Utilization of Gas Sensor Array and Principal Component Analysis to Identify Fish Decomposition Level

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Abstract-Fish meat is a source of minerals and protein and contains excellent nutrients for the human body. However, non-fresh (rotting) fish are sometimes in the market for sale. Consuming rotting fish puts people at risk of getting diseases. This paper describes research to build a smelling device (e-nose) to identify fish freshness. It aims at detecting unsafe fish flesh to sort them out from being sold. We cut red snapper into cubes and put them into an open space at room temperature for five days. During the period, a gas sensor array acquired data of gas smell from the rotting fish. The output voltage of the sensors was processed using the differential baseline method. Later, feature extraction took the maximum value from the response of the gas sensor array, while the Principle Component Analysis (PCA) method identified the pattern. The results suggest that the gas sensor array responds to changes in the smell of fish meat that undergo a decay process. The PCA method is capable of recognizing the pattern of the maximum value characteristic of the gas sensor array response, as evidenced by the cumulative values of PC1 and PC2 reaching 95.95% with an accuracy rate of 98.2%. It shows the correlation between the aroma profiles of fish meat during the spoilage process, which produces a sharper aroma due to microbiological growth in the fish meat.

Keywords: gas sensor, sensor array, principle component analysis, TGS

1. Introduction

Fish is a food item that is very popular with many people, besides it tastes good, fish also contains protein and high nutritional content including minerals, vitamins, and unsaturated fats [1], [2]. This will be different when the fish consumed is not fresh anymore or even not suitable for consumption because it has started to rot. This condition is a concern because it is related to health, because consuming fish meat that is no longer fresh can trigger disease in the human body. The freshness level of fish is influenced by the length of distribution, hygienic sanitation, transportation and also the handling method [3] so that it reaches consumers, the fish is no longer fresh. In principle, the condition of the freshness level of the fish begins when the fish dies, so that's when the freshness of the fish begins to decrease [4] even in the process of decay it can occur in just a few hours [5]. Meanwhile, the freshness of the meat will greatly affect whether the fish is suitable for consumption [6] especially in the food industry [7] [8]. The process of decay and freshness of the fish is influenced by microorganisms, whereas the effect of

the microorganisms itself depends on the species and size of the fish [9].

Decay process will usually give off an unpleasant aroma that can be smelled directly by our noses, but standardization in assessing the freshness of fish is still subjective [10]. The unpleasant smell is influenced by very complex chemical compounds [4]. So it requires a special instrument to detect the aroma of the fish, one of which is the gas sensor array system.

The gas sensor array system has a working principle similar to the sense of smell in humans by recognizing the response pattern to odors or aromas [11], namely the smell of various gas content in nature. The sensor array system will detect the aroma using several gas sensors arranged according to certain rules [12] and accessed individually and simultaneously so that independent sensors work [13]. Gas sensor array system known as electronic nose (e-nose) has great potential for detecting an aroma with simple techniques and preparation [14]. This system continues to develop, as reported on a review by Loutfi et al (2015) on the use of e-nose for food quality control [15] and also analysis of agricultural products including quality [16] and

evaluating the freshness of fish [17] and beef [18] [19] [20].

The output from the gas sensor array system will then be analyzed using the pattern recognition method, including using statistical methods such as Principal Component Analysis (PCA), Linear Discriminant Analysis (LDA), partial least squares (PLS), multiple linear regression (MLR), cluster analysis (CA), and using artificial neural network (ANN) methods, such as multi-layer perceptron (MLP), fuzzy inference systems (FIS), self-organizing map (SOM), radial basis function (RBF), genetic algorithms (GAS)), neuro-fuzzy systems (NFS) and adaptive resonance theory (ART) [11].

Research related to the detection of fish freshness has been carried out with freshwater fish such as catfish, tilapia and pomfret, for the characteristics of the area of the sensor response when odor is on and five gas sensors are used [4]. Another study to detect the freshness of marine fish by using 3 gas sensors with classification using neural network [21] and classification of freshness of fish in cold storage [22] whereas in this study both utilize e-nose technology which is an array system of gas sensors to detect the level of fish spoilage with sea snapper with the characteristics used in the form of the maximum value of the sensor response and used more gas sensors, i.e. eight gas sensors.

