IJCTA, 9(5), 2016, pp. 2405-2413

Quality Identification of Used Cooking Oil Based on Feature Fusion of Gas Sensor and Color

A.J. Ishak*, R.Z. Abdul Rahman*, A.C. Soh*, R. Shamsudin, S.A. Jalo*, F.C. Lim* and H.K. Lin***

ABSTRACT

In Malaysia, a recognition system to identify the hazardous substance in used cooking oil is still at very minimal stage. The presents of HNE in reused cooking oil increases the health concern in our modern community and assessment of the oil quality had received much attention, since such assessment is useful in determining the discarding point of the oils. This paper primarily present the result of quality identification system of used cooking oil through an image analysis that uses RGB color extraction technique and odor extraction techniques to extract a set of feature vectors. The result obtained after implementing an ANN technique to identify quality level of the oil shows the outcome of the trained ANN was successful because of a high regression coefficient of 0.98. Furthermore, the system had successfully classified the randomly selected ten (10) samples for testing correctly.

***Keywords**: Oil Quality Classification, Color & Odor Extraction, Data Fusion, Artificial Neural Network, Physical & Chemical Properties.

1. INTRODUCTION

Frying is one of the oldest and most popular method of cooking food since it generates pleasant flavors, aroma and attractive appearance in food. It is the must simples and yet faster method of cooking as it's requires the immersing of a food item in a hot oil for a few minutes. The common culture of many food vendors' such as kitchens, stalls or restaurants is reusing cooking oil in frying process for profitable reasons. Heating cooking oil at the range of 170-220^{o}C frying temperature in the presence of oxygen (air) increase the rate of hydrolysis, oxidation and polymerization reactions that heavily affect its quality.

Recycling (reusing) cooking oils and fats for frying food lead to different changes in their physical and chemical properties. The formation of highly toxic compound such as 4-hydroxy-trans-2-nonenal (HNE) is associated with continuously recycling cooking oil for frying process. The consumption of fried foods containing HNE is a contributing factor for the high risks of cardiovascular disease, stroke, parkinson's disease, alzheimer's disease, huntington's disease, and various liver disorder as well as cancer disease [1].

The chemical and physical parameters of the oil are usually determined by American Oil Chemists Society (AOCS) standard procedures for quality assessment. The AOCS is consider as official method of testing quality of cooking oils [2]. Though, it is the most common and reliable approach to determine Total Polar Material (TPM), Free Fatty Acid (FFA), Peroxide Value (PV), change in the oil color, and etc. but it is very skillful and highly tasking to performed, its consume large quantity of solvents, takes longer time for analysis and costly. Moreover deciding on the best parameter (indicator) is also challenging, [3, 4 & 5].

* Department of Electrical and Electronic Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang, 43400 Selangor, Malaysia, *Email: asnorji@upm.edu.my*

** Department of Process and Food Engineering, Faculty of Engineering, Universiti Putra Malaysia, Serdang, 43400 Selangor, Malaysia.

Chromatography that was first developed for separating color in a compounds was improved to a highly advance (sophisticated) devices that is currently capable of separating a wide range of mixtures [6]. Column chromatography is frequently use for measuring total polar materials, free fatty acids, mono and diglycerides content in used oil. In many countries, column chromatography is the official method of determining the total polar materials. The official limit of the Total Polar Materials/Compound (TPM /or TPC) in many countries are specified as 24%. The most widely used property of any fat is its fatty acid composition. This indicates what fatty acids are present and at what level and is universally determined by gas chromatography (GC) of the methyl esters derived from the triacylglycerols [7].

The major disadvantage of column chromatography lies in its execution and inconsistent results especially when different pack were used as weighing agent. Furthermore the proportionality different between the polar and non-polar components in the oil heavily affect the results while Testo, 270 and others are not precise enough.

The subjective evaluation of the oil color is the must easiest way to judge the oil quality, though it may be misleading because of differences between individual sighting ability. The rate of darkening of cooking oil differs from one oil to another and moreover the darkening depends on the initial color of the oil, [4]. The darkening of oil color during frying process depends on the initial color of the oil and the type of food used in frying [8]. In addition the oil color becomes unacceptable first, much earlier than its flavor and the odor, [9].

Fourier transform infrared (FTIR) spectroscopy has advanced dramatically in recent years and is now used as an alternative way of measuring several properties important for lipid analysts [7]. An FTIR spectrometer can record the entire infrared spectrum in one second and this can be added to many other scans through a fast Fourier transform algorithm to produce a conventional infrared absorption spectrum [10].

