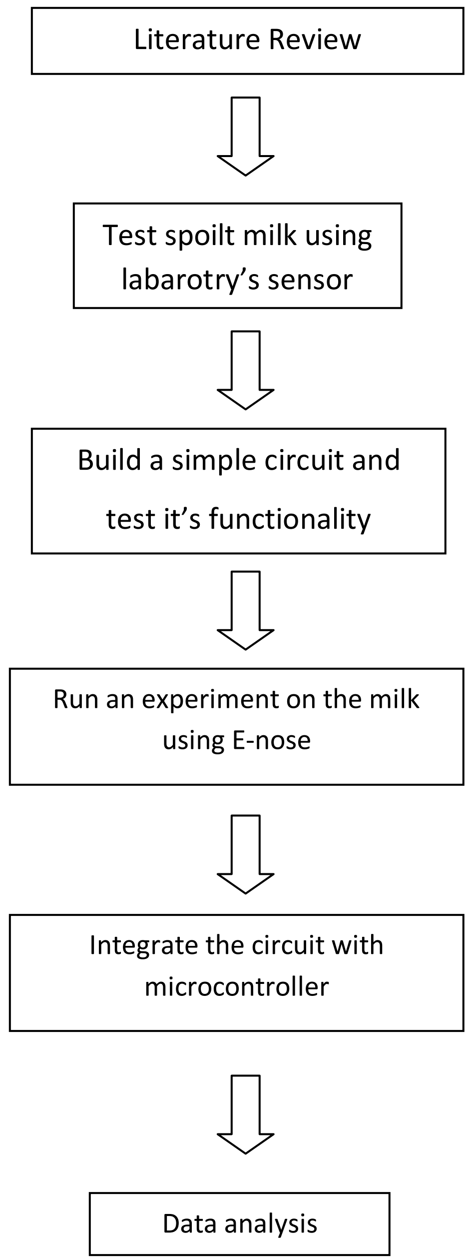
For the project, the author did a literature review about the milk itself. Since the milk is our experiment subject, it is important to have a sufficient knowledge about the milk. There are a lot of researches have been done to study what cause the milk to spoil. One of the studies states that there are bacteria of lactic acid present in the milk and are the main cause of it to spoil. The process of which the bacteria convert the lactose into glucose results in producing of lactic acid are form inside the milk is where it is called fermentation process. H Ledenbach and T Marshal [10] in their study of microbiological spoilage of dairy product stated that this process causes the production of lactate, ethanol and carbon dioxide gas. For the raw milk, there are some kind of enzymes present and cause the milk to smell bad if it is spoiled. Because of this characteristic, it is possible by using E-nose the author could distinguish between spoiled milk and fresh milk.

M Kihal et al in his research under the topic of "Carbon Dioxode by Lueconostoc mesenteroides grown in single and mix culture of Lactocuccus lactis in skim milk", add some chemical inside a milk to study the growth of carbon dioxide gas in a skim milk [11]. Based on his experiment results that had been carried out for 24 hours long, the growth of carbon dioxide was somehow reduced when adding some sort of chemical inside the milk, whereas the growth was increasing when added some other chemical. He also observed the changing of pH value for during the effect of both chemicals added inside the milk. The point here is not about reducing or increasing the growth of carbon dioxide, it is that the author wants to proof that there was a research been done where it is known that the milk produce CO2 gases and can be captured to be measured. Inside this paper, the author also referred to the results inside this literature by M Kihal et al and compares it with the results obtained during the experiment.

To detect a gas coming out from the spoiled milk is not that simple. Usually what is needed is a very small closed space without air outside to flow through. If the carbon dioxide gas is restrained inside a small space, the gas might undergo redox reaction to form a carbon monoxide gas ($CO_2 + 2\ e^- + 2H^+ \rightarrow CO + H_2O$). The process is usually really slow and difficult to occur but it is possible for a long period of time. So, to build an electronic nose the author sees that it should not be just only to stick with one gas detector. It would be best if we combined a lot of detector and do data analysis to have a better results and conclusions.

RESEARCH METHODOLOGY

To complete the project, there are steps need to be followed. Below are the steps that the author followed during the whole project period



GANT CHART

No	Detail / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Order and buy components	■	■	■	■	■	■	■	■	■					
2	Built a circuit							■	■	■	■	■	■		
3	Progress report								★						
4	Experiment on spoilt milk							■	■	■	■	■	■	■	
5	Integrating the circuit									■	■	■	■	■	
6	Pre-EDX											★			
7	Viva													★	
8	Final Report														★

Figure 1.1: Gantt chart for the final semester project implementation

■ Processes

★ Milestones

EXPERIMENT

For the experiment part, the author divides it into 3 parts. The first part is to investigate the gas released by the spoilt milk, the second part is to build and test the gas sensor functionality and the last part is to run the experiment on the milk using E-nose.

Part 1

In order to see whether the project is feasible according to the knowledge that author gained in literature review, an experiment were done by using an existing gas sensor to detect the presence of gas produced by spoiled raw milk. The readings were taken at 3 different period of time for every minute and stop when the sensor sounds an alarm as a signal to inform us that the readings exceed the threshold. The apparatus was set up as in figure below.

