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# RELATIONSHIP BETWEEN CAPACITANCE VALUES AND DIESEL CONTAMINATION LEVELS IN CRUDE PALM OIL

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## ABSTRACT

Measurement of crude palm oil (CPO) contamination is a major concern in CPO quality monitoring. In this study, capacitive sensing technique was used to measure diesel contamination levels in CPO. This technique was choosing because it is provide immediately real-time information of contamination in CPO. Low cost capacitive sensing system was developed in this study by using AD7746 capacitance to digital converter. The effect of diesel contamination levels range from 0% to 50% in CPO and the output of capacitance sensor at a room temperature (25°C) were investigated. The results showed that capacitance value decreased with increases in diesel contamination levels. The regression model for this research $y=0.0002x^2-0.0125x+0.9360$ with $r^2$ value of 0.96. These results indicated that capacitive sensing technique has potential for CPO quality monitoring.

***Keywords:*** *crude palm oil (CPO), capacitive sensing technique, diesel contamination*

## INTRODUCTION

Crude palm oil (CPO) is a type of edible vegetable oil which obtained from mesocarp of palm fruit (Elaise guineensis) during palm oil milling process from fresh fruit bunch (FFB) and also known as the golden commodity. The increment of CPO demand over a year, gives profitability for Malaysia, as one of the major exporter of CPO. Due to that, any deterioration and degradation of CPO is a major concern in CPO quality monitoring. Quality of CPO could be deteriorated during palm oil milling process. [3] reported that water contamination and degradation might occur by condensation of sterilizer during sterilization, unutilized heat insulation during fruit digestion stage, high pressure during pressing stage, badly oxidized sludge oil and high temperature of CPO during clarification stage and overheated of CPO in storage tank after purified.

Edible oil (CPO) also could be contaminated with inedible oils such as petroleum oil, castor oil, and diesel oil. In October 1999 up to 85,000 metric tons of CPO were rejected because of diesel contamination during shipping process from Indonesia to Netherlands [8]. This contamination caused by an inadequate cleaned road transport tankage for transporting edible oil and uses of second hand tanks for storage. This contamination also may affect serious health implication to the consumers. Previously, gas chromatographic (GC) technique was used to detect various mineral hydrocarbons in edible oil. However, diesel oil component cannot be detected by using GC [1]. High performance liquid chromatography (HPLC) was also used to analyse diesel and other petroleum components in petroleum industry [1, 4]. Generally, these techniques were labour intensive, time consuming and required complex laboratory steps.

With the advancement of sensing technology, dielectric technique was widely used in quality monitoring and analysis in various agricultural and food products [6] and [2].

[7] studied the dielectric permittivity of the fruits range from 10MHz to 1.8GHz frequency to determine the fresh fruit quality. Other researchers, [2] suggested that dielectric spectroscopy technique has potential for quality control of oil and practical application in anti-adulteration after they found that the relaxation frequency was different among the vegetable oils such as peanuts, corn, sunflower, soybean, olive and various seed oil when measurement were taken at microwave frequency range. This technique, however require high cost of equipment investment.

The objective of this study is to develop a low cost capacitive sensing system that able to measure diesel contamination in CPO. The system has advantages in term of real-time monitoring, portability, fast response and high accuracy.

## MATERIALS AND METHODS

The low cost capacitive sensing system was developed to measure the diesel contamination in CPO. Two important parts were hardware and software development. For hardware development, AD7746 capacitance to digital converter (Analog Devices Inc., Shanghai, China) as shown in 'Fig. 1' was used in this system. AD7746 was chosen based on its high accuracy (4±fF factory calibrated), high resolution capability, high linearity (+0.01%) and function as capacitance to digital converter (CDC). This component has two capacitive input channels which were used for capacitive measurement. A PIC16876A (Microchip Tech. Inc, USA) microcontroller also was used in this system for system control. A full circuit board for low cost capacitive sensing system was developed as shown in 'Fig. 2'