Artificial neural networks (ANN) are biologically inspired networks inspired by the human brain in its organization of neurons and decision making process which are useful in application areas such as pattern recognition, classification, etc. [11]. The decision making process of the ANN is more holistic, based on aggregate of entire input patterns, whereas the conventional computer has to wade through the processing of individual data elements to arrive at a conclusion. Ishak et al. have implemented the neural network technique to classify types of weed images [12].

However, there are various types of devises for measuring quality of used cooking oil, most of those devices are standalone system that could measure only one parameter that there designed for. Therefore, an intelligent identification system for evaluating quality of reused cooking oil required more research.

2. RESEARCH METHODOLOGY

This section will discuss the preparation of the samples, acquisition of data, and the design of the model for the research. A typical representation of the study is shown in figure 1.

2.1. Samples Collection from Respondents

In developing an intelligent recognition module, it is important to obtain and study the preliminary data for developing the algorithm. Since, the effect of recycled frying on cooking oil is not widely unveil. A refined cooking palm olein and chicken meat are used for the proposed of the study because of their affordability and availability in Malaysia. Twenty respondents were given one bottle of the palm olein each and they were requested to cook the oil using chicken meat. The first batch of the frying was carried out using one litter of the oil after the first batch of frying 300ml of the oil was removed and store as sample one. The second batch frying was continues with the remaining 700ml after which another 300ml was removed and stored as sample two before proceeding to the third batch of frying with the remaining 400ml to obtained