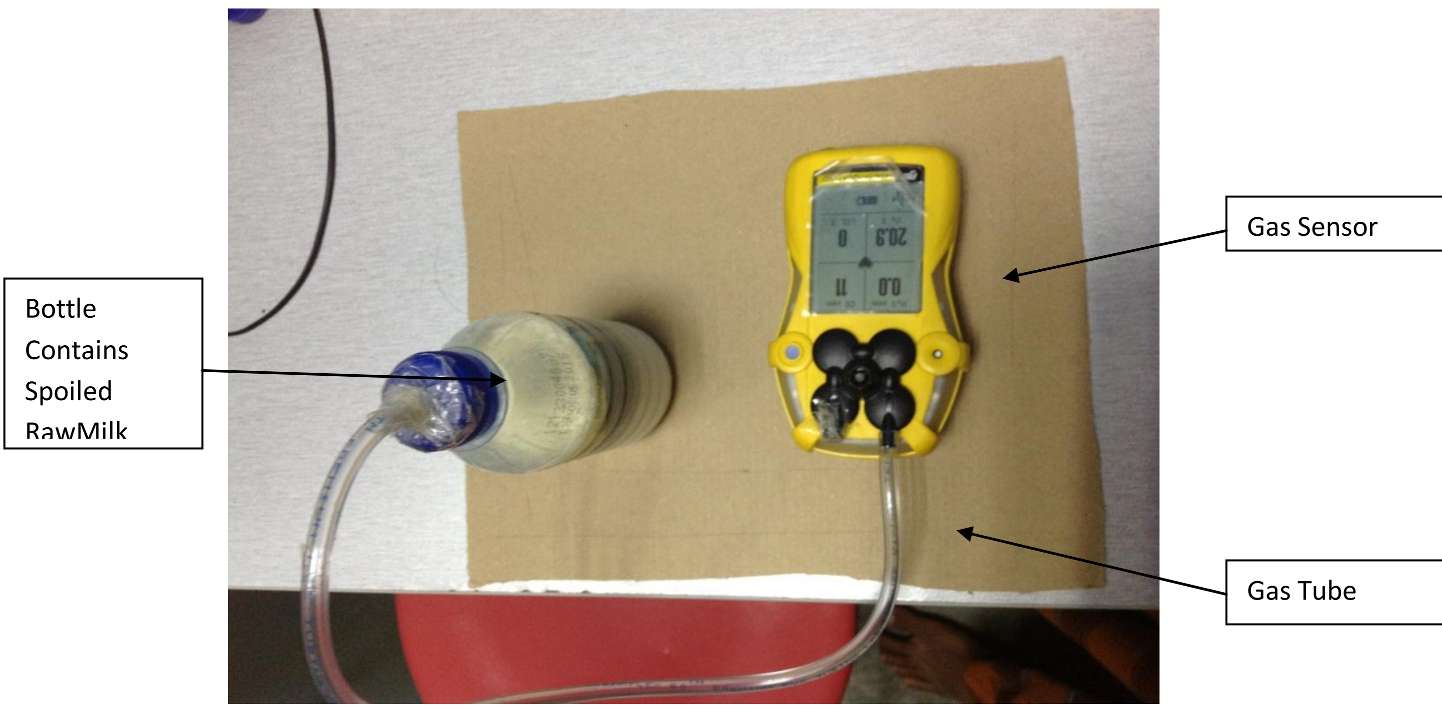


Figure 2.1: The set up of the apparatus for the experiment

Tools

Below are the tools involve during this experiment

1. Gas Alert Quattro BW technologies by Honeywell

Sensor Specifications

Gas	Measuring Range	Resolution
Hydrogen sulfide (H_2S)	0-200 ppm	0.1 ppm
Carbon monoxide (CO)	0-1000 ppm	1 ppm
Oxygen (O_2)	0-30.0%	0.1%
Combustible gases (%LEL)	0-100% LEL 0-5.0% v/v	1% 0.1%

Figure 2.2: The gas sensor and its specification

2. Bottle
3. Gas tube
4. Spoiled raw milk

Results and Findings

The tests were conducted in a room temperature after the milk is completely spoiled where the milk produced a sour, bad and rancid smell. After the author saw that there are concentrated white solid forms on the milk and the bottom of the milk is almost become clear instead of yellowish white, the assumption was made that this milk is completely spoiled. This is due to the fermentation process occurred inside the milk. Before the milk was spoiled, the author also has conducted a test to capture the gas and take the reading. Unfortunately, for a straight 2 hours, there was no reading on the gas sensor. So, author assumed that if the milk was not spoiled yet, it did not produce an amount of gas that is detectable by the sensor.

Before conducting the experiment, there are actions that the author takes precautions on in order to get the best results. Below are the actions taken before the author was conducting the experiment.

- Make sure the bottle cap is tightly closed
- Make sure that the sensor is set back to normal condition first before starting next test
- Make sure that the connection of the gas tube with the bottle cap is secured; without any air flow in between of them.
- Make sure that the gas tube is completely clean from the outside contaminant and clean from the gas from the test conducted before.

Test 1

Below is the result obtained for the 1st test. The reading taken stop when carbon monoxide parts per million (ppm) exceeds 35ppm. The sensor was switched off.

