Detection of Milk Spoilage Using Electronic Nose with Artificial Neural Network

Abstract – **Electronic Nose System has been popular in many aspects especially in quality assurance of food and beverages. This study focused on developing an electronic nose with gas sensor arrays (LPG, Carbon Monoxide, Smoke, Alcohol, Benzine, Hexane, Ammonia, Ethanol, Toluene, and Formaldehyde) trained using Artificial Neural Network implemented using Python programming language. The training and formulation of the database were done using ten milk samples recorded every hour for thirteen hours. Digital pH meter was used to validate the claim to the spoilage of milk. Testing was done using ten samples exposed to the e-nose system. Confusion matrix was used to summarize the correct and incorrect prediction, it was also used to compute for the accuracy. The accuracy of the e-nose system with ANN was 88.33%. The researchers met all the objectives stated, thus concluding the study to be successful.**

Index Terms - **Electronic Nose, E-Nose, Milk Spoilage, Artificial Neural Network, Milk**

I. INTRODUCTION

A staple in the human diet for sources of calcium and protein is milk. It is even regarded as a necessity of a human being because it is high in calcium, carbohydrates and protein which provide much strength to the human body [1]. Milk decay is a natural procedure that elevates alarms in the health of many people. Some factors such as microorganisms, enzymes, air, and time affect milk spoilage. If one store milk at a room temperature exposed in light for several hours produces spoiled milk. Electronic Noses have become very popular as monitoring tools in evaluating food value and wellbeing, it is a device aimed at mimicking animal noses [2], moreover, it has a group of gas sensor and a pattern appreciation algorithm. Volatile chemical profiles are the most reflective in terms of food adulteration, electronic nose appears as excellent candidates for process monitoring and to detect pollutant gas [3] since e-nose contains machinery for chemical recognition [4,5].

Previous researches have dealt with e-nose that includes gas sensor arrangement, a gas sampling machinery, and a pattern appreciation algorithm [6] Artificial Neural Network is an example of a pattern recognition engine applied in various fields such as in facial recognition [7]. The e-nose can be trained to recognize a pattern. However, in [8] electronic tongue was used for assessment of fresh milk while [9] used electronic nose in pure cow ghee, [10] used electronic sensor-based system for analysis of infection behavior of milk.

The problem is that people have different perception on how to determine if a certain food or beverage is spoiled or not [11] which leads to the inconsistencies in assumptions. According to [6] two groups can be made according to the quantities the five basic senses can detect. The physical principles are well known which leads to successful construction of artificial counterparts while the chemical interfaces are not. Many characteristics of olfactory system and taste are indistinct from functional point of view. The sensor system is a crucial section for an electronic nose [12] because a variety of gas sensors are available in the market, but they are sensitive to different gases.

In this paper, we present a study that developed an electronic nose in detecting spoilage of carabao milk, specifically the study aims to (1) develop an electronic nose system that can distinguish whether the milk is spoiled or not (2) implement Artificial Neural Network as a pattern recognition algorithm and (3) determine milk spoilage in relation to the changes in the gases present over time.

The development of the proposed e-nose system shows that it can be an alternate for smart home applications. E-nose plays and vital role in detecting chemicals in odorless compounds [13]. Moreover, damaged or contaminated milk can be detected by this device which prevents people from suffering from illness that can be caught in spoiled milk.

The research focused on determining carabao milk spoilage as an “odour event”. The researchers developed an e-nose system that contains gas sensors, specifically MQ-2, MQ-3, MQ-137, MQ-138. The e-nose is trained using multi-layered back propagation artificial neural network. The training and formulation of the database consists of ten samples carabao milk and the sensor readings were recorded for 13 hours as well as the digital pH meter. The temperature and humidity are also considered, and the setup was conducted indoor at a certain room temperature. The testing was conducted exposing the electronic nose to ten sample beverage, digital pH meter was used to validate the claim to the freshness of the sample. Moreover, to summarize and compute the accuracy of the e-nose system, confusion matrix was implemented.