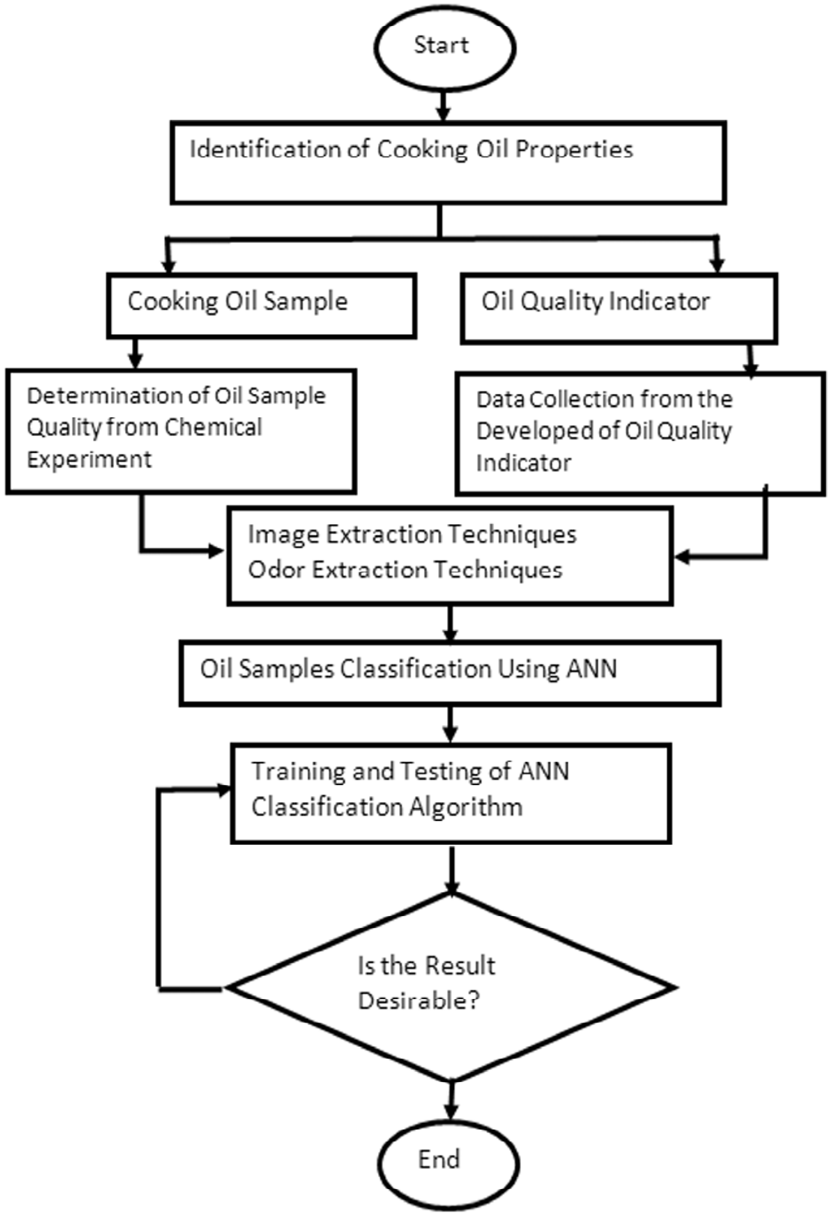


Figure 1: Quality cooking oil classification

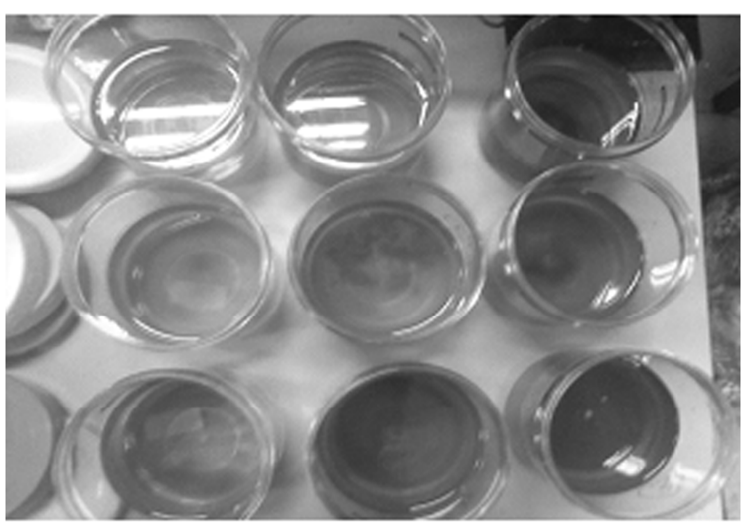


Figure 2: Samples of used oil

sample three. The frying was carried out on the same day by the respondents and immediately the samples were collected and stored at room temperature prior to analysis as shown in figure 2.

2.2. Samples Collection from Random Hawker Stalls

The other source of samples were collected randomly from twenty two (22) food Hawker stall in night market at Seri Kembangan. The hawker stall samples shown in figure 3 are from different stall, the sample was collected from each hawker stall after completing the night market of the day, and cold at room temperature prior to analysis. The sample from hawkers were collected because analysis of the oil samples from the twenty respondents using FFA were far form discarding point (in good condition).

3. IDENTIFICATION OF THE OIL SAMPLE QUALITY

3.1. Determining Free Fatty Acid Content

In order to determine the actual quality of oil sample, Food Quality Laboratory from Department of Food and Process Engineering in University Putra Malaysia was booked for the experiment. The titration was carried out to calculate the FFA content in the oil samples using Palm Oil Research Institute Malaysia (PORIM) test method as shown in figure 4.

A 2g of oil sample was poured into test tubes and mixed with 50ml of Isopropyl Alcohol, the mixture was put in water bath and heated to approximately 50°C for homogenization as shown in figure 5. A 0.5ml drop of phenolphthalein is added to the homogenized mixture and stir for few seconds. The stirred sample was neutralized using 0.1N of sodium hydroxide (NaOH) solution. The volume of NaOH used was recorded once a permanent reddish or pink color appears. The volume of NaOH used was substituted into the formula below to calculate the percentage free fatty acid in the oil.