Time	CO(ppm)
12:12pm	0
12:13pm	13
12:14pm	17
12:15pm	19
12:16pm	20
12:17pm	22
12:18pm	28
12:19pm	31
12:20pm	34
12:21pm	37

Table 1: Result for Test 1

From this experiment result, the author saw that the spoiled milk released a small amount of carbon monoxide gas. At the time of 12:12pm, the reading is zero which is not because of there is no production of CO gas. It is because the gas took some times to flow through the gas tube to reach the end of the tube which is exactly on the surface of the sensor. For every 1 minute the reading were took and it can be seen that it is increasing by time.

<u>Test 2</u>

After the author has conducted the 1st test, the bottle cap with the gas tube was opened and been replaced with a cap without the tube. This was done to let the gas to completely flown out from the gas tube and to let the 'auto zeroing' of the sensor to take place. After 3 minutes, test 2 was ready to start, the reading were taken for every 1 minute. The sensor sounds an alarm when the carbon monoxide reaches the threshold value. Below are the results for the 2nd Test.

Time	CO(ppm)
12:25pm	0
12:26pm	0
12:27pm	0
12:28pm	7
12.29pm	11
12.30pm	12
12:31pm	12
12.32pm	12
12:33pm	14
12:34pm	13
12:37pm	14
-	
12:42pm	14

Table 2 : Result for Test 2

From this experiment it can be seen that the concentration of carbon monoxide gas is low compared to before. As the author observed, the concentration of CO (ppm) at time 12:25pm until 12:27pm is zero. The CO gas took a longer time than before to reach the end of the gas tube where the sensor at. This is because during the opening and closing of the bottle cap, the gas might flow out from the bottle and cause the concentration of CO gas to decrease. But still, the readings were obtained and from time 12:37pm to 12:42pm, the reading of CO (ppm) stayed constant.

Test 3

This last test were conducted 2 days after the 1st and 2nd test were conducted. Below is the result for the 3rd Test.

Time	CO(ppm)
9:50pm	0
9:51pm	23
9:52pm	24
9:53pm	25
	27
	31
	32
	33
	34
9:54pm	35
	36

Table 3: Result for Test 3. Yellow color represents the reading taken for every 10 seconds.

From this experiment, by observing this result, it is obvious that after 2 days the concentration of CO gas increased. Between 9:53pm to 9:54pm, the reading increase drastically every 10 seconds.

Findings

The 3 tests conducted were using the same gas sensor. This gas sensor made by Honeywell has the capability to detect 4 types of different gas as stated on its specification in figure 2 above. During all of the 3 test conducted, the reading of hydrogen sulfide gas (ppm), combustible gas (%) and oxygen gas (%) was not change. The readings of hydrogen sulfide gas constantly zero, same for the combustible gas, whereas the reading of the oxygen gas is always constant at 20.9%. To be logic, if there is a percentage of CO_2, the percentage of O_2 should be decrease. But, referring to the specification of the sensor in figure 2, the resolution for detecting a percentage of O_2 gas is 0.1% which is very big to detect the small change of percentage of CO_2 gas. The resolution need to be at least 0.01% to detect the changes of the concentration of the CO_2 gas.

Part 2

For the 2nd part, the author ordered 2 types of gas detector electrical component which are TGS2442 for the detection of carbon monoxide gas and TGS2600 for the detection of air contamination. Below are the pictures of the gas detector that is used to build the circuit.

Figure 2.4: TGS2442 for detection of the carbon monoxide gas

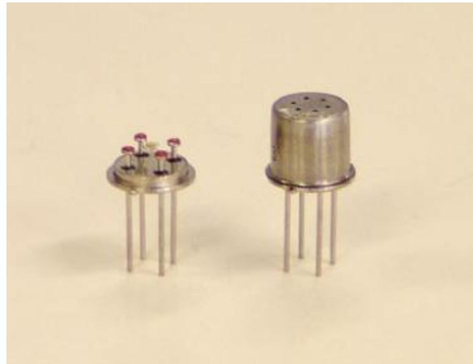


Figure 2.5: TGS2600 for the detection of air contamination

Both of these components have their own datasheet and schematic circuit diagram design. The author referred to the given schematic diagram to build the circuit. Since for the TGS2442 required a microcontroller chip to complete the circuit, the author started to build the simple circuit first using TGS2600 which has simpler schematic circuit diagram. Below are the picture of the circuit built and its schematic diagram.