II. METHODOLOGY

The inputs are the gases from the carabao milk which is gathered via the array of gas sensors shown in Figure 1. Gas sensors will generate signals which is received by the Arduino Uno to convert the analog signals to digital. The conversion of signals is done because the Raspberry pi can only read digital signals. After that, the application of Artificial Neural Network will be used to analyze the data gathered. The output is whether the milk is spoiled or not based from the data gathered also, the e-nose will display unknown if the sensor response are not on the database meaning the sampling chamber consist of unknown beverage.

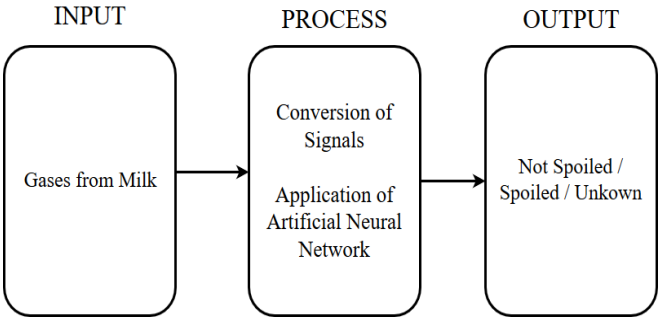

Fig. 1 Conceptual Framework

A. Hardware Development

The actual picture of prototype is shown in Figure 2. The figure also shows the processing of the prototype during the actual testing. The capturing process is automated, the device captures multiple times. It compares the first capture to the second capture, if the values have minimal difference it proceeds to the classifying algorithm if not, it will capture again.

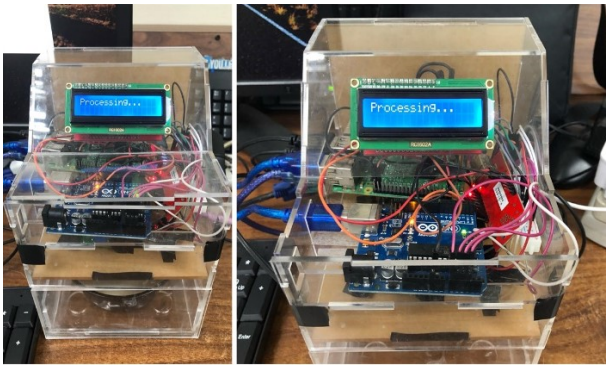

Fig. 2 Actual Picture of Prototype

1) Sampling Chamber: The sampling chamber is where the carabao milk will be placed shown in Figure 3. It will be exposed to the gas sensor array for the gases to settle. The capacity of the Sampling chamber is approximately 100 ml which is enough for generating gases which will be absorb by the gas sensor array.

2) Sensor Chamber: This is where the four gas sensors are placed. The chamber contains four (4) types of sensors shown in the Table I derived on [6]. The chamber also holds the DHT22 AM2302 which detects the temperature and humidity shown in Figure 3.

The actual picture of the prototype zoomed with parts which are divided by two, the sampling chamber and the sensor chamber shown in Figure 3. The sampling chamber is exposed to the sensor chamber which allows the gases to settle in the sensor. The sensor then reads and generates signal to be passed in the microcontroller.

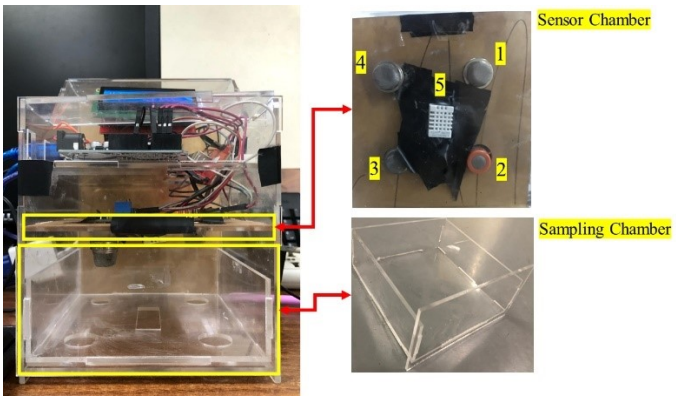

Fig. 3 Parts of the Prototype

TABLE I
GAS SENSOR

Number	Sensor name	Detects
1	MQ-2	LPG, Carbon Monoxide, Smoke
2	MQ-3	Alcohol, Benzine, Hexane
3	MQ-137	Ammonia, Ethanol
4	MQ-138	Toluene, Formaldehyde
5	DHT22 AM2302	Temperature, Humidity

The sensors output multiple data shown in the Table I, reference column.