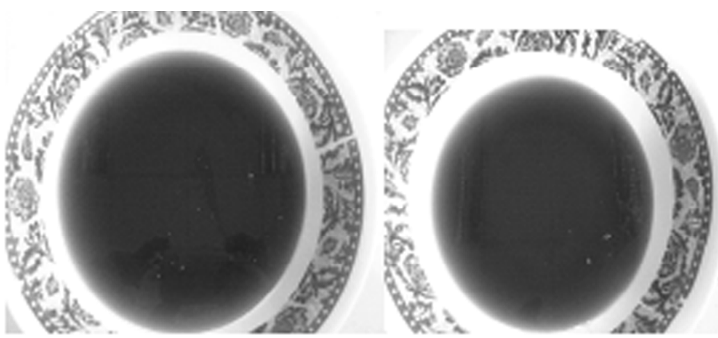


Figure 3: Samples of used oil from hawker stalls

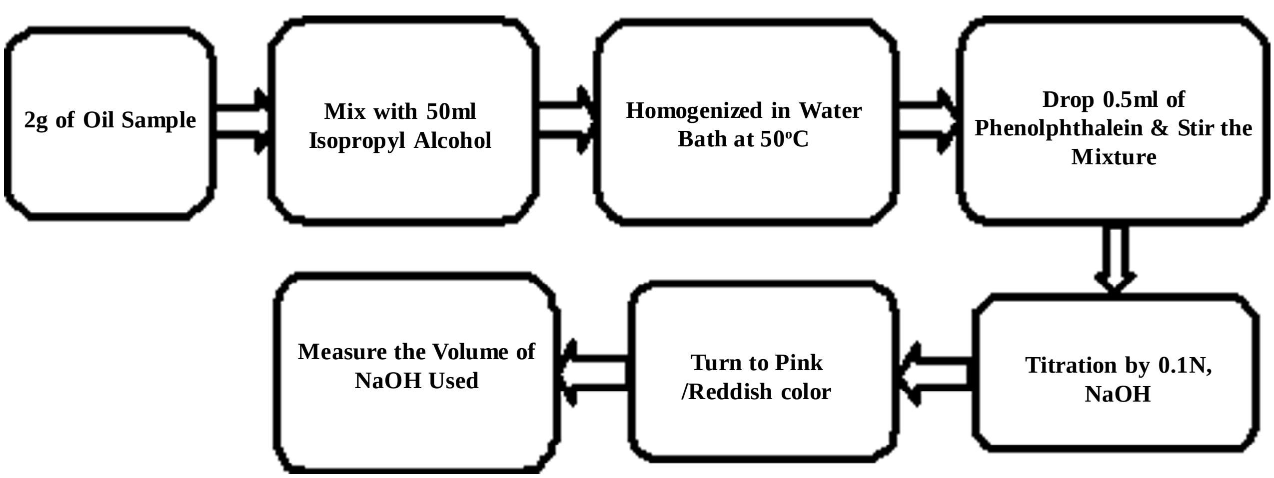


Figure 4: Block diagram of the FFA testing

$$\%FFA = \frac{25.6 \times N \times V}{w} \tag{1}$$

where V is volume of NaOH, then N as normality (concentration) of NaOH and w is weight of the oil used.

4. DETECTOR DESIGN

The color detection was to read the values of Red, Green and Blue (RGB) colors of the oil sample. The oil samples were snap by RGB camera and processed in MATLAB software for extracting RGB colors as

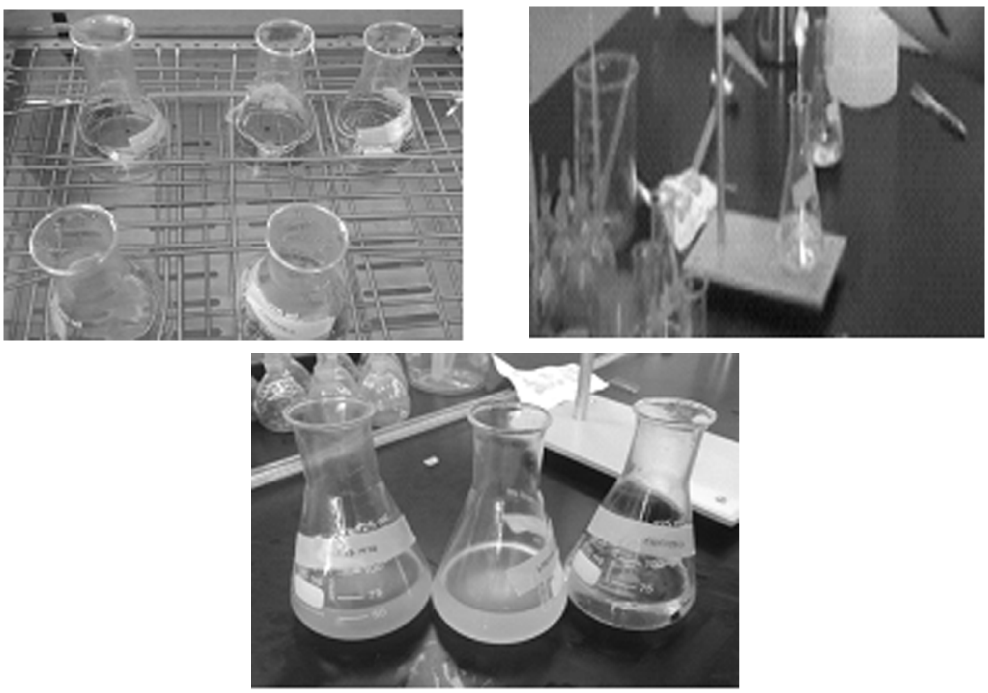


Figure 5. The procedure of determining FFA content, (a) The mixed of solution in a water bath, (b) The titration procedure, (c) The permanent reddish or pink solution.