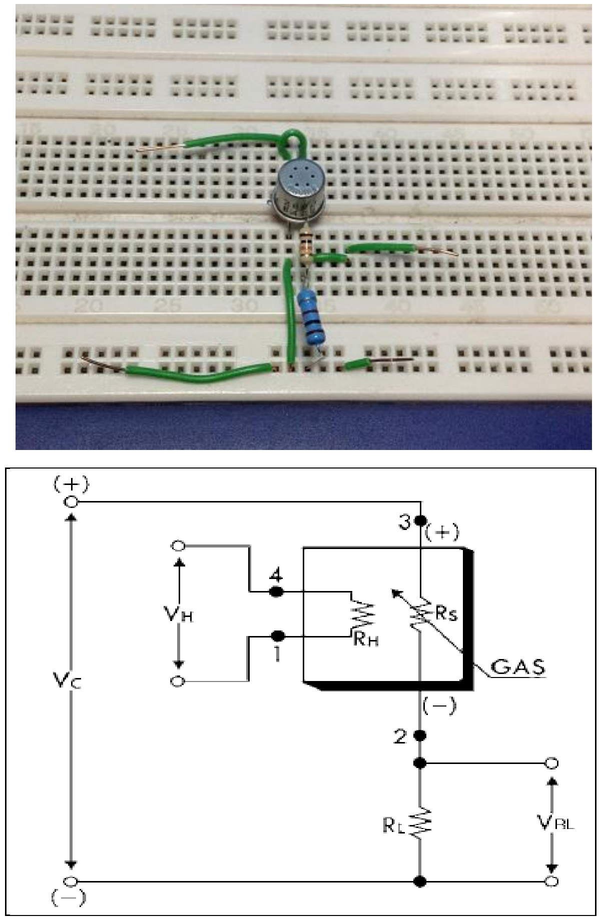


Figure 2.6: Electrical circuit with the schematic diagram

A 5V DC voltage was drawn from power supply to supply the circuit. It was connected to 2 voltage inputs: Vc and Vh which are shown inside the circuit diagram above. The load resistance (RL) was chosen to be 11kΩ. The measurement was taken at output voltage (Vrl) and from that value; sensor resistance (Rs) can be calculated in order to see the concentration of gas captured. Below is the picture of how the experiment was set up.

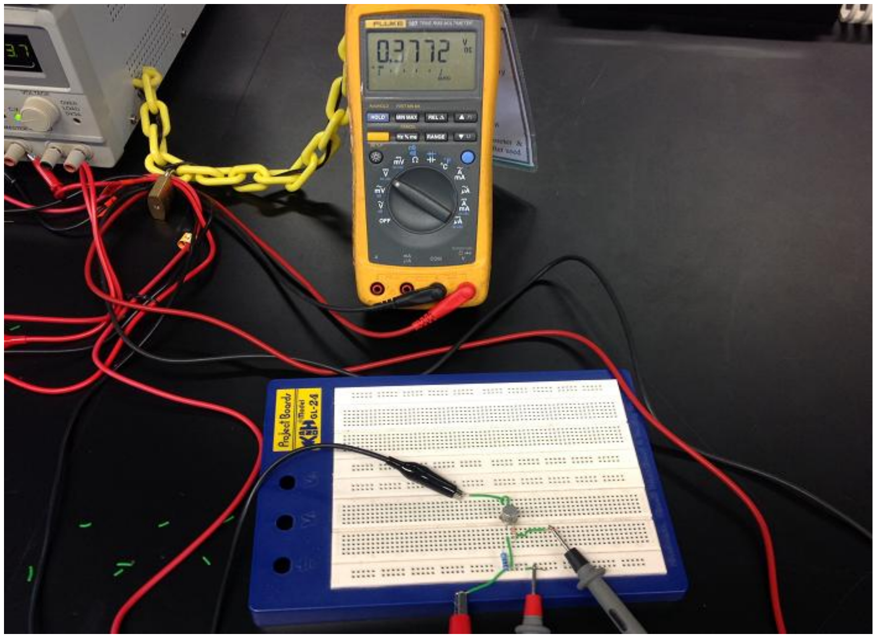


Figure 2.7: The 2nd part experiment set up

Results and Findings

As for the beginning of this experiment, the author was just concentrating on to see whether the circuit is function or not. Since the main use of this sensor is to monitor air quality, the author would like to see any changes happened to the output voltage of the circuit if it is blown by a little bit of air from surrounding. But, because the experiment was done in the lab, the author would have to blown the circuit by himself to check the reading on the multi-meter. The reading on the multi-meter was captured one time before the blow, two times during the blow and one time after the blow. Below are the pictures and the reading of the multi-meter for each part.

Reading Captured	Analysis
	Reading : 0.215V The reading was captured before the blow and it is not constant but varies around this voltage level.
 	Reading : 0.1945V, 0.1782V The reading was captured during the blow. As the author saw, the reading was decreasing and 2 pictures were taken to see the changes. The reading passed through 0.1945V and 0.1782V.
Reading Captured	Analysis
	Reading : 0.1803V The reading was captured after the blow. As the author saw, the reading was increasing back to its original reading. From below than 0.1782V, increase passed through 0.1803V.

Based on these reading, the author could calculate the sensor resistance (Rs) to see the concentration of the gas involved. Since the author did not have a specific sample of gas to be used, the calculation part was not necessarily done. Below is the expression to calculate the value or Rs;

$$R_S = \frac{V_C \times R_L}{Vout} - R_L$$

When we got the value of Rs, by referring to the graph below obtained from the sensor datasheet, we can see the concentration of the certain gas in ppm.