2.   Method

The research flow process, system design, materials, sensors and classification methods are discussed as follows.

a.   Procedure and Data Retrieval

This research has several stages as shown in the research flow chart shown in Figure 1
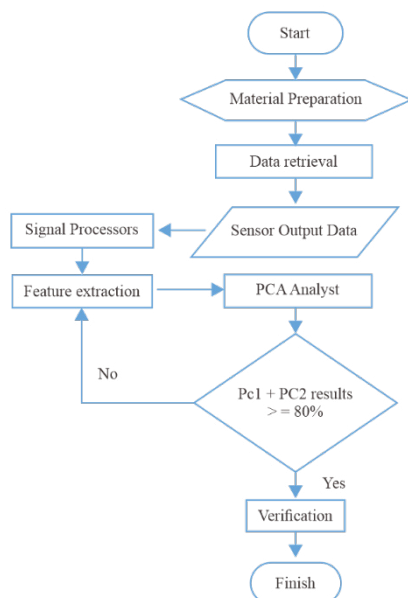

Figure 1. Research flow diagram

The material to be tested is inserted into the container or sample room and the gas sensor array device and data acquisition are placed in the measurement room. The

recorded data is then carried out by a signal processor before determining the characteristic value. With the characteristic values that have been obtained, analysis with PCA is carried out to determine how the system can discriminate against the freshness of a fish based on the detected odor. If the number of PC components is equal to or more than 80%, the system is declared capable of verifying the detected odor, otherwise it is possible to change the characteristic value.

b.   System planning

The system used in this study is as shown in Figure 2.In the sensing system, there are 8 sensors, namely TGS2620, TGS2612, TGS832, TGS822, TGS2603, TGS2600, TGS813 and TGS826 which have different characteristics (Table 1).). In addition to these gas sensors, there are also additional humidity sensors and temperature sensors to monitor environmental conditions. All these sensors are in one room which is also equipped with a pump to suck the sample aroma into the sensor room in the sensing process and another pump to suck in free air during the purging process, Figure 2.
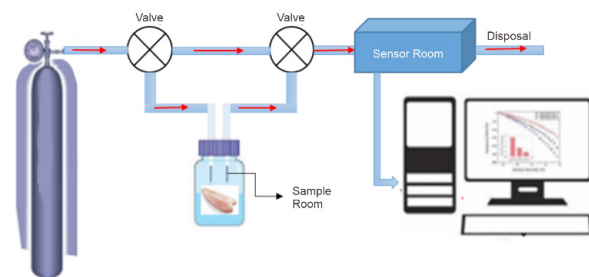

Figure 2. Block Diagram of the System

The sensor array is linked into the data acquisition system. The data acquisition system is set for the sensing process to be carried out for 150 seconds and when the purging process is set for 300 seconds. While the sample is placed in the sample room where it is connected to two valves, which will open and close the channel when the sensing and purging process occurs.

c.   Material

The material used in this study is a type of fresh snapper which is then cut into 10 pieces with roughly the same weight, namely (10 ± 2) grams resembling dice and stored for five days in an open room at room temperature to be tested with sensor array system.

Of the samples that have been prepared, ten samples will be tested every day with repetition three times for each sample and carried out for five days. The first day of data collection was calculated when the fish samples were purchased.

d.   Gas Sensor Array

The gas sensor array consists of several types of gas sensors that are non-selective. The gas sensor used in this study is a gas sensor type Tauguchi Gas Sensor (TGS).

The following is a breakdown of the functions of each gas sensor used as in Table 1.