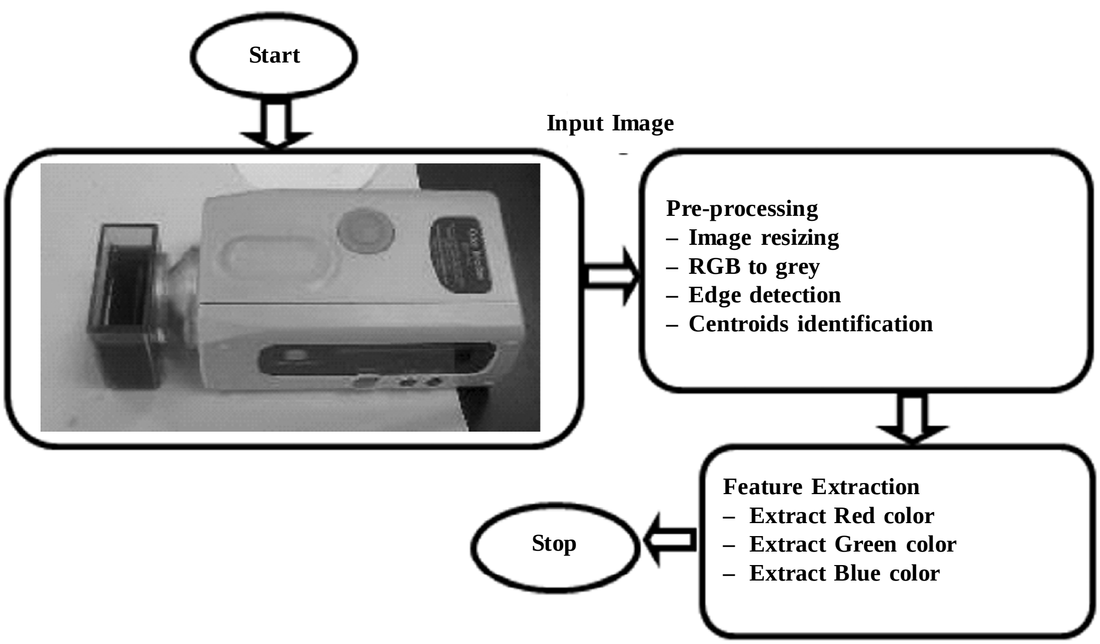


Figure 6: Block Diagram of RGB Detection using MATLAB

shown in figure 6. The snap pictures were pre-process first by resizing the samples image for uniformity, follow by converting the RGB image to grey scale before edge detection operation. The pre-process stage is to ensure the snap pictures have the same dimension and traceable boundaries before extraction of the samples RGB color.

For development of gas sensor, Figaro TGS 2620 was used because of it excellent sensitivity of organic solvents and volatile vapors. The circuit was constructed with two voltage sources, one for the heating element V_H and the other one for the circuitry V_C as shown in figure 7. The heater voltage (V_H) is applied to the integrated heater to control the sensing element for optimal sensing while the circuit voltage (V_C) is applied to measure the voltage drop across the load resistor (V_{RL}) which is connected in series with the sensor. In this study, 470&! load resistor R_L was chosen for the circuit construction as specified in the datasheet of the gas sensor.

5. QUALITY CLASSIFICATION SYSTEM

Artificial Neural Network is an analogy of human nervous system, the system is capable of processing data input and gives out the appropriate output response as illustrates in figure 8. A supervised training technique was used for the ANN quality classification because the actual quality of the oil samples were known from titration and Testo 270 testers. The classification system can be easily trained using a set of given input and output (target) data and a feedforward back propagation weight adaptation techniques was used to minimize error. A binary log-sigmoid transfer function was used as activation functions for both the input to hidden layer and hidden layer to output nodes because it is better compared to bipolar sigmoidal function.