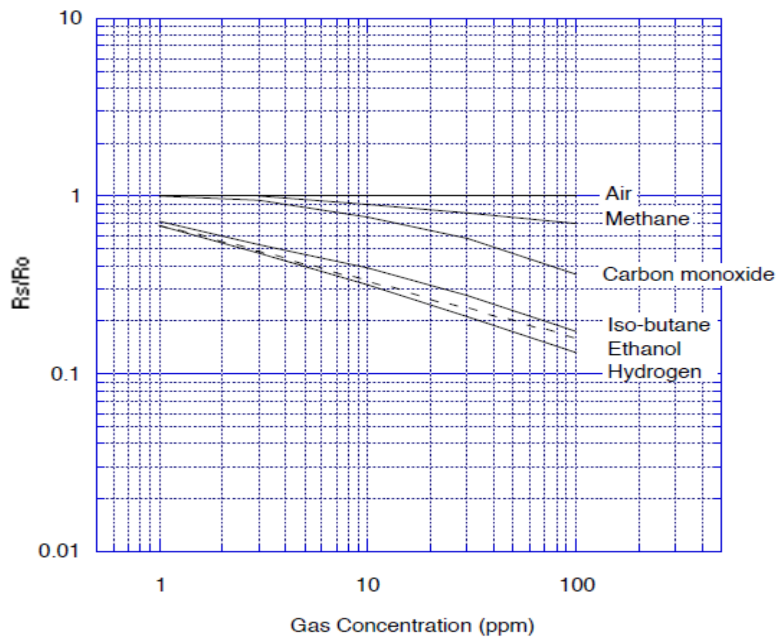


Figure 2.8: Sensor resistance against gas concentration (Ro = sensor resistance in fresh air)

Part 3

In this part, the author used a sensor that is very sensitive towards carbon dioxide (CO_2) gas. This sensor was used to measure the concentration of the CO_2 gas that was produced by milk. The test has been conducted 4 times for an average time of 5 hours for each run. The 1st test is on the unpasteurized fresh milk, 2nd is on unpasteurized spoilt milk, 3rd is on pasteurized fresh milk and the last one is on the pasteurized spoilt milk. Figure below is how the experiment was set up.

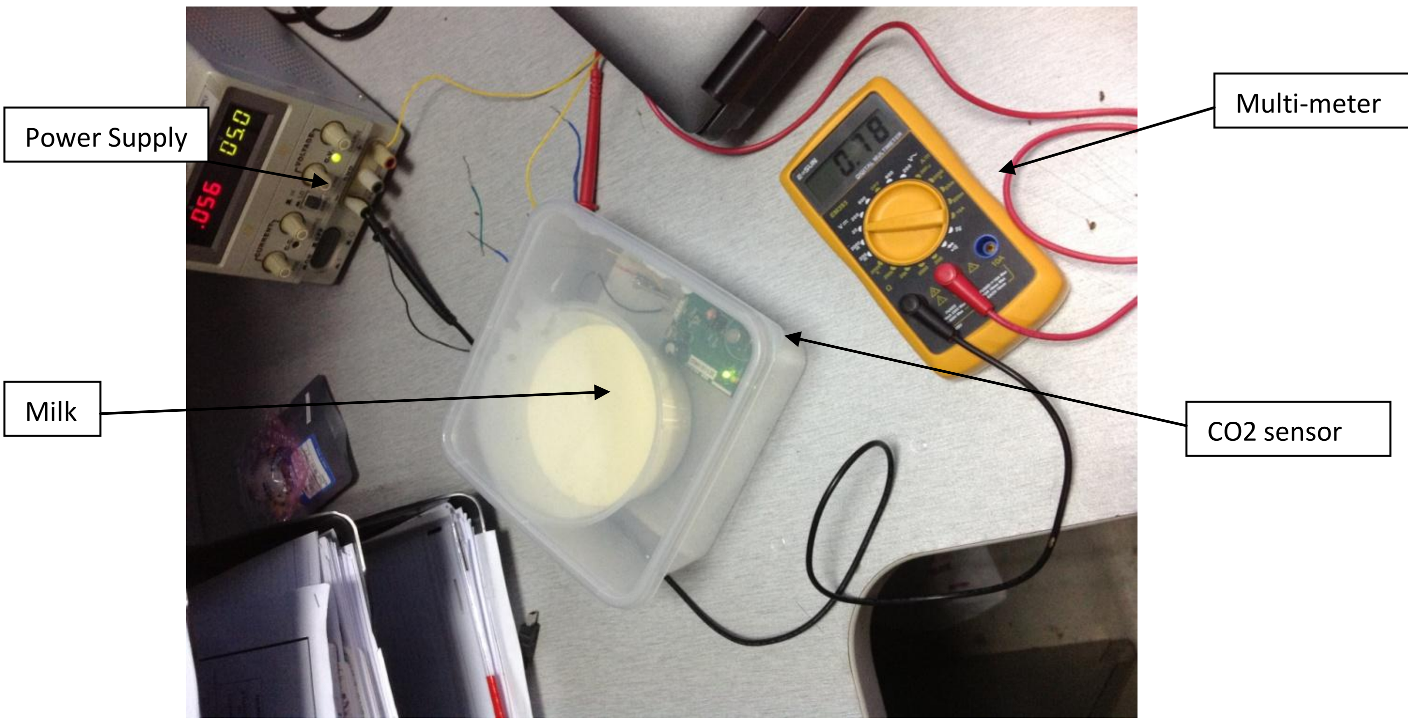


Figure 2.9 : The experiment set up for the 3rd part of experiment done for this project

Tools

In this experiment, the gas sensor used is called CDM4161 by Figaro which used a gas detector named TGS4161 that is sensitive towards CO2 gas. This sensor is powered up with 5V direct current voltage and has 1 voltage output pin and 2 control output pin. The readings of CO2 gas concentration were taken at the voltage output pin. Below are the specifications of the sensor.

