

An Analysis of Lard by using Dielectric Sensing Method

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Abstract—Culinary often uses lard to enhance the flavour and crispiness of food. But foods containing lard or fat from pig is non-permissible for Muslim and vegetarian. Due to that, lard detection technique is becoming an important element in the food industry. This research conducted a potential rapid first stage screening of lard using a dielectric sensing method of interdigitated electrode (IDE) to measure the impedance value of lard. The measurement is taken using LCR meter EDC-1630, which is capable to supply frequency in between the range of 100Hz to 100 kHz. The IDE is optimised using TAGUCHI method where the best optimisation result consists of 42 number of an electrode. The graph of the result shows the relationship of impedance, frequency supplied and a number of reheating hour. Data were analysed using statistical method linear regression to prove the relationship of impedance and number of reheating hours. The results show that R-square value for IDE 42 was more constant compare to other IDE, which was at 0.96 to 0.98.

Index Terms—Dielectric Sensing; Impedance; Lard.

I. INTRODUCTION

Lard is a form of fat in saturated or unsaturated form that extracts from the fatty acid tissue of pigs. Usually, it is extracted from the back skin, muscle, surrounding digestive organs, surrounding the kidneys of pig [1]. Scientifically, lard is known as triglyceride, it mainly consists of fats or fatty acid. Culinary uses lard to enhance the flavour and crispiness of food. In addition, lard consists of 48% of monosaturated fat that is able to reduce the risk of depression and cholesterol compare to other types of fat.

However, it becomes the main concern in cuisine where chef and baker use lard as shortening or cooking oil. This had increased the risk of consumption of pork content. Foods which contain lard or pig content is non-permissible for Muslim and vegetarian. In the Islamic religious, *halal* means permissible or allowed. In Islamic law, it emphasises the prohibition of food containing pork or lard.

Due to that, the lard detection technique is becoming an important element to be implemented in the food industry. An experimental investigation was conducted to explore the inclusion of lard in food by using an interdigitated electrode circuit. Interdigitated electrode is a circuit which combines two comb-shape like form. The design of interdigitated electrode is simple and effective. From the design, it is able to generate capacitive sensing field when it is supplied with a

small voltage. The spacing in between of each line on sensing layer is able to measure the changes of dielectric of material. The objectives of this study are to analyse the lard by using dielectric sensing method and evaluate the potential and limitation of impedance measurement for lard detection. Data analysis using statistical method linear regression is adopted to measure the result of lard.

II. LITERATURE REVIEW

In previous studies, there are some achievements of lard detection for halal authentication. The existing current issue is the ingredient label does not include the adulteration of food origin [2], causing the worries of consumers. Therefore, there are methods to identify food adulteration by determining the ratios of different types of chemical composition and analyse the chemical properties of food in the market. The methods used include Polymerase Chain Reaction (PCR) analysis, Electronic Nose (E-Nose), Gas-liquid chromatography (GLC), Fourier Transform infrared Spectroscopy (FTIR), Differential scanning calorimetry and Interdigitated Electrode Sensor.

Polymerase chain reason (PCR) is a highly sensitive method of extracting the tissue and obtaining the information of deoxyribonucleic acid (DNA). Sampled species can be identified using this method. Deoxyribonucleic acid (DNA) is a type of genetic form molecule which carries important unique information of cell [7]. In addition, DNA is stable and non-destructive which brings advantage in the analysis. Therefore, PCR is a high sensitivity method for lard detection.

Electronic Nose or also known as electronic sensing is a device which consists of a multisensory array, processor, software base, and databases [3]. This method uses sensor array and pattern recognition system to reproduce the capabilities of human senses. This method is not only applicable to lard detection but on a wide variety market, including automobile, chemistry, biomedical, food and packaging. This method is designed according to the abilities of human senses.

On the other hand, gas-liquid chromatography (GC) is chromatography used to analyse the samples that can evaporate without decomposition state. This method is able to separate material into two phases, where one phase is in mobile and another in stationary. The liquid represents the stationary phase, whereas the gas represents the mobile phase.

GLC is applicable to complex analysis, which can respond rapidly, high accuracy and high sensitivity. The working principle of GLC is as shown in Figure 1.