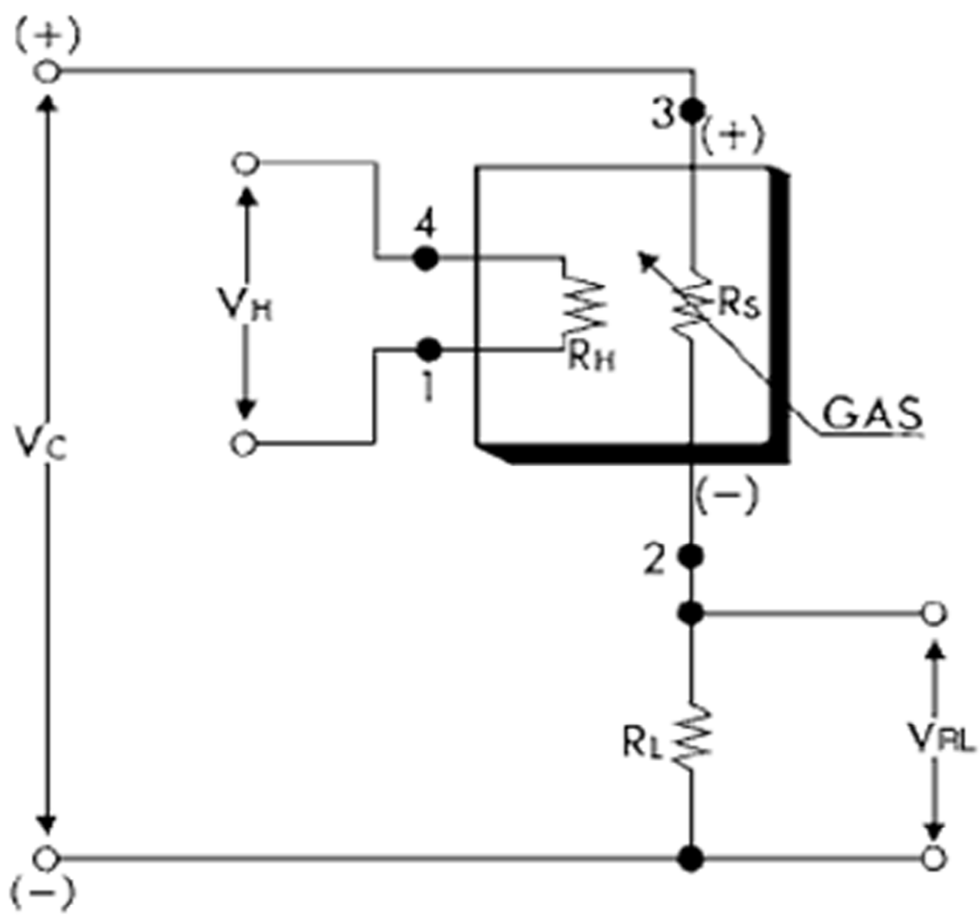
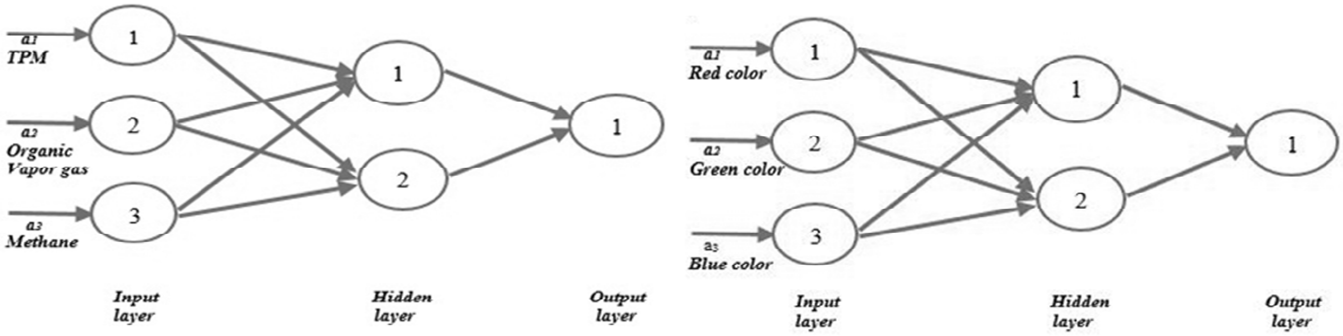


Figure 7: Gas sensor circuit



(a) (b)

Figure: 8 (a) and (b) Three layer feedforward ANN

6. RESULTS

A scatter plot which is an excellent tool of comparing a relationship between two pairs of values was used to ascertain the correlation strength between the sensors and FFA. The strength of the correlation between the sensors and the FFA shown in figure 9, describe the relationship between the parameters. The closer the red dots towards the green line the higher the correlation between the two variables.

The statistical analysis portrays a satisfactory result between the three parameters namely; TPM, Organic Vapor and Methane with FFA content. The TPM Sensor had the must strongest correlation coefficient of $r = 0.986$ with FFA than other sensors. The other two gas sensors also had strong correction coefficient of $r = 0.833$ for organic vapor and $r = 0.838$ for methane gas. A Mean Square Error (MSE) of 0.065, 0.069 and 0.072 was attained for the TPM sensor, organic vapor gas sensor and methane gas sensor, respectively. The results obtain shows the higher the correlation coefficient, the lower the mean square error. The statistical analysis results proves the data obtained from the three sensors can be used for ANN training.

