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EFFECT OF DIESEL CONTAMINATION ON CAPACITANCE VALUES OF 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 monitor diesel contamination levels in CPO. A low cost capacitive sensing system was developed by using AD7746 capacitance to digital converter. The capacitance value of CPO samples with different contamination levels (v/v%) ranged from 0% to 50% was collected at a room temperature (25°C). The objective of this study is to find a relationship between capacitance values and diesel contamination levels in CPO. The results showed that capacitance value decreased as the diesel contamination levels increased. For the 0% to 50% contamination range, the regression equation was $y = 0.0002x^2 - 0.0125x + 0.936$ with R^2 value of 0.96. For the 0% to 10% contamination range (where the percentage was the representative of potential contaminations levels found in CPO) the correlation equation was $y = -0.02x + 0.95$ with R^2 value of 0.95. These results indicated that capacitive sensing technique has potential for CPO quality monitoring.

Keywords: Crude palm oil (CPO), Capacitive sensing, Diesel contamination.

1. Introduction

Deterioration and degradation of crude palm oil (CPO) is a major concern in palm oil industry. Depending on the processing method, CPO could be deteriorated at a few stages in palm oil milling process, which consequently affects its quality. Gee [1] reported that water contamination and degradation might occur by condensation of sterilizer during sterilization, high pressure during pressing stage, badly oxidized sludge oil, high temperature of CPO during clarification stage and overheated of CPO in storage tank after purified.

CPO could also 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 [2]. 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 often reported to be used for determination of various mineral hydrocarbons in vegetable oil. However, not many addressed diesel oil contamination [3]. High performance liquid chromatography (HPLC) was also used to analyse diesel and other petroleum components in petroleum industry [3, 4]. Generally, these techniques were expensive, 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 [5, 6] and also in oil-related industrial operations [7]. The potential of using dielectric sensing technique in vegetable oil quality monitoring have been studied and reported. Lizhi et al. [8], for example, conducted a study on the dielectric properties of edible oils and fatty acids as a function of frequency, temperature, moisture and composition. The result indicated that the dielectric constant of corn oil increased with increasing moisture content and decreased significantly with increasing frequency. Their study also showed a positive result in discriminating adulterated edible oils. They concluded that the information about dielectric properties could be useful in oil identification, quality evaluation and quality monitoring during oil processing and storage. Besides, Lizhi et al. [9] conducted further study to distinguish olive oil adulterated with other vegetable oils. Their study showed a good prediction capability for different concentrations of adulterant in olive oil. Other than that, Cataldo et al. [6] investigated the dielectric properties of several vegetable oils such as peanut, corn, sunflower, soybean, olive, and various seed oil using microwave dielectric spectroscopy. They found that the relaxation frequency differed among the vegetable oils, and it was a key to identifying different kinds of oil. They suggested that dielectric spectroscopy technique has potential for practical application in adulteration detection and oil quality control. The drawback of this technique however, it mostly worked in high frequency region (microwave region) which requires high cost of equipment investment for robust application.

The aim of this study was to develop a low cost capacitive sensing system that able to measure diesel contamination in CPO. The specific objective of this study was to investigate the effect of diesel contamination on capacitance value of CPO. The system has advantages over the conventional technique in term of real-time monitoring, portability, fast response and high accuracy.

2. Materials and Methods

The low cost capacitive sensing system was developed to monitor the diesel contamination in CPO. An AD7746 capacitance to digital converter (Analog Devices Inc., Shanghai, China) as shown in Fig. 1 was used in this system. The AD7746 was chosen based on its high accuracy (4$\pm$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 a low cost capacitive sensing system was developed as shown in Fig. 2.

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

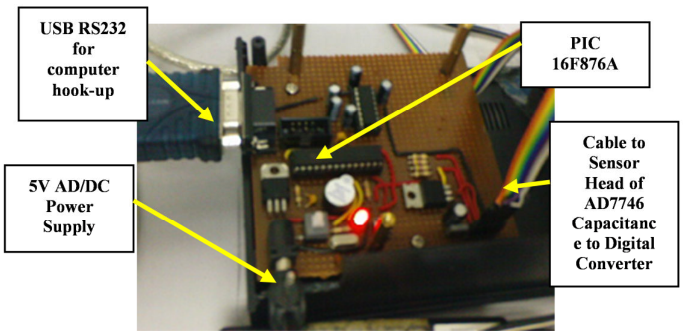

Fig. 2. Circuit Board for Capacitance Measurement Using AD7746 Capacitance to Digital Converter.

For software development, MPLAB Integrated Development Environment (Microchip Technology Inc. Shanghai, China) software was used and the source code of sensing operation was written in C programming language. Figure 3 shows the whole programming flow chart for capacitance measurement and CPO contamination detection.

In the sample preparation, pure CPO with density of 0.89 kg/l was obtained from a local palm oil processing mill. In this study, Diesel No.2 with the density 0.83 kg/l was used as the contaminant. The experiment was carried out at different diesel contamination levels. Fifteen samples were prepared with incremented level of contamination (v/v) of 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40 and 50%. The measurement was taken at a room temperature of 25°C. Prior to the experiment, the sensor was calibrated by setting 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 three replications. Average capacitance values (pF) were recorded and analysed.