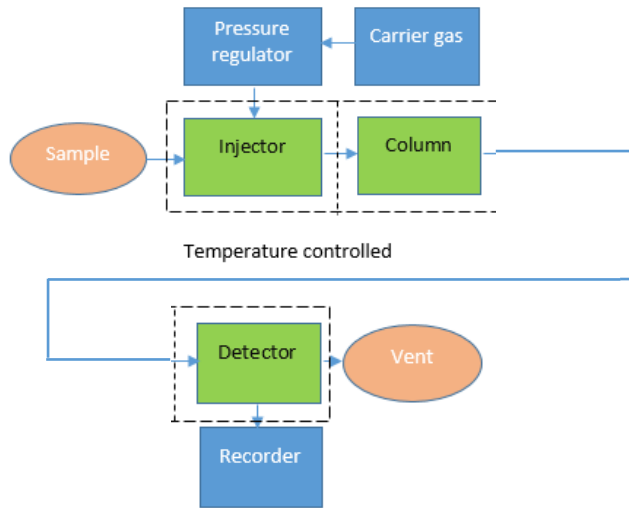


Figure 1: Gas Liquid Chromatography working principle [8]

Besides, the infrared spectrum of the sample can be obtained by using the method of Fourier transform infrared spectroscopy (FTIR) either in solid, liquid, or gas state. This method is used to identify the chemical, physicochemical and morphological properties of samples. The basic working principle of this method is measuring the amount of light absorbed by a sample used in terms of wavelength. The motion of molecules in samples affects the wavelength and frequencies measured [9].

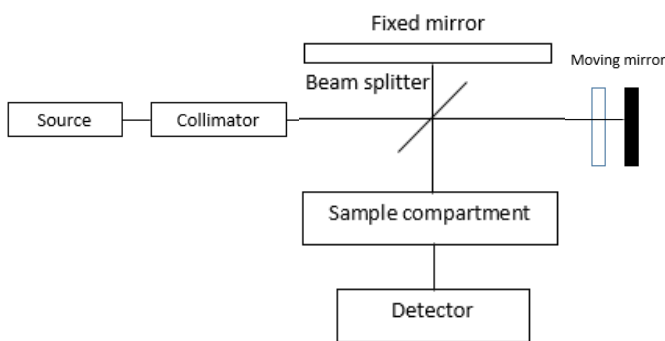


Figure 2: How FTIR's work [9]

As for Differential scanning calorimetry (DSC) technique, it is a method used to measure the characteristic properties of the sample by using the thermoanalytical technique. Thermal analysis is based on the changes on the temperature in between the sample and reference in heat content. This method is able to measure the total heat change in the process of exothermic or endothermic [9][10].

As seen above, all the methods are time consuming, chemical based technique and require a trained person to

handle and check the lard adulteration. A possible technique, Interdigitated electrode (IDE) designed sensor is a potential biosensor device, which is relatively cheap and has wide range usage applicable for various applications [14]-[19]. The simple interface of interdigitated electrode (IDE) is a device that can measure various types of sample by incorporating with other types of instrument. The basic design is showed in Figure 3.

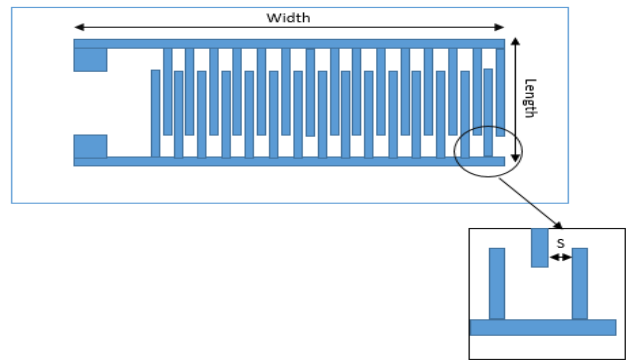


Figure 3: Design of Interdigitated electrode [13]

The working principle of IDE is based on dielectric sensing which is also known as capacitive sensing. The fringing in IDE design will generate an electric field in between each of two fringes after alternative voltage supply. Based on previous studies, the interdigitated electrode is able to measure impedance in low conductivity solution due to the high sensitivity of it [4]. The Equivalent circuit of IDE is as shown in Figure 4.