7. DEVELOPMENT OF CLASSIFICATION SYSTEM USING ARTIFICIAL NEURAL NETWORK

The ANN set up shown in figure 10a and 10b were used for classify quality of reused cooking oil. The network in 10a has three input nodes of TPM, organic vapor and methane sensors, two hidden nodes and one output node for FFA. While the network in 10b also has three input nodes of red, green and blue colors, with two hidden nodes and one output node for gas sensor. The learning rate of both the classification

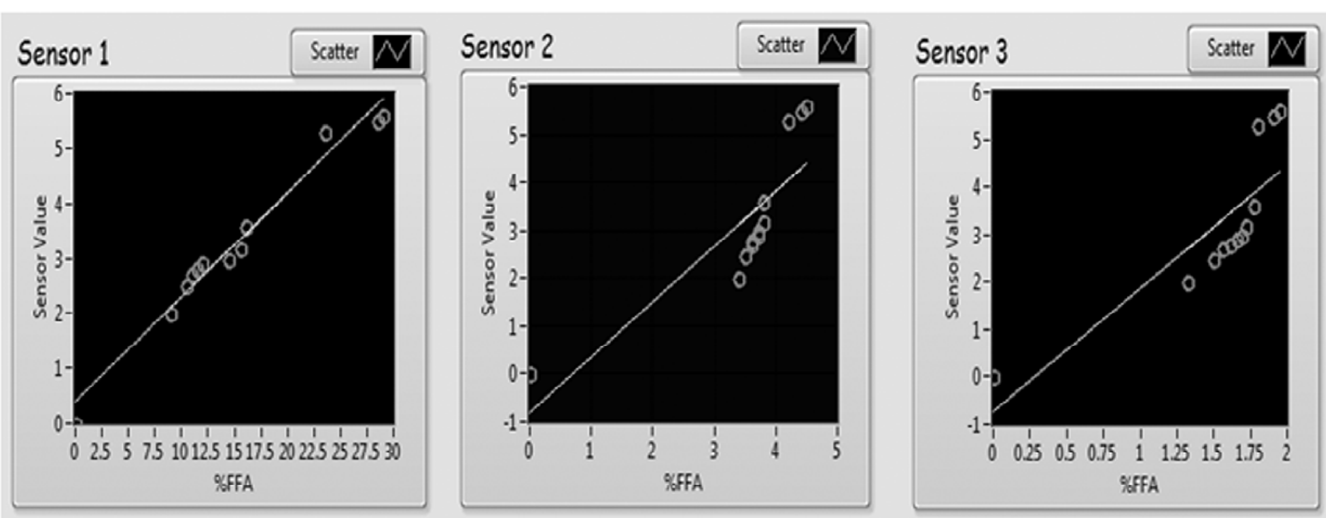
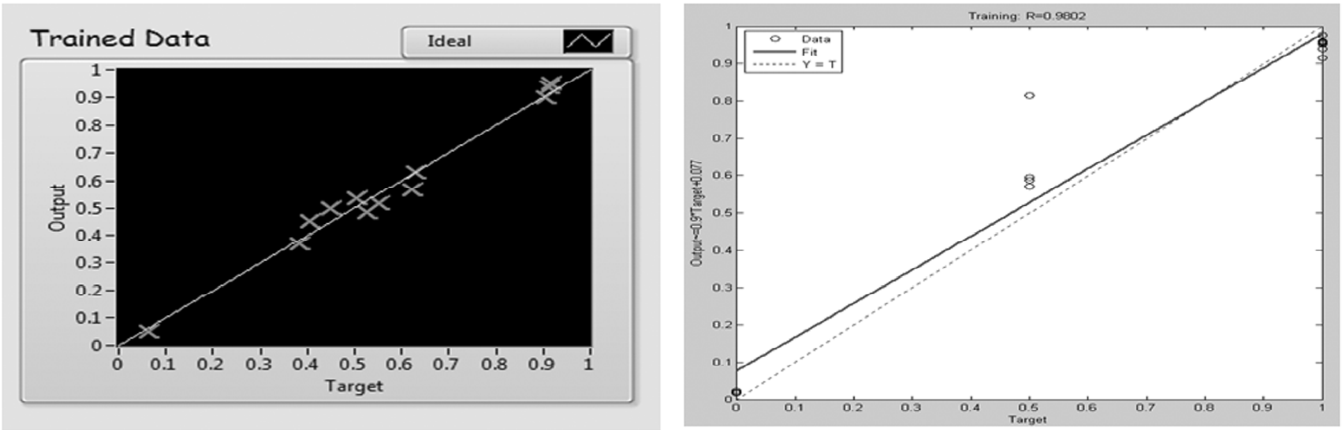


Figure 9: Correlation between TPM Sensor, Organic Vapor Gas Sensor and Methane Gas Sensor with FFA.