Model No.	CDM4161
Target gas	Carbon dioxide
Detection range	ambient ~ 4,000ppm
Sensor	TGS4161
Principle	Solid state electrolyte
Power supply	5.0±0.2V DC regulated
Operational temperature and humidity	-10~+40°C, 5~70%RH (avoid condensation)
Storage temperature and humidity	-20~+60°C, 5~90%RH (pack in a mositure proof bag)
Warm up time	2 hours
Response time (90%)	approx. 2 minutes
Accuracy	approx. ±20% full scale (Note 1)
Expected lifetime	10 years under normal conditions (Note 2)
Signal update	every second
Power consumption	max. 300mW
CO2 concentration signal	0~4V DC = 0~4,000ppm (Note 3)
Control signal	ON: CO_2 conc. exceeds threshold OFF: CO_2 conc. decreases to 90% threshold
Malfunction signal	OFF: Float (NC) ON: LOW output
Dimensions	45 x 60 x 19mm (45 x 67 x 30mm incl. CN1)
Weight	approx. 17g

Figure 2.10 : sensor's specifications

This sensor has 4 operation modes; warm up period, CO2 concentration lower than calibrated concentration, C02 concentration exceeds the calibrated concentration and trouble mode. Each of these modes gives different signal for the 3 LEDs; red, green and yellow to turn on or off or blink. Below are the details.

Condition	Green LED	Yellow LED	Red LED	Control signal (CTRL)	Trouble signal (TRBL)	CO_2 conc. signal
Warm up period	Blink ON/OFF	OFF	OFF	OFF	OFF	0.4V
CO_2 Conc. < Threshold	ON	OFF	OFF	OFF	OFF	CO_2 conc./1000V
CO_2 Conc. ≥ Threshold	ON	OFF	ON	ON	OFF	CO_2 conc./1000V
Trouble	ON	Blink ON/OFF	OFF	OFF	ON	HIGH

Figure 2.11 : Signal output in operation mode

Results and Findings

<u>Unpasteurized Fresh Milk</u>

For this run, the author can see the growth of carbon dioxide gas. The concentration is increasing over time and at some point the production rate of this gas become slower and slower. Below are the results for the unpasteurized fresh milk.

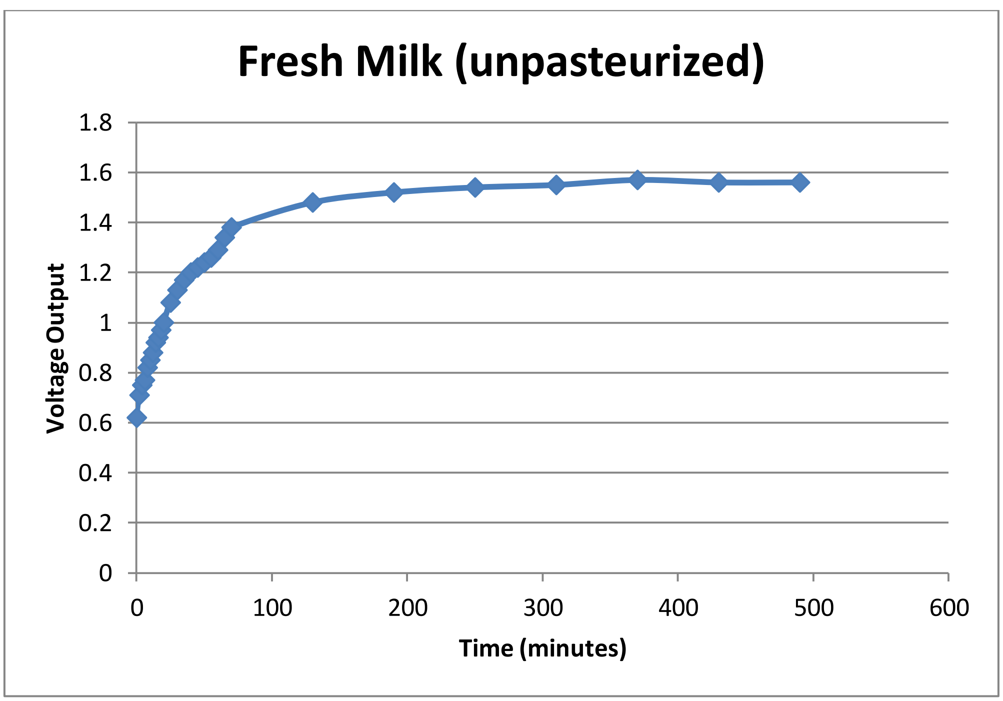


Figure 2.12 : Voltage output reading over time for unpasteurized fresh milk

Pasteurized Fresh Milk

This run is the same as the unpasteurized milk. The different is the gas concentration is not as high as the unpasteurized milk which is below than 0.9V. Below are the results.