Table 1. Types of gas sensors used

Number	Sensor Type	Gas type
1.	TGS 2620	Alcohol, solvent vapor
2.	TGS 2612	Methane, Propane, Butane
3.	TGS 832	Hydrocarbons
4.	TGS 822	Organic pollutant vapor
5.	TGS 2603	Air Pollutants
6.	TGS 2600	Air Pollutants
7.	TGS 813	Methane, Propane, Butane
8.	TGS 826	Ammonia

e.   Sample Testing

Before taking data, the sensor is heated for about 30 minutes with the intention that the sensor is in a stable condition. After that the data recording process was carried out for 450 seconds with the sample placed in the sample room.

f.   Data processing

In this process, the data that has been obtained from the recording results will be pre-processed to improve the baseline value. Next, determine the feature extraction in the form of the maximum value of the sensor response and proceed with pattern recognition.

g.   Principle Component Analysis (PCA)

Principle Component Analysis (PCA) is an unsupervised method with a mathematical transformation, which is to explain how many variants are in an experimental data. Correlated data will be transformed into a set of values that are not linearly correlated which is called Principle Components (PC) [23]. PC values are not interrelated but sequential, so that the first order will contain the largest eigenvalues of all the original variable values [24].

Therefore, this PCA method will transform data into new coordinates, where the first coordinate is the Principle Component (PC1) value which has the largest eigenvalue. Whereas the second coordinate is the Principle Component (PC2) which has the second largest eigenvalue, and so on.

3.   Result

a.   Gas Sensor Array Response Test

At this stage, it is to determine the performance of the gas sensor array system on the spoilage process of fish meat. The results of the sensor array response for five days are shown in Figure 3.

Based on the results of the recording obtained as shown in Figure 3, it can be seen clearly that the high

response of the gas sensor array to changes in the condition of the fish meat from day one to day five. Especially for the TGS813, TGS2603, TGS832, TGS822, TGS2620 and TGS826 gas sensors. However, these results cannot be analyzed further before feature extraction is carried out.

The amount of data on the results of the gas sensor array response test for each day is 30 data as shown in Table 2.
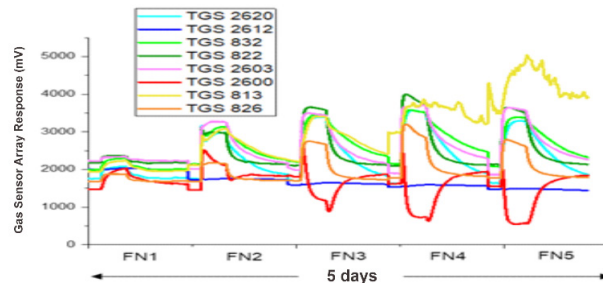

Figure 3. Graph of sensor response for 5 days of measurement.

b.   Signal Processors

The data resulting from the response of the gas sensor array is then carried out in a preprocessing process using the baseline differential method to eliminate additive errors that come from the baseline value itself or from the sensor array response [25]. The equation form of this method is as follows.

$$X_{ij} = V_{ij}^{max} - V_{ij}^{min} \qquad (1)$$

Where X_{ij} is the baseline manipulation, V_{ij}^{max} is the gas sensor array response to the sample, and V_{ij}^{min} is the baseline value.

In this preprocessing process what is done is to improve the baseline conditions from the initial results of recording the data obtained as shown in Figure 4, where the gas sensor array response looks different in the baseline conditions so that by manipulating the baseline value the gas sensor array response results will change to something like shown in Figure 5. This is done with the hope of optimizing the feature extraction in the next process.
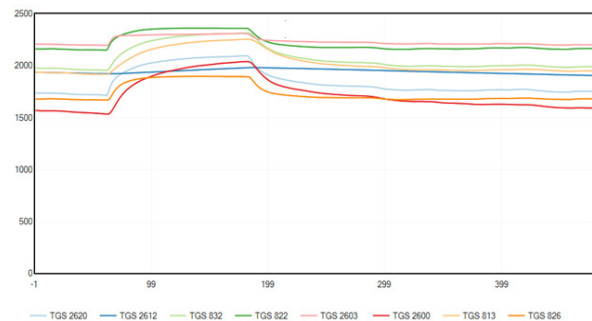

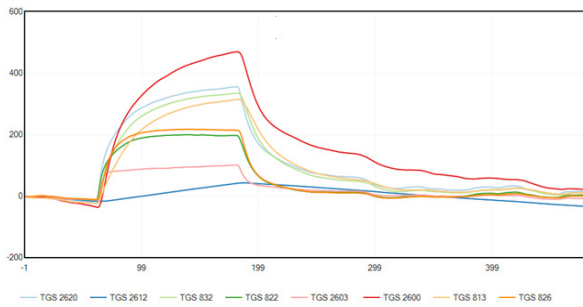**Figure 4. Graphic response of the recorded gas sensor array**

Figure 5. Graphic response of the preprocessed gas sensor array

The next step is to perform feature extraction of the gas sensor array response which has been pre-processed. For feature extraction in this study used is to take the maximum value of each gas sensor response. This maximum value will be used as input data in pattern recognition analysis using PCA. The result of feature extraction from the maximum value of the sensor array response is as shown in Figure 6 where the result is the result of one fish meat sample for five days of observation..