Fig. 1: Sensor Head for AD7746 Capacitance to Digital Converter

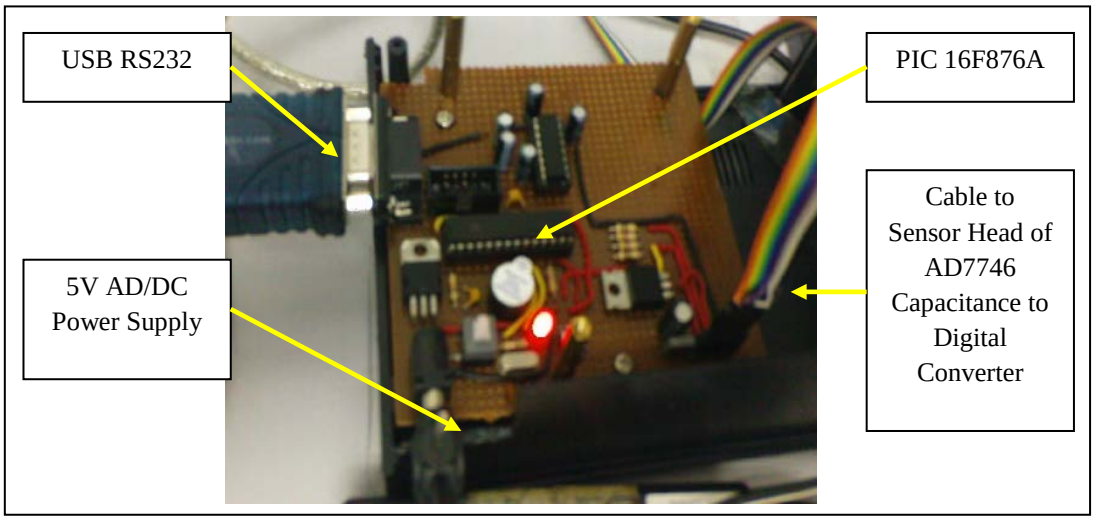


Fig. 2 : Circuit board for capacitance measurement using AD7746 Capacitance to Digital Converter

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For software development, MPLAB IDE was used in this project and the source code of sensing operation was written in C programming language. 'Fig. 3' showed the whole programming flow chart for capacitance measurement and CPO contamination detection.