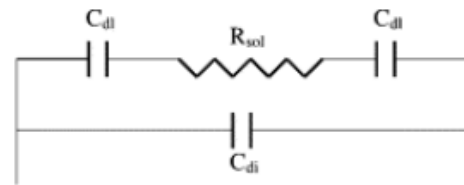


Figure 4: Equivalent circuit of IDE [13]

The characteristic of capacitive from Cdl in low-frequency range had been studied previously. As the frequency increases, the impedance is decreased. Cdl does not provide impedance when reaching the threshold frequency, causing $Rsol$ becomes an independent frequency. Hence, it contributes to impedance measurement.

III. METHODOLOGY

There are three methods used in this project, which are a Taguchi statistical method, LCR meter measurement, and linear regression.

A. Taguchi method

Taguchi method or robust design is a statistical method designed to enhance the fundamental function and performance of productivity by Dr. Genechi Taguchi [20]. Noise factor has been taken into consideration in this design to

maximise the improvement. Overall, this design has been divided into few main steps as shown in Figure 5.

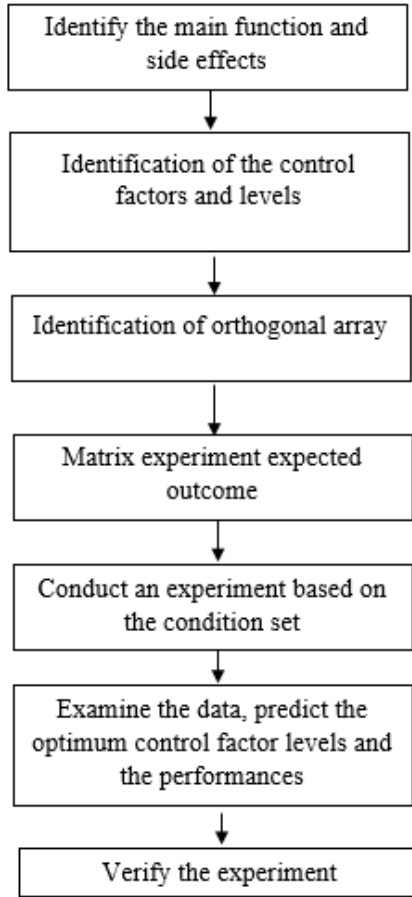


Figure 5: Steps for Taguchi method

In this experiment, there are a few factors affect or influence the dielectric sensing sensitivity. The control factors affected in this design are as listed below:

- Electrode width
- Electrode length
- Spacing between electrode
- Frequency supplied

By using the Taguchi statistical method stated above, the optimal design is obtained by selecting the higher value of SNR.

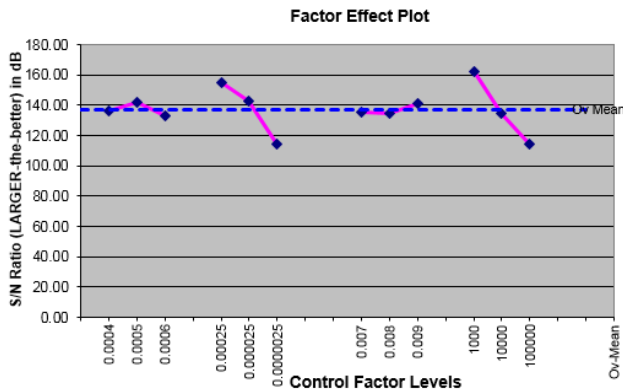


Figure 6: SNR's result level of control factors

Figure 6 shows the results of SNR value in between of all the control factors using the Taguchi Method. The best parameters from the results are shown in Table 1.

Table 1
The most optimised parameter with the highest sensitivity from the Taguchi Method test

| Parameter | Value |
|----------------------|-----------|
| Width | 5.00E-04m |
| Spacing of electrode | 2.50E-04m |
| Length of electrode | 9.00E-03m |
| Frequency | 1000Hz |

B. Linear regression

Linear regression is a statistical method use to analyse the relationship in between the dependent variable and independent variable. The dependent variable in this study is the number of reheating hours, where the independent variable is the impedance of lard. Linear regression model assumed the relationship of dependent variable and independent variable is linear. By using excel data analysis tools, it is able to generate the output of intercept coefficient and coefficient of x. The R square obtained in the result shows the percentage of Y determined by X.

