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Fibre Optic Displacement Sensor For Honey Purity Detection In Distilled Water

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Abstract: This paper reported a simple fibre optic displacement sensor (FODS) detecting honey purity in distilled water. The sensor detected the purity of honey at different concentrations of honey. Kelulut and Tualang act as pure honey, whereas A1 Honey and A2 Honey as adulterated honey demonstrate the sensor's performance. The displacement curves of honey solutions with various concentrations by using the FODS system. The pure honey with a higher concentration has greater sensitivity 0.2344 mV/mm for Kelulut and 0.2312 mV/mm for Tualang. It can detect the signal closer to the sensor's sensitivity in the air. However, adulterated honey has increased sensitivity as the concentration decreased, which is for A1 Honey is 0.1901mV/mm and A2 Honey is 0.1504mV/mm. The proposed sensor had a real-time measurement, consistent performance, and the most straightforward sensor design, giving valuable parameters for detecting honey purity.

Keywords: Fibre Optic, Fibre Optic Displacement Sensor, Honey

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1. Introduction

Honey is partly a food substance in flower nectar or other parts of flower plants produced by honey bees [1-2]. Honey has many benefits, especially for nutrition and medicine, which act as antioxidants since it is a natural sweet substance. However, since honey is often sold commercially, it causes a bulk of adulterated or fake honey, especially in South East Asia, including Malaysia. The adulterated or counterfeit honey can cause harm to consumers' health [3]. Generally, consumers find it almost impossible to know whether it is pure or impure honey because of the same colour and nearly similar properties and tastes [4].

Nowadays, the benefits of honey cause it to have higher demands in the commercial market as it can be a good source of antioxidants, used in medicine as it can heal wounds, help for digestive issues, soothe a sore throat, etc [5]. Thus, honey is known as one of the most faked foods globally. Many companies have taken advantage of the rising popularity of honey, which caused consumers difficulty determining whether it is pure honey or adulterated honey. Various technologies and methods led by many researchers, such as high-performance liquid chromatography (HPLC), stable carbon isotope ratio analysis 3 (SCIRA), Fourier transform infrared (FTIR), and others [6-7] which can determine the purity of honey. Still, it has more disadvantages such as time-consuming, required operators to develop high skills, which are essential in process separation of chemicals and more elevated cost for isotope tests [8]. Various studies of fibre optic displacement sensors have been reported in the past few years, such as temperature measurement [9], cholesterol detection [10] and fibre interferometric [11].

There are traditional and modern methods that have led many researchers to recognise the purity of honey. In conventional ways, Physicochemical Parameter and Melissopalynogical, known as studies, used human senses to identify the origin of honey by its appearance, for example, using computer vision, including aroma that used electronic nose and taste using electronic tongue [12]. Whereas for modern methods, there are many analytical techniques such as Chromatographic Methods, Mass Spectrometry, Infrared Spectroscopy, Nuclear Magnetic Resonance (NMR) and Molecular Techniques. These techniques can determine sugar and amino acids acid profiles, including identifying honey compounds, proteins, and DNA [13]. However, these methods are still under consideration. More disadvantages include time-consuming, required operators to develop high skills that are important in process separation of chemicals and high cost [14-15].

Therefore, a simple technique to identify pure and fake honey is proposed by using fibre optic displacement sensors (FODS) to distinguish the concentration of liquid suitable to detect the purity of honey from adulterated ones. Fibre optic displacement sensors are considered a new method for determining the development variety of sensors. This research will discuss a technique using fibre optic displacement sensors (FODS) to determine the purity of honey.

2. Materials and Methods

Figure 1 shows the schematic diagram of honey purity detection by using the FODS system. He-Ne laser source with a wavelength of 633 nm was used in this study. This technique uses a bifurcated fibre bundle with two fibres side-by-side in the common end and breaks out into two legs. For transmitting fibre, it is connected to a light source that will allow a beam to enter the fibre to the end of the probe that will emit the light to the flat mirror. On the other hand, receiving fibre is connected to an oscilloscope capable of collecting the reflected light with high-speed detection. After the light travels out from transmitting fibre, it will scatter and collect it.