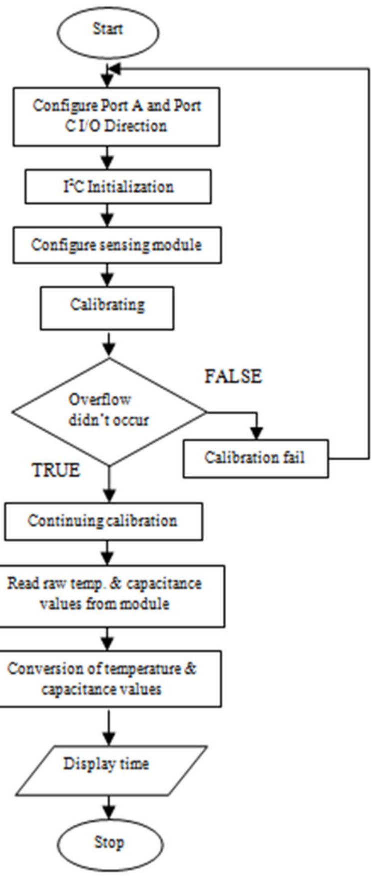

Fig. 3. Programming Flow Chart for Capacitance Measurement and CPO Contamination Detection.

3. 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 pF. When 10% of diesel was added into CPO, the mean capacitance value was decreased to 0.802 pF and at 50% diesel contamination level, the mean value decreased to 0.695 pF as indicated in Table 1. From the analysis, it showed that the mean capacitance value was decreased with the increment of diesel contamination levels. In this analysis, the standard deviation range from 0.01 to 0.06 pF.

In Fig. 4, a rapid decrement in capacitance value was observed at 0% to 10% diesel contamination while at 10% to 50% contamination, a slightly gradual decreased was observed. The density of pure CPO is 0.89 kg/l while the density of Diesel No. 2 is 0.83 kg/l. When 10% of diesel was added into pure CPO, the density value of resulting mixture becomes 0.88 kg/l by using Eq. (1).

$$\text{Maximum Density} = \frac{D_1(R_1) + D_2(R_2)}{100} \tag{1}$$

where D_1 is the density of CPO, 0.89 kg/l, D_2 is the density of Diesel No. 2, 0.83 kg/l, R_1 is the percentage of CPO and R_2 is the percentage of Diesel No. 2.

Table 1. Mean and Standard Deviation of Capacitance Value for each Diesel Contamination Levels.

Percentage of Diesel (%)	Mean Capacitance Value (pF)	Standard Deviation (pF)
0	0.945	0.0332
1	0.922	0.0142
2	0.930	0.0381
3	0.906	0.0166
4	0.898	0.0382
5	0.882	0.0144
6	0.886	0.0122
7	0.834	0.0052
8	0.834	0.0170
9	0.810	0.0066
10	0.802	0.0193
20	0.748	0.0644
30	0.731	0.0440
40	0.711	0.0078
50	0.695	0.0570

The more percentage of diesel added in a CPO, the density of the mixture became lower. Theoretically, lower density oil (mass) contains fewer numbers of molecules per unit volume [10]. Thus, the interaction between the molecules and the electric fields may decrease and therefore a decrease in the capacitance value. In this study, higher diesel contamination level in the CPO produced lower density mixture. Hence, the value of capacitance decreased.

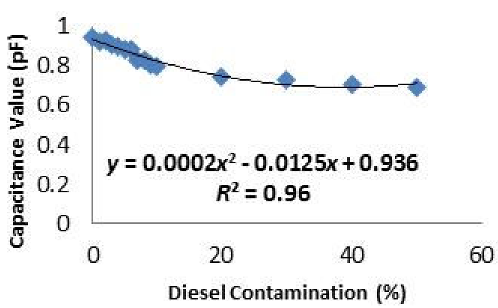

Fig. 4. Capacitance Value of CPO vs. Diesel Contamination Levels at 0-50% Contamination.

A curve fitting was done to find the relation equation between the capacitance value and the 0% to 50% diesel contamination levels for CPO quality monitoring.

Overall, at the 0% to 50% contamination range, the regression equation of CPO with diesel contamination at room temperature, was y = $0.0002x^2$ -$0.0125x$ + 0.936; yielded the correlation coefficient of 0.96 as shown in Fig. 4. It was clearly seen that the capacitance value of CPO could be an indicator to determine the diesel contamination level of CPO.

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

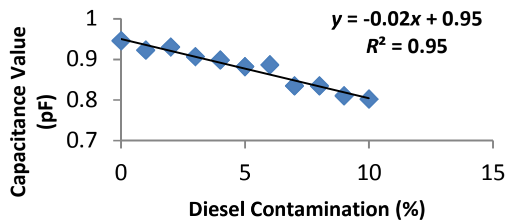

Fig. 5. Capacitance Value of CPO vs. Diesel Contamination Levels at 0-10% Contamination with Linear Regression Model (R^2=0.95).

Overall, both equations gave a good correlation and showing that the developed low cost sensing system has potential to be used for future prediction of diesel contamination in CPO. The system then is expected to be improved with further model validation in real application.

4. Conclusions

The effect of diesel contamination in CPO particularly on its capacitance values was investigated. From this study, we found that:

- capacitance value decreased as the diesel contamination level increased in CPO. For the 0% to 50% contamination range, the regression equation was y = $0.0002x^2$ - $0.0125x$ + 0.936 with R^2 value of 0.96. For the 0% to 10% contamination range (where the percentage was the representative of potential contaminations levels found in CPO) the correlation equation was y = -$0.02x$ + 0.95 with R^2 value of 0.95.
- It can be concluded that the diesel contamination in CPO give significant effect on the capacitance values of the mixture.

The low cost capacitive sensing system developed in this study 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 equation 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, other possible contaminations such as iron, copper and other impurities can be tested to explore the versatility of the sensing system for CPO quality monitoring.

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