The gas emitted by the milk will go to the Sensor chamber which consists of the array of sensors, it will generate signal and will be received by the Arduino Uno which converts the analog signals to digital and pass it to the Raspberry pi as shown in Figure 4. The raspberry pi is connected to a laptop which contains the GUI that can view the sensor response and the output for the freshness of milk. Both the Raspberry pi and Laptop is powered by an AC power supply.

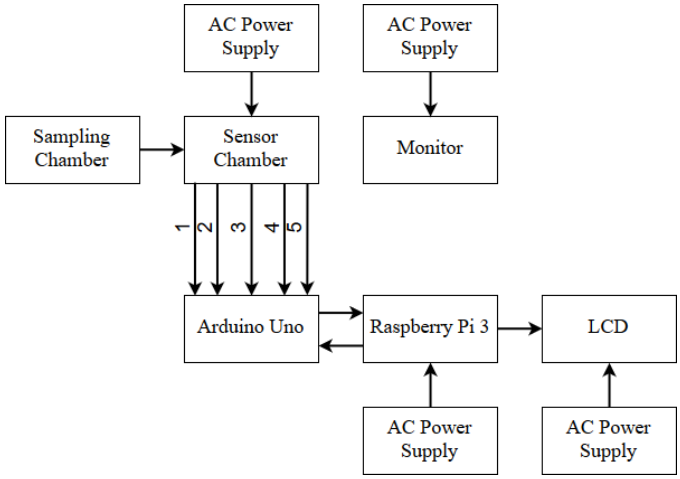

Fig. 4 Block Diagram of The System

B. Software Development

1) Artificial Neural Network: The analysis method used for the application of e-nose is multi-layered Artificial Neural Network (ANN) with backpropagation algorithm. The construction and purpose of genetic neural network are the basis of this computational model [14]. Multi-layered back propagation algorithms require training using known data set. The system used twelve (12) neurons in the input layer representing the ten (10) gases emitted by the milk, temperature, and humidity from the DHT22 AM2302 shown in Figure 5. Moreover, there are 3 hidden layers with 13 neurons each and an output layer which is Not Spoiled, Spoiled, or Unknown. Sigmoid function is used as an activation function. It is used to normalize the input values for them to range from 0 to 1.

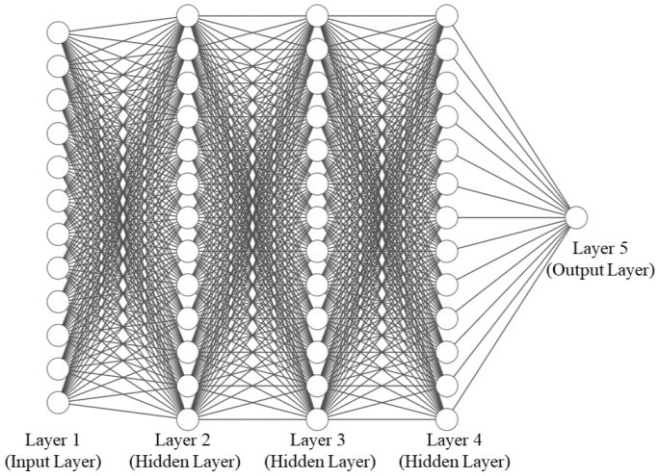

Fig. 5 Neural Network Diagram for the E-nose System

C. Training and Formulation of Database

The electronic nose system can determine if the sample is spoiled or not by training the gathered data. For the training and formulation of database, 10 milk samples were used. These milks were observed one at a time until it was spoiled to see the pattern of spoilage based on the sensor response recorded every hour.