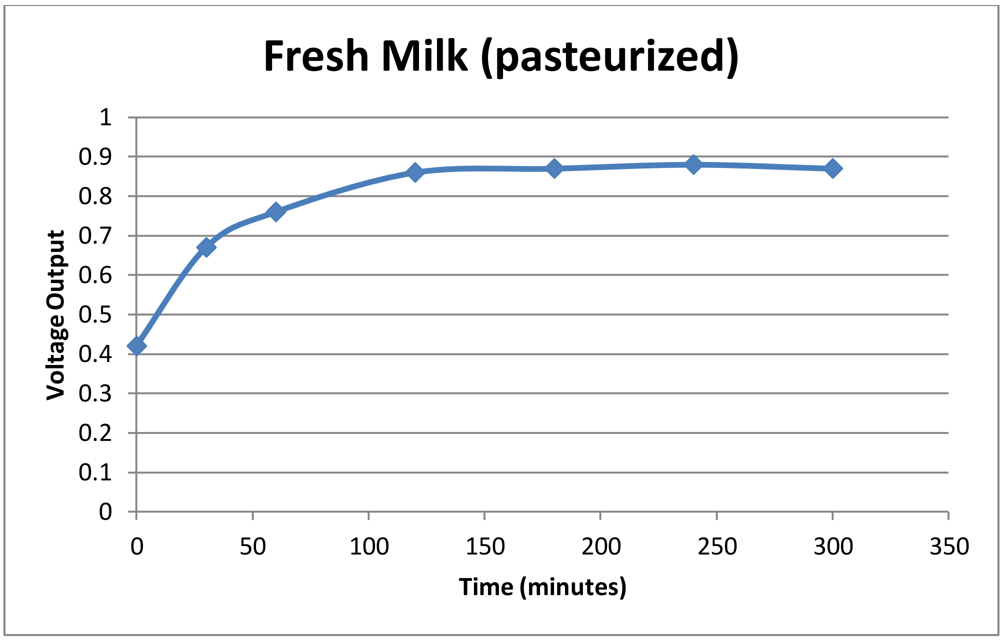


Figure 2.13 : Voltage output reading for pasteurized milk

Unpasteurized and Pasteurized Spoilt Milk

For this part, the milk used to be tested has been made sure it was totally spoilt. The spoilt milk in author definition is when the color of milk is yellowish, smell sour, taste sour and lumpy with two or more layers are form just like in the figure below.

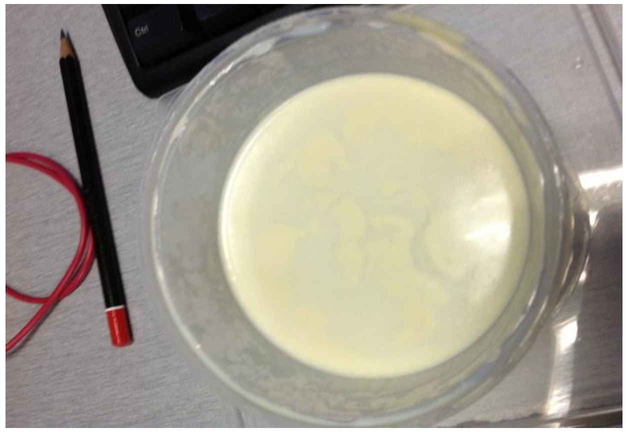


Figure 2.14 : Appearance of the spoilt milk

The experiment was conducted on the spoilt milk and the voltage readings were taken. Below are the results of the voltage output reading for the unpasteurized and pasteurized spoilt milk.