IV. EXPERIMENT PROCEDURE

Experiment set-up is important to ensure the result taken reached the requirement. There are some preparation and precaution need to be noted.

A. Sensor preparation

The sensor used is interdigitated electrode or also known as IDE. The sensor design of interdigitated electrode (IDE) is done by using COMSOL Multiphysics, where the structure design is shown in Figure 7. IDE sensor designed with a different number of electrodes has been fabricated to see the trends of the impedance as the number of electrodes increases with frequency. There are four different numbers of electrodes which are 30, 34, 38, and 42. The design shown in Figure 5 is the IDE sensor with 42 electrode number including its specification, whereas all the specification of IDE designed is tabulated into Table 2. The sensing area material of IDE used copper.

To fabricate the design of IDE on printed circuit board (PCB), the design is required to transfer from COMSOL into CorelDraw 12 in order to print it on a transparent sheet or positive mask. Next, the positive mask art work will be exposing to UV at 375nm, which is able to polymerise the photo-resist on printed circuit board (PCB) and the final output is as shown in Figure 8.

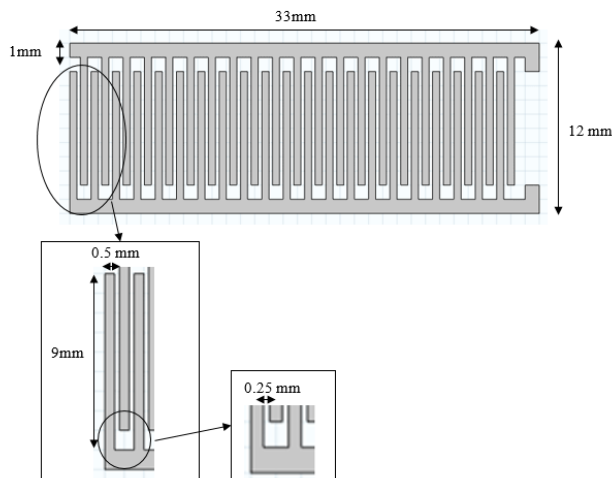


Figure 7: Design in COMSOL Multiphysics of 42 electrodes

Table 2
Specification of interdigitated electrode sensor (IDE)

| Specification | Number of electrodes | | | |
|----------------------------------|----------------------|-------------|-------------|-------------|
| | 30 | 34 | 38 | 42 |
| Length of electrode | 9mm | 9mm | 9mm | 9mm |
| Width of electrode | 0.5mm | 0.5mm | 0.5mm | 0.5mm |
| Spacing of electrode | 0.25mm | 0.25mm | 0.25mm | 0.25mm |
| Area of interdigitated electrode | 25mm x 12mm | 27mm x 12mm | 30mm x 12mm | 33mm x 12mm |

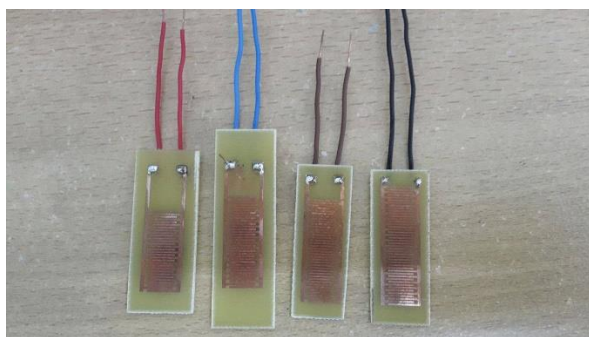


Figure 8: IDE design on PCB

B. Sensor calibration

LCR meter EDC-1630 was connected with LCR meter test clip with 4 BNC cable as shown in Figure 9. In this calibration, distilled water was used as the liquid for calibration. The set-up for calibration is as shown in Figure 10. This calibration technique was taught by the *Institute Penyelidikan Halal UPM* (Halal Research Institute, UPM).