(a) (b)

Figure 10 (a) ANN Training Output for MSE and (b) ANN Training Output R

system were fixed at one and there is no momentum and bias applied for training the systems. The output of the trained ANN is very much closed to the target value for both system because of minimum MSE of 0.0011 and higher regression coefficient of about 0.98 as can be seen in figure 10a and 10b.

8. VALIDATION OF THE DEVELOPED CLASSIFICATION SYSTEM

The data used for validating the classification system were selected randomly for the trained data as tabulated in table 1 below. The system successfully classified the samples according to target, though, the test data was obtained from the train data an accuracy of 100% was obtained with the system.

Table 1
Input Data for Testing Of ANN System

R	*G*	*B*	*Target Output*	*Classified*
60	27	17	1	GOOD
129	46	10	1	GOOD
76	27	21	1	GOOD
162	112	14	0	BAD
161	90	14	0.5	OK
139	63	22	1	GOOD
164	113	15	0	BAD
46	39	47	0.5	OK
164	112	15	0	BAD
162	112	14	0	BAD

9. CONCLUSIONS

The concept of this proposed cooking oil quality classification system is simple yet easy to be implemented. With this system, user does not require any chemical knowledge in order to carry out cooking oil quality inspection. The trained ANN was considered successful because of the high regression value of up to 0.98. Finally, the ANN classification system was validated using ten randomly selected samples from the input sample and it shows a correct classification for all the tested data inputs.

REFERENCES

[1] P. S. Uriarte, and M. D. Guillén. "Formation of toxic alkylbenzenes in edible oils submitted to frying temperature: influence of oil composition in main components and heating time." *Food research international* 43.8 (2010): 2161-2170.

[2] D. Fireston. “Official methods and recommended practices of the AOCS”. *The American Oil Chemists’ Society*, 2009.

[3] G. Bansal, et al., “Evaluation of commercially available rapid test kits for the determination of oil quality in deep-frying operations.” *Food chemistry* 121.2 (2010): 621-626.

[4] C. Gertz. “Chemical and physical parameters as quality indicators of used frying fats.” *European Journal of Lipid Science and Technology* 102.8 9 (2000): 566-572.

[5] E. Kress-Rogers, P. N. Gillatt, and J. B. Rossell. “Development and evaluation of a novel sensor for the in situ assessment of frying oil quality.” *Food Control* 1.3 (1990): 163-178.

[6] F. D. Gunstone. “The chemistry of oils and fats.” *Sources, Composition, Properties and Uses. Great Britain: Blackwell Publishing Ltd. 345p* (2004).

[7] F. D. Gunstone. Oils and Fats in Food Industry. Oxford: Wiley-Blackwell, (2008).

[8] M. K. Krokida, et al. “Color changes during deep fat frying.” *Journal of Food Engineering* 48.3 (2001): 219-225.

[9] S. Paul, G. S. Mittal, and M. S. Chinnan. “Regulating the use of degraded oil/fat in deep fat/oil food frying.” *Critical reviews in food science and nutrition* 37.7 (1997): 635-662.

[10] Gunstone F. D. (2004). The Chemistry of Oils and Fats. Covertry: Blackwell Publishing Ltd.

[11] R. P. Lippman. Pattern classification using neural networks. IEEE, (1989). Commun. Mag., 47-64.

[12] A.J. Ishak, A. Hussain, M.M. Mustafa. “Weed image classification using Gabor wavelet and gradient field distribution.” *An International Journal of Computers and Electronics in Agriculture*, Elsevier 66 (2009): 53-61.

[13] M. K., Krokida, V., Oreopoulou, Z. B., Maroulis, D., Marinos-Kouris. Color changes during deep fat frying. *Journal of Food Engineering, 48(9)*, 219-225. (2001).

[14] J. Clark. *Column Chromatography*. Retrieved 2012, from Chemguide.co.uk. (2007).