Based on these results, it can be seen that the response of the sensor array system tends to get bigger due to changes in the condition of the fish meat undergoing a process of decay. On the first day (FN1), it can be seen that the maximum values for all gas sensors are around 2000mV to 2300mV so that it appears to be piled on the graph. On the second day (FN2) the gas sensor response has begun to separate and it can be seen that the TGS2612 sensor shows the lowest maximum value response compared to other gas sensors, this condition continues until the fifth day (FN5). While the gas sensors TGS2620, TGS832, TGS822, TGS2603, TGS813 showed the highest response values with values ranging from 2300mV on the second day (FN2). For the third day (FN3), the highest response was shown by the TGS822 sensor with a value of 3684mV and on the fourth (FN4) and fifth (FN5) the highest response was shown by the TGS813 gas sensor with a value of around 6243mV.
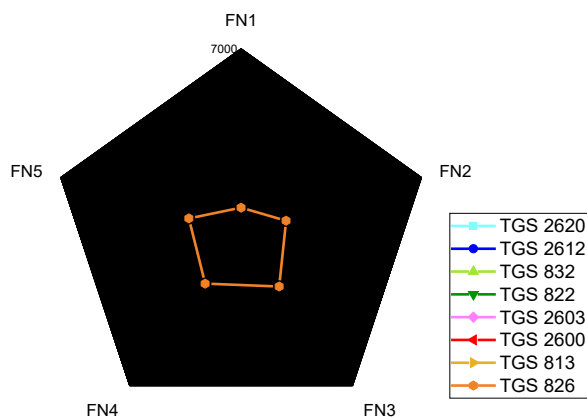

Figure 6. Graphic response to the maximum value of the gas sensor array for 1 sample for 5 days.

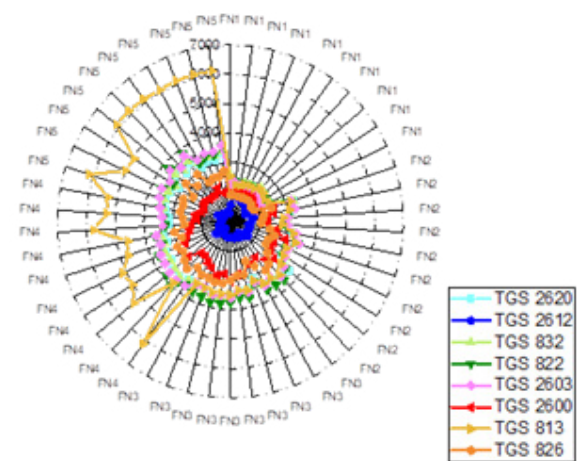As for the distribution of the average maximum value of each sample can be seen in Figure 7.

Figure 7. Graphic response to the maximum value of the gas sensor array for 10 samples in 5 days.

4. Discussion

The results of PCA analysis for the discrimination of fish odor samples for five days as shown in Figure 8 show that the cumulative value variance is 95.95% with the contribution value on PC1 of 86.05% and PC2 value of 9.90%. Based on the distribution of the data variance, it can be seen that the array of gas sensors in detecting odors from fish meat samples for five days are correlated. This is seen in the sample on the first day (FN1) where the data variant collects on the negative side of PC1 and is in the positive area on PC2. This condition indicates that the sample is still in fresh condition. While the data variant on the second day (FN2) seems to collect on the negative side of PC1 and PC2 although some data are in the positive area of PC2. For the data variant on the third day (FN3), it can be seen that some of them have collected the variant data on the second day of sample (FN2), but on the third day of data variant (FN3) all are on the negative side of PC1 and PC2. For variants of the sample data on the fourth (FN4) and fifth (FN5) days are dominant in the positive area of PC1 even though there is one data that is in the negative area of PC1.