Figure 9: LCR meter test clip with 4 BNC cable



Figure 10: Calibration set-up

C. Lard preparation

This technique is taught by the *Institute Penyelidikan Halal UPM* (Halal Research Institute, UPM) and documents in journals as well [12]. Lard was bought fresh from the market and in a solid state fat. In order to extract the oil from it, lard is required to be heated in the oven for two hours. After it was heated for two hours in the Memmert oven, the lard changed colour into yellow gold, transforming into lard oil in an aluminium container. Second, the lard was poured into a beaker with the aid of filter funnel and three folds of Muslin cloth. Third, the lard oil was slowly poured into the Schott glass bottle equipped with filter funnel, filter paper, and Sodium Sulphate at temperature around 70 Celsius to avoid clotted of lard. The overall process is showed in a block diagram in Figure 11.

D. Experiment set-up

The experiment set up was equip with digital LCR meter EDC-1630, LCR meter test clip with 4 BNC cable, retort stand with two holder, test tube, and a IDE sensor.

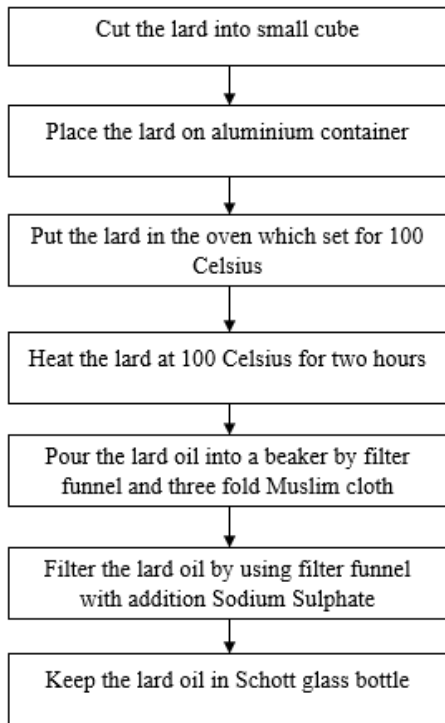


Figure 11: Extraction of lard



Figure 12: Experiment set-up

There are a total of four categories of lard that have been prepared according to the number of reheated hours. Each of the figure shows three samples which have the same characteristic on reheating hour. Figure 13 shows the three sample without reheated, while Figure 14, Figure 15 and Figure 16 show different heating period: 2 hours, 4 hours and 6 hours of reheating respectively.

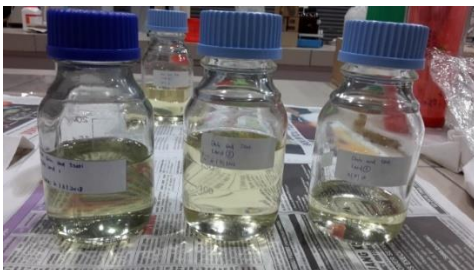


Figure 13: No reheating



Figure 14: Reheating 2 hours

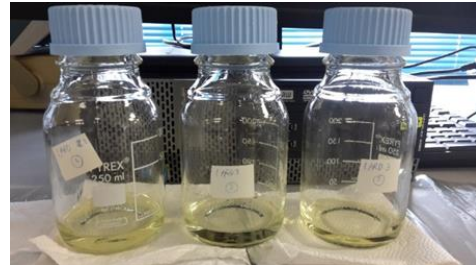


Figure 15: Reheating 4 hours

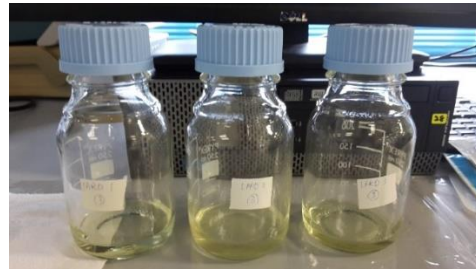


Figure 16: Reheating 6 hours

V. RESULTS AND DISCUSSIONS

A. Impedance measurement

The impedance measurement value was obtained by measuring resistance, capacitance, and inductance. The impedance value was varied by tuning the frequency value in the range from 1 kHz to 100 kHz. In this study, impedance value was taken at 1000Hz, 10000Hz, and 100 kHz by using four interdigitated electrode (IDE) with different number of electrode at room temperature (25 °C).