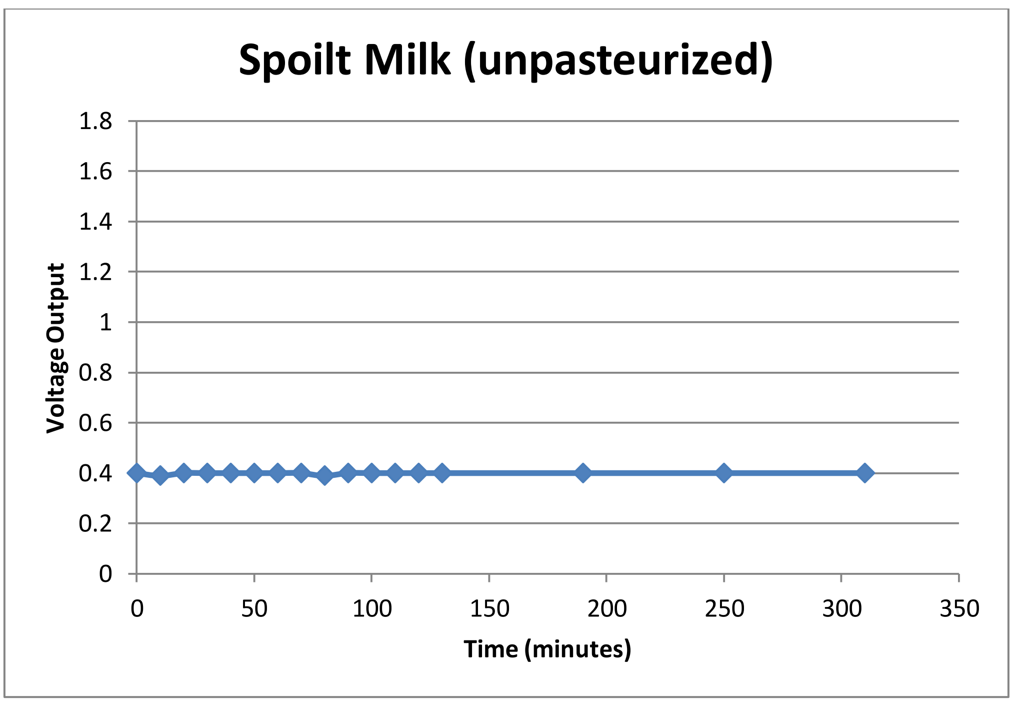


Figure 2.15 : Voltage output reading for unpasteurized milk

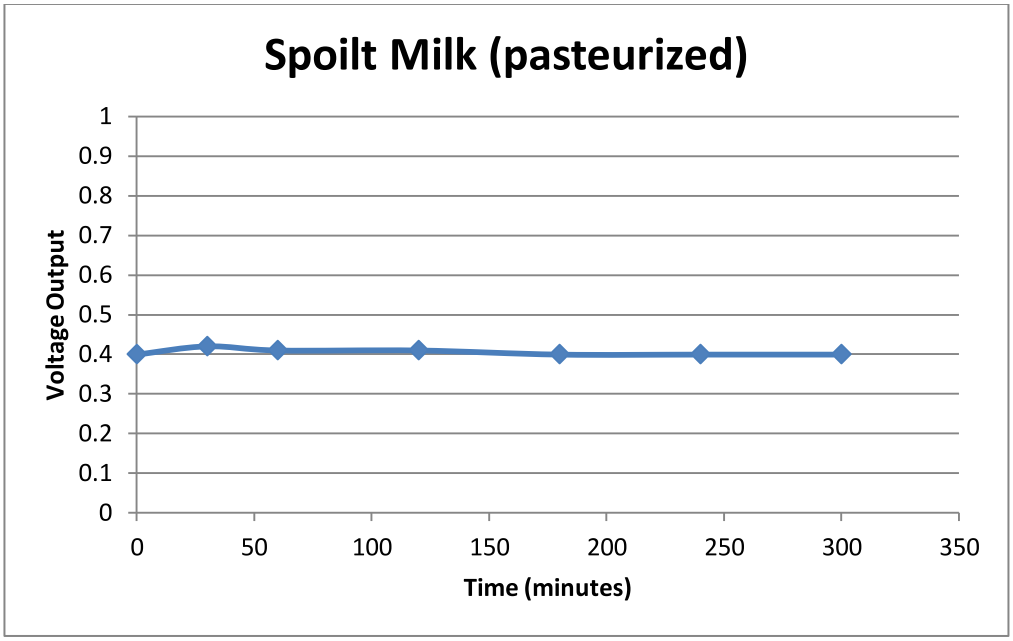


Figure 2.16 : Voltage output reading for pasteurized milk

As the author can see, there is a big difference compare to both voltage output reading for fresh and spoilt milk. The results for these entire experiments done are discussed in the next part of this paper which is discussion.

DISCUSSION

For the first part of the experiment, the main purpose to conduct that test is to see whether it is applicable or not to use a gas sensor to detect the volatile compound produced from the milk. Based on all the results of these 3 tests, the author found that it is possible to detect the gas. There is gas presence even though it is not very high in concentration. The experiment was conducted only after the milk was completely spoiled. However, if the author refers back to the literature, the fermentation processes of bacteria inside the milk produce carbon dioxide (CO_2) gas instead of carbon monoxide (CO) gas. But here in our experiment, the sensor detects the presence of carbon monoxide gas. Before the experiment was conducted, the author expected to have a reading of decreasing percentage of oxygen (O_2) gas because of the presence of CO_2 gases instead of increasing value of CO ppm.

Based on this problem, the author did a research on CO_2 gas and what reaction might take place that could change the CO_2 gas to be CO gas. The author found out that it is possibly because the carbon dioxide gas has undergone a redox reaction. Inside that small confined space with no air flow to the inside and to the outside, the reduction of CO_2 gas to become CO gas is possible. To support that assumption, the author sees that the concentration of CO gas is very low and the sensor was not able to detect a very low concentration of CO_2 gas to decrease the reading of oxygen percentage because of its high resolution.

The second part of the experiment was conducted to test and analyze the function of the sensor for the last part of this project which is to build a final circuit and test it with the spoilt milk. For this part of experiment, the author bought two different type of sensors named; TGS2442 and TGS2600 which have their own sensitivity towards certain gases. From this experiment results, the author saw that the sensor is working.

The last part of the experiment which was conducting an experiment on fresh and spoilt milk to see the growth of carbon dioxide gas was successfully done. The results obtained shown a big different between fresh milk and spoilt milk. For fresh milk, we can see that the CO2 gas increase and at some point the production rate become slower. These results were compared with the results from the experiment done by M Kihal et al and were the same (refer Appendix A). For the spoilt milk, the graph is not really convincing which why there is no production of CO2 gas anymore come into a question. If we review the literature by M Kihal et al, they stated that the process of milk to become spoil somehow do not only releasing CO2 gas, but there are other gases like ethane or methane and carbon monoxide also. So the author can hold to the assumption that the spoilt milk had completely released all of its CO2 gases during the fermentation process inside results in very small changes in voltage output for the first one hour during the experiment done and stay constant most of the time.

CONCLUSION

The conclusion drawn from this paper is the author has proved that by using electronic nose the spoiled milk could be differentiate by sensing the gas produced from the milk. There are different of how the gases and what type of the gases are produced by fresh milk and spoilt milk. So it is relevance in a way to differentiate fresh milk and spoilt milk by using E-nose. The future work for the continuation of this project, the author suggested improving the electronic nose by combining other MOSFET sensor which has their own sensitivity towards different type of volatile compound in order to get the best results and a lot of data to do better analysis.

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APPENDICES

APPENDIX A