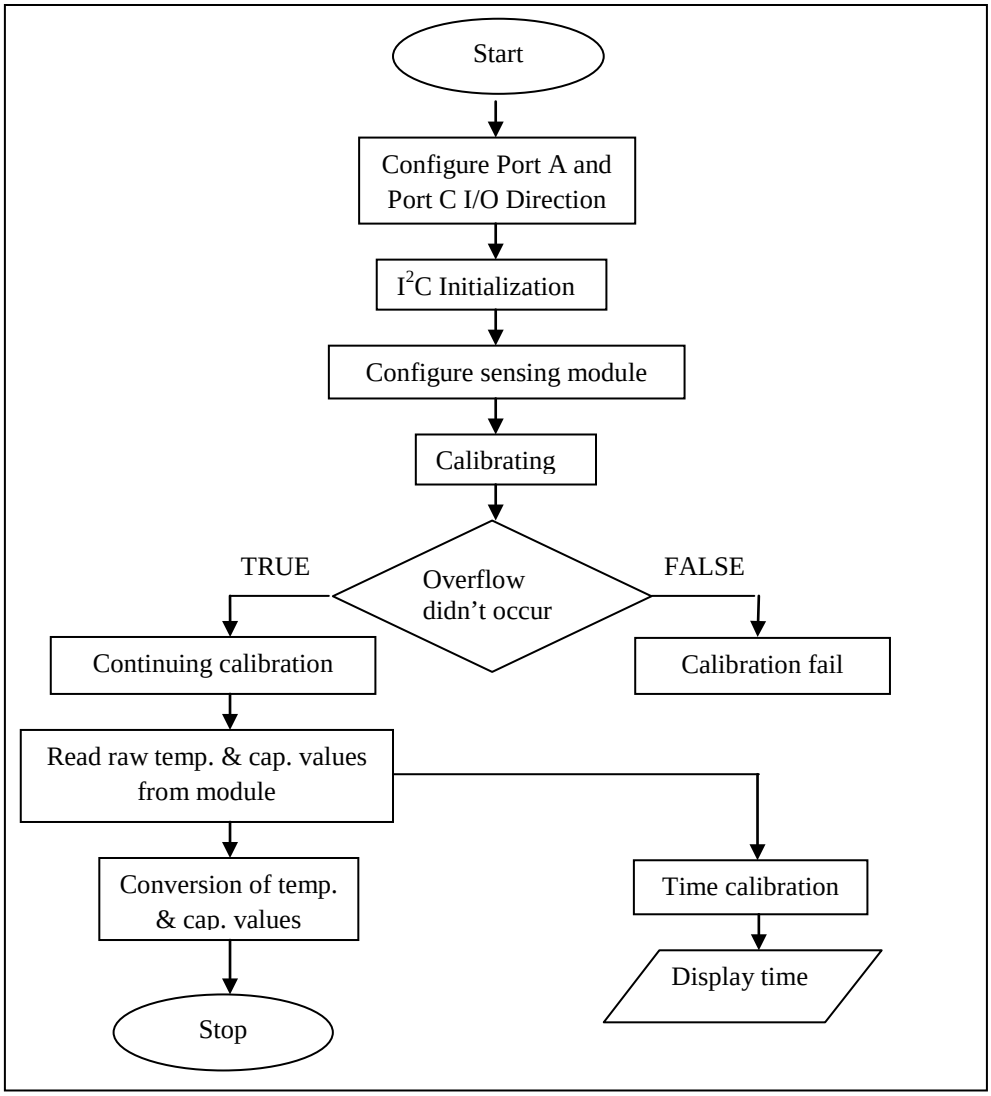


Fig. 3: Programing Flow Chart for Capacitance Measurement and CPO Contamination Detection

For the sample preparation, pure CPO sample was obtained from a local palm oil processing mill. In this research, Shell Diesel B5 was used as a contaminated component. The experiment was carried out at the different diesel contamination levels. Fifteen (15) samples were prepared with ( 0,1,2,3,4,5,6,7,8,9,10,20,30,40 and 50 )% level of contamination and the measurement was taken at a room temperature. Prior to the experiment, calibration process was done by setting the programme and recording the air capacitance value as a zero scale. Then, the sensor head was immersed into the pure sample for at least one minute to obtain constant capacitance value of pure CPO. After that, the capacitance values for all samples were measured at desired diesel contamination. The experiment was done in replications. Average capacitance values (pF) were recorded and analysed.

## RESULTS AND DISCUSSIONS

The capacitance values of CPO were observed at various diesel contamination levels. Descriptive data analysis was done to analyse the data. The mean capacitance value for pure CPO was 0.945. When 10% of diesel was added into CPO, the mean value was increased into 0.802 and at 50% diesel contamination level, the mean value keep increased into 0.695 as indicated in Table 1. From the analysis, it showed that the mean value keep decreased with the increment of diesel contamination levels. In this analysis, standard deviation range from 0.01 to 0.06. Most of the diesel contamination levels had a standard deviation less than 0.04.

Table 1: Descriptive analysis for each diesel contamination levels

| Percentage of Diesel (%) | Capacitance Value (pF) Mean | Variance $s^2$ | Standard Deviation s |
|---|---|---|---|
| 0 | 0.945 | 0.0022 | 0.0332 |
| 1 | 0.922 | 0.0004 | 0.0142 |
| 2 | 0.930 | 0.0029 | 0.0381 |
| 3 | 0.906 | 0.0006 | 0.0166 |
| 4 | 0.898 | 0.0029 | 0.0382 |
| 5 | 0.882 | 0.0004 | 0.0144 |
| 6 | 0.886 | 0.0003 | 0.0122 |
| 7 | 0.834 | 0.0001 | 0.0052 |
| 8 | 0.834 | 0.0006 | 0.0170 |
| 9 | 0.810 | 0.0001 | 0.0066 |
| 10 | 0.802 | 0.0007 | 0.0193 |
| 20 | 0.748 | 0.0083 | 0.0644 |
| 30 | 0.731 | 0.0039 | 0.0440 |
| 40 | 0.711 | 0.0001 | 0.0078 |
| 50 | 0.695 | 0.0065 | 0.0570 |

In Fig. 4, the CPO with 0% to 10% diesel contamination had a rapid decrement in capacitance value compared to diesel contamination of 10% to 50% which slightly decreased with increases in diesel contamination levels. This correlation showed that the capacitance value was closely related to density. Theoretically, less density contains the fewer numbers of molecules per unit volume. Thus, the interaction with electric fields might be less also and therefore a decrease in capacitance value. In this research, higher diesel contamination levels caused a less density in contamination CPO samples. Hence, the value of capacitance decreased.

In this study, 0% to 50% of diesel contamination levels were used to develop a model in CPO quality monitoring. Overall, the model of CPO with diesel contamination at room temperature, ($y= 0.0002x2-0.0125x+0.9360$) yielded the high accuracy with $r^2=0.96$ as shown in 'Fig. 4'. It was clearly seen that the capacitance value of CPO could be an indicator to determine the contamination level of CPO.

However, only a small range (0% up to 10%) of diesel contamination in CPO usually occurs during shipping process and storage stage. In this analysis, 0% up to 10% of diesel contamination levels showed rapidly decreased in capacitance value with a linear regression model $y= -0.02x + 0.95$, $r^2 =0.95$ as indicated in 'Fig. 5'.

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Overall, both models gave a good correlation and thus we can use these models for future prediction of diesel contamination in CPO. On the other hand, accuracy of the data might be affected by non controlled environment temperature and humidity that occurred during data collection. The results then are expected to be improved with additional data for more accurate equation model of CPO with diesel contamination.