1) Digital pH Meter: For more accurate classification if the milk is spoiled or not, digital pH was used to validate the claim. The pH level of milk is between 6.7 and 6.0 [8]. If it's greater than 6.7, the milk signifies mastitis otherwise, the presence of bacteria and deterioration. The calibration process is as follows:

- Make pH calibration solution, fill in 250ml distilled water in container
- Clean the electrode with distilled water then pat with tissue or towel.
- Press "CAL" for 5 seconds.
- If the digital pH meter flashed three time at 6.86-point calibration, remove the pH meter to the solution, dry it and place protective ca

III. TESTING

TABLE II
SUMMARY OF TESTING SAMPLE

Legend	Sample	Actual Value	pH meter
A	Sample 1	Milk, Not Spoiled	6.27
B	Sample 2	Milk, Not Spoiled	6.51
C	Sample 3	Milk, Not Spoiled	6.07
D	Sample 4	Milk, Not Spoiled	6.42
E	Sample 5	Milk, Not Spoiled	6.58
F	Sample 6	Milk, Spoiled	5.02
G	Sample 7	Milk, Spoiled	5.13
H	Sample 8	Milk, Spoiled	4.93
I	Sample 9	Milk, Spoiled	5.32
J	Sample 10	Milk, Spoiled	5.21
K	Sample 11	Unknown	-
L	Sample 12	Unknown	-

The researchers tested 10 samples summarized in Table II to determine the accuracy of the e-nose system. The milk samples will be recorded five times. The actual values are results in the digital pH test of the milks where:

NotS – Not spoiled
Sp – Spoiled
Un – Unknown

TABLE III
SUMMARY OF TESTING RESULT

Testing Sample	**Actual Value**	**Electronic Nose System trained with ANN**				
		Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
A	NotS	Un	NotS	NotS	NotS	NotS
B	NotS	NotS	NotS	NotS	NotS	NotS
C	NotS	NotS	NotS	NotS	NotS	Sp
D	NotS	NotS	NotS	NotS	NotS	Sp
E	NotS	NotS	NotS	NotS	Sp	NotS
F	Sp	Sp	Sp	Sp	Sp	Sp
G	Sp	Sp	Sp	Sp	Sp	Sp
H	Sp	Sp	NoSp	Sp	Sp	Sp
I	Sp	Sp	Sp	Sp	Sp	Sp
J	Sp	Sp	Sp	Sp	NotS	Sp
K	Un	Un	Un	Un	Un	Un
L	Un	NotS	Un	Un	Un	Un

Table III illustrates the summary of the outcomes of the testing made by the researchers. Five trial was made for each sample, a total of 60 classifications were done. The actual values are based on the result of the Digital pH meter. The first five samples with actual values NotS which means Not Spoiled, there are four incorrect readings throughout the testing period. The next five with actual value Sp which mean Spoiled, there are two incorrect readings. The last two testing with actual value Un which mean Unknown there was only one incorrect reading over the period of testing.

Actual picture for the testing is shown in Figure 6 which contains sample 1, milk with pH value of 6.27. The figure also shows the result in the Electronic Nose which is Not Spoiled shown in the LCD.

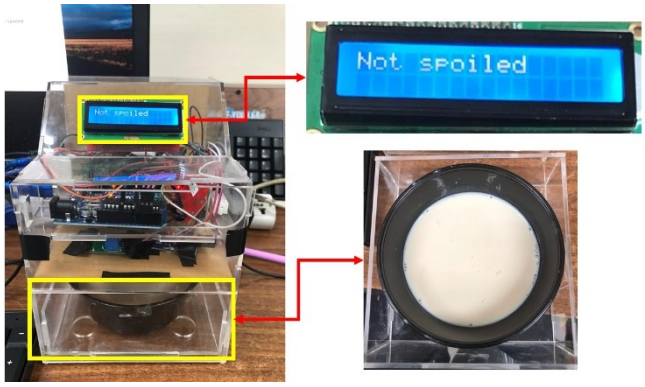

Fig. 6 Testing Sample 1

Sample 6, milk with pH value of 5.07 is shown in Figure 7. The result in the Electronic nose is spoiled which agrees to the actual value of the milk based from the result in digital pH meter.