This study measured three samples heated by different number of reheating hour. The samples have been reheated for 2, 4 and 6 hours. IDE 30, 34, 38, and 42 indicated the number of electrode. The result showed that impedance decreased as number of reheating hours increased. According to Figure 16, 17, 18, and 19, it clearly shows the difference impedance value of sample for reheating hour for 0, 2, 4 and 6. It is possible due to the increasing of dipole which affected the content of fat in phospholipid [5].

Besides, impedance measurement from 1 kHz to 10 kHz clearly shows the decreasing of impedance as reheating hours increase. However, the sample shows overlapping of impedance at higher frequency after more than 10 kHz because dipole at high frequency was unable to follow the rapid reversal field, causing absence of reaction to the electric field [6].

Table 3
Adjusted R² value of sample of IDE 30

| Sample | Adjusted R square |
|--------|-------------------|
| 1 | 0.8545 |
| 2 | 0.9230 |
| 3 | 0.9153 |

The adjusted R² value indicated the percentage of Y determined by X. From Table 3, the range of adjusted R² is within 0.85 to 0.95 or equal to 85% to 95%. The adjusted R² for IDE30 indicates the result of impedance and reheating hour was linearly related with more than 85%.

B. Linear regression data analysis

Linear regression analysis was used to relate the reheating hours (predictor) and impedance (response variable). The regressed relationship in between the impedance and reheating hours was based on the same frequency supply as shown in Figure 17, 18, 19, and 20. By using linear regression, it is able to indicate the percentage of Y determined by X. The higher the percentage, the higher the linearity in between the two variables.

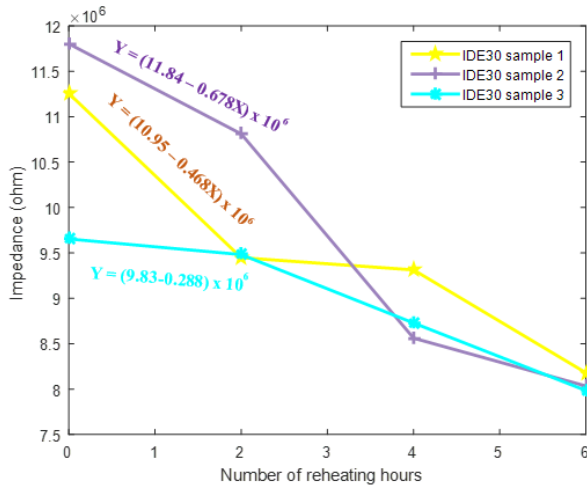


Figure 17: Impedance measurement of 1000Hz regressed to reheating hours by using IDE30

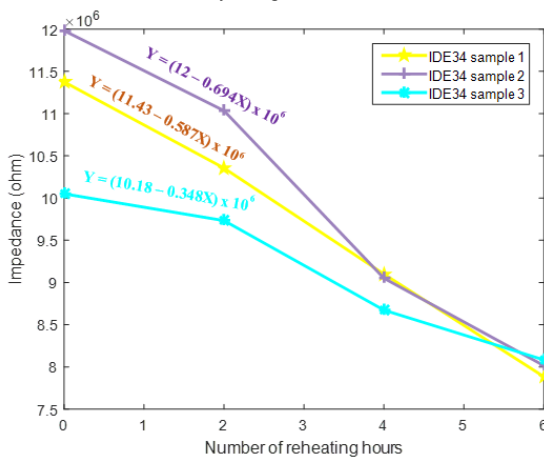


Figure 18: Impedance measurement of 1000Hz regressed to reheating hours by using IDE34

Table 4
Adjusted R² value of sample of IDE 34

| Sample | Adjusted R square |
|--------|-------------------|
| 1 | 0.9971 |
| 2 | 0.9697 |
| 3 | 0.9449 |

Table 4 shows the adjusted R² value within the range of 0.95 to 0.99 or equals to 95% to 99%.