Based on the results of discrimination with the PCA method, it is clear that changes in the condition of the sample are increasingly decaying based on the distribution of data from the covariance results. These results also indicate that this method is able to discriminate against the condition of fish meat based on odors detected using a gas sensor array system.

After the results of discrimination based on the PCA method were obtained, then the fish odor data set was tested to determine the accuracy and sensitivity level. Data from feature extraction that has been obtained are then distributed into two data sets for training and testing. The complete distribution of the data set can be seen in Table

2. While testing the data set with various methods in order to obtain the method with the highest level of validation which is expected to have a high degree of accuracy against the discrimination results of fish meat spoilage based on the odor detected using the array system sensor. For a comparison of several methods used as shown in Table 3.

Based on the comparison of methods as in Table 3, where the number of features used is 10 for each condition based on the day or with a total test data of 50 data sets. The fish odor classification process using the Quadratic Discriminant Analysis (QDA) method has the highest

validation value when compared to other methods, namely 94.10%. Therefore, the QDA method is used for the next process, namely the classification process whose results are as shown in Table 4.

Based on the results of the matrix configuration as in Table 4, it can be seen that from the actual data on the condition of the fish each day, the average sensitivity value is 98% with one detected data on the second day that is included in the third day category. Meanwhile, the level of accuracy from the prediction results obtained an average of 98.2%.
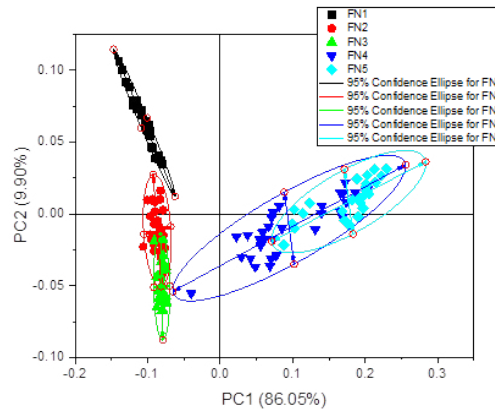

Figure 8. The distribution of data on the results of discrimination using the PCA method

Table 2. Distribution of the fish condition dataset

	Data Training	Data Test	Total
Day 1	20	10	30
Day 2	20	10	30
Day 3	20	10	30
Day 4	20	10	30
Day 5	20	10	30
Total	100	50	150

Table 3. Comparison of methods

Classification Method	LDA	QDA	LR	NB
Number of features	10	10	10	10
Parameter	Linear	Quadratic	Linear	Normal
Cross Validation	92,40%	**94,10%**	87,90%	82,90%

Table 4. Confusion matrix of the methods used

	Prediction					Sensitivity (%)
	Day 1	Day 2	Day 3	Day 4	Day 5	
Actual						
Day 1	**10**	0	0	0	0	100
Day 2	0	**9**	1	0	0	90
Day 3	0	0	**10**	0	0	100
Day 4	0	0	0	**10**	0	100
Day 5	0	0	0	0	**10**	100
						98
Accuracy (%)	100	100	90,9	100	100	**98,2**

The accuracy and sensitivity values obtained are high enough so that it can be said that the results of the evaluation of the QDA model are very maximal in classifying the level of fish meat rot.

5.   Conclusion

Based on the results of this study, it can be concluded that the level of spoilage of fish meat can be detected by using a gas sensor array system combined with the PCA method. Discrimination using the PCA method obtained a cumulative value variance of 95.95%, which means that the system has been able to determine the diversity of data structures based on aroma with a value contribution of the first component or PC1 of 86.05% and the value of the second component or PC2 of 9.90%. These two components are the highest value components of the total value of the components in the PCA method. While the level of accuracy of this system in classifying fish conditions based on their aroma is 98.2%. This result shows that the proximity of the measurement results to the actual conditions is very good, while the sensitivity level is 98%, which means that the ability of the gas sensor array to respond to changes in value when measuring is high.

Acknowledgement

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