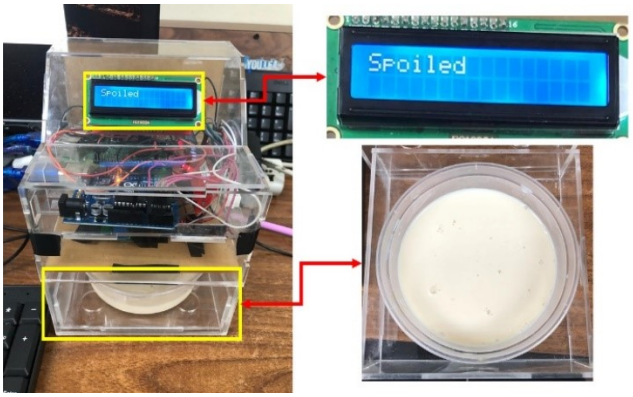

Fig. 7 Testing Sample 6

Actual picture for the result of testing in Sample 11 which contains an unknown sample to the system. Unknown sample consists of variety of beverage other than milk. For this testing, the researchers used water as the unknown sample.

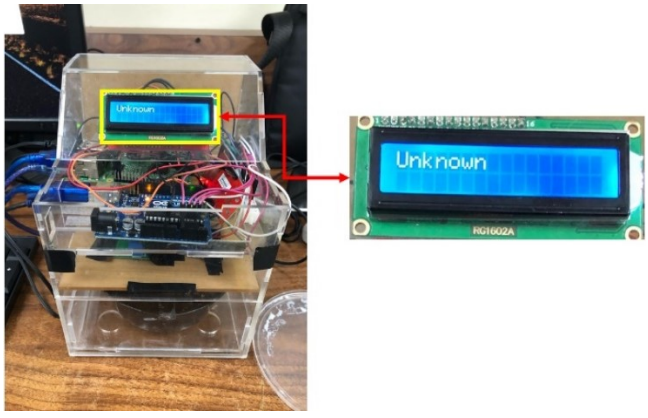

Fig. 8 Testing Sample 11

A. Confusion Matrix

TABLE IV
CONFUSION MATRIX TABLE

	ANN E-nose Not Spoiled	ANN E-Nose Spoiled	ANN E-Nose Unknown	Classification overall
Actual Not Spoiled	21	3	1	25
Actual Spoiled	2	23	0	25
Actual Unknown	1	0	9	10
Truth overall	24	26	10	60

The summary of results is shown in the Table IV which counts the correct and incorrect prediction of the Electronic Nose System. The confusion matrix is used to summarize these results in order to compute for the accuracy of the system.

IV. RESULTS AND DISCUSSIONS

Based from the results from the testing stated above, the overall accuracy of e-nose system is computed as follows:

$$Accuracy = \frac{total\ correct\ predictions}{total\ predictions\ made} \times 100$$

The accuracy for Electronic nose system with Artificial Neural Network is:

$$Accuracy = \frac{53}{60} \times 100$$

$$Accuracy = 88.33\%$$

The error rate is computed to show how often the electronic nose system's generate incorrect prediction. The error rate is computed as follows:

$$Error\ Rate = \frac{total\ incorrect\ predicions}{total\ prediction\ made} \times 100$$

Substituting values, the error rate was computed to be 11.67% for E-Nose System with ANN.

The results of the testing were shown in Table IV for E-Nose System with ANN. Computing the necessary equation leads to the accuracy of 88.33% which gives 11.67% as the error rate. the Electronic Nose generates incorrect prediction due to inconsistency of the temperature and humidity of the room. The prototype was able to determine spoilage in milk with the use of gas sensor arrays and implementing the database trained using the pattern recognition algorithm, Artificial Neural Network.

IV. CONCLUSION AND RECOMMENDATION

Based on the results of the testing, the researchers successfully developed a device that determines whether the milk is spoiled or not using electronic nose system which is based on gas sensors arrays. The researchers were also able to implement artificial neural network applied in Python to

generate pattern in the spoilage of milk formulate the database. Moreover, the researchers were able to determine milk spoilage based on the gases present over time. Confusion matrix was used to measure and determine the accuracy as well as the error rate. The accuracy is 88.33% while the error rate for system with is 11.67%. incorrect predictions are generated due to inconsistency in the temperature and humidity of the room. Overall, the researchers met all the objectives, thus concluding the study to be successful.

For future research, the group recommends the following: (1) widened the variety of samples covered (2) make the gas sensor array more organized to avoid error and (3) increase the training database to obtain higher accuracy.

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