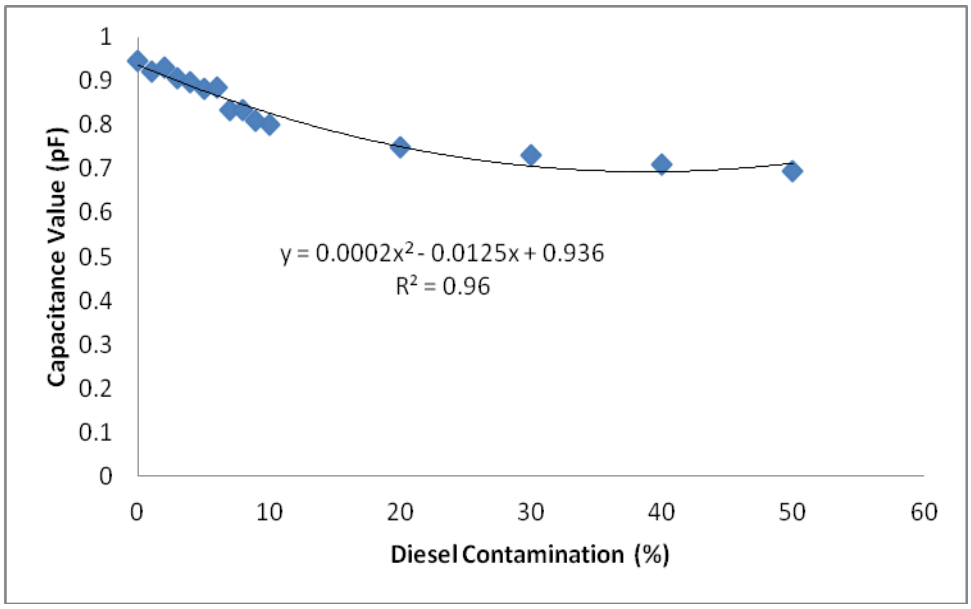


Fig. 4 : Capacitance value of CPO versus diesel contamination levels (0-50)% contamination.

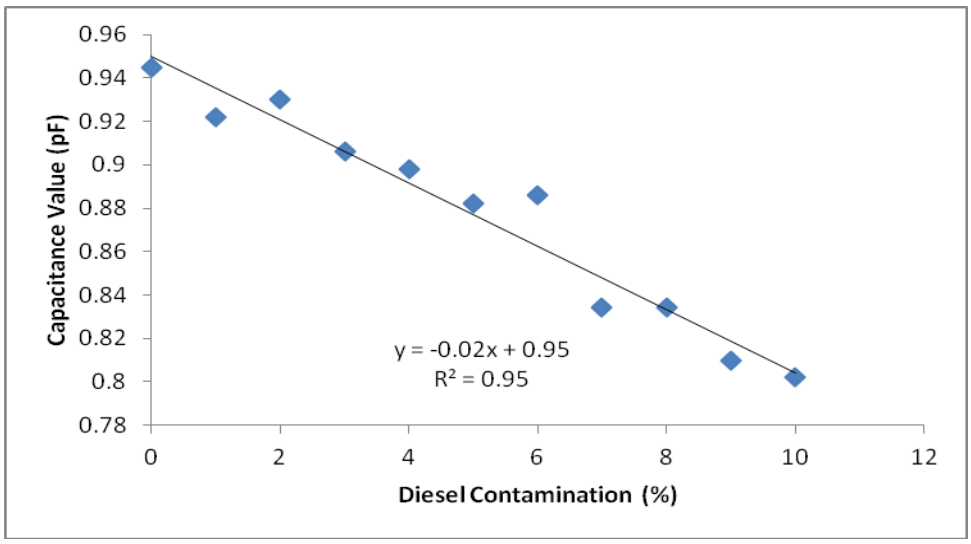


Fig. 5 : Capacitance value of CPO versus diesel contamination levels (0-10)% contamination with linear regression model ($r^2$=0.95)

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## CONCLUSIONS

From this research, it can be concluded that the low cost capacitive sensing system has been succcessfully developed and has potential to be used as a sensing mechanism of CPO quality monitoring. Extended work on model validation should be conducted to test the feasibility of the developed model in real application. The modification of the capacitive input channel in the AD7746 capacitance to digital converter should also be studied to improve the accuracy of measurement.Besides that, other possible contaminations such as free fatty acid (FFA), iron, copper and other impurities can be analysed to provide more information for CPO quality monitoring. Large amount of data sets should also be collected for accuracy in data analysis.

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