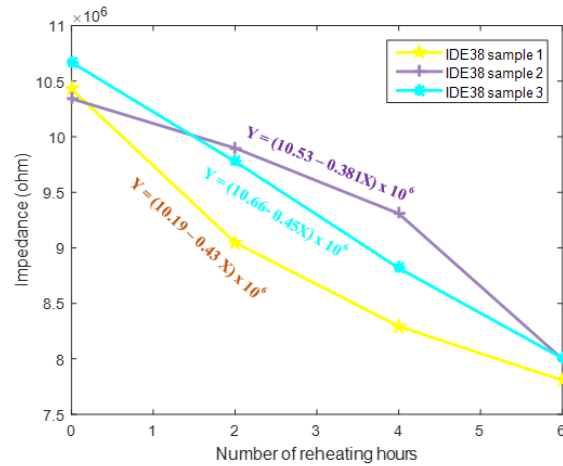


Figure 19: Impedance measurement of 1000Hz regressed to reheating hours by using IDE38

Table 5
Adjusted R² value of sample of IDE 38

| Sample | Adjusted R square |
|--------|-------------------|
| 1 | 0.9208 |
| 2 | 0.9017 |
| 3 | 0.9985 |

Table 5 shows the adjusted R² value for sample measured using IDE 38. The adjusted R² is within the range of 0.92 to 0.99 or equals to 92% to 99%.

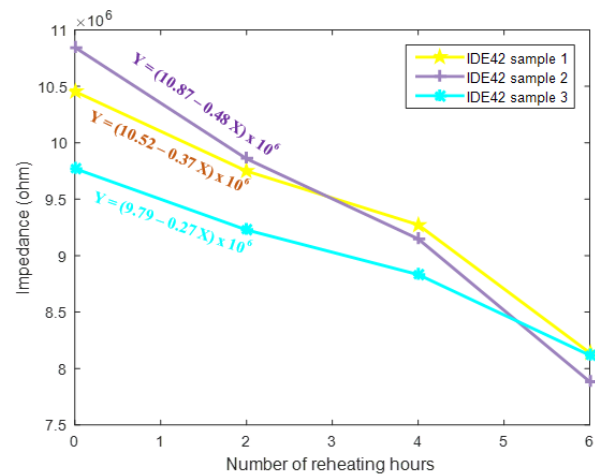


Figure 20: Impedance measurement of 1000Hz regressed to reheating hours by using IDE 42

Table 6
Adjusted R² value of sample of IDE 42

| Sample | Adjusted R square |
|--------|-------------------|
| 1 | 0.9549 |
| 2 | 0.9826 |
| 3 | 0.9811 |

Table 6 shows the adjusted R² value for the samples measured using IDE 42. The adjusted R² is within range of 0.96 to 0.98 or equals to 96% to 98%. It clearly reveals that the measurement results show higher accuracy and precision when using IDE 42. The linearity between the dependent and independent variables for three samples is almost similar.

C. Discussion

The design of interdigitated electrode (IDE) is important as it affected the sensitivity and accuracy of the results obtained. Based on the Taguchi method, the best optimised result is IDE 42, which consists of 42 number of electrode. Taguchi method is a statistical method used to identify control factors that reduce the variety of product by minimising uncontrollable factors (as noise factor) in experiment and manipulating it to optimal control factor.

The result shows that the impedance value of lard was affected by varying the number of reheating hour. As the reheating hour increases, the impedance value of lard decreases. The first comparison made was between the same sample using the same IDE, but different number of reheating hour. This may be due to lard oxidation that has been thermally broken down, causing the number of polar molecules to increase. In the formula, impedance and dielectric constant is inversely proportional; thus, causing impedance value to decrease.

Analysis based on linear regression shows the linearity between impedance (independent variable) and the number of reheating hour (dependent variable). The graph compares the linearity of the result using different IDE. All of the results were almost similar as they have high adjusted R square value or high linearity. R² value for IDE 42 is more constant compared to the other IDEs.

VI. CONCLUSION

In conclusion, an analysis on lard using dielectric sensing method has been successfully carried out. The dielectric sensing method used interdigitated electrode (IDE) was conducted to measure the changes of impedance due to changes of dielectric constant of material. The frequency range of 1 kHz to 10 kHz is considered as the most suitable range to measure impedance lard. As a result, impedance of lard decreases gradually as the number of reheating hours increases within this range of frequency. Lastly, linear regression shows the linear relationship between the impedance and the number of reheated hours.

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