Therefore, the scattered light will transmit into the oscilloscope to measure the reflected light from the liquid surface of honey purity. The fibre optic probe was adjusted axially in the range of 0 to 25 mm and gradually increased by 5 mm. Along the lines of each increment, the Tektronix TDS 3052c oscilloscope will detect the output intensity of the beam for different types of honey. The output light from the He-Ne laser source was coupled into the transmitting fibre cause the light propagated through it and exited at the end of the probe. A honey solution in the cuvette reflected the light to receiving fibre on the probe. Thus, the other end of the receiving fibre was connected to the oscilloscope to record the reflected light. The reflected light was collected at 0 to 25 mm of displacements from the honey solution's surface. Based on the setup above, the electric linear actuator displaced the sensing probe and controlled it using software installed in the laptop. This procedure is carried out at room temperature, 25 °C under atmospheric pressure with a speed of 1mm/second and stroke length 100 mm of the linear actuator. In this study, two concentrations have been used, which is for 100% honey does not dilute in distilled water to maintain the purity whereas for 50% of honey was diluted as 1% honey solution is defined as 1gram/100mL of distilled water.

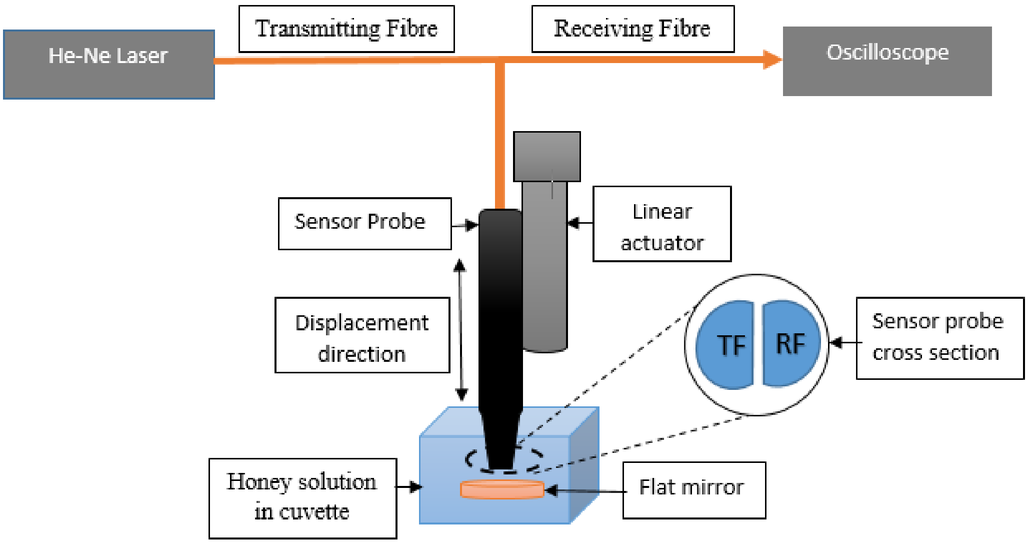


Figure 1: Schematic diagram of honey purity detection in distilled water

3. Results and Discussions

Figure 2 and Figure 3 show the displacement curve for 100% and 50% concentrations of Kelulut, Tualang, A1 Honey and A2 Honey were obtained using the He-Ne source. The effect of small displacement is caused by the probe that was measured closed towards the flat mirror, which shows the signal of output from the oscilloscope at a minimum value since there is no light occurring in the fibre. Therefore, when the distance from the flat mirror increases, it causes the size of the reflected beam of light towards the fibre also increases. The graph shows that with wavelength 633nm, the reflected beam of light increases from a low value and after the signal of output reaches the peak value, it will cause displacement to decrease. It is due to the relationship of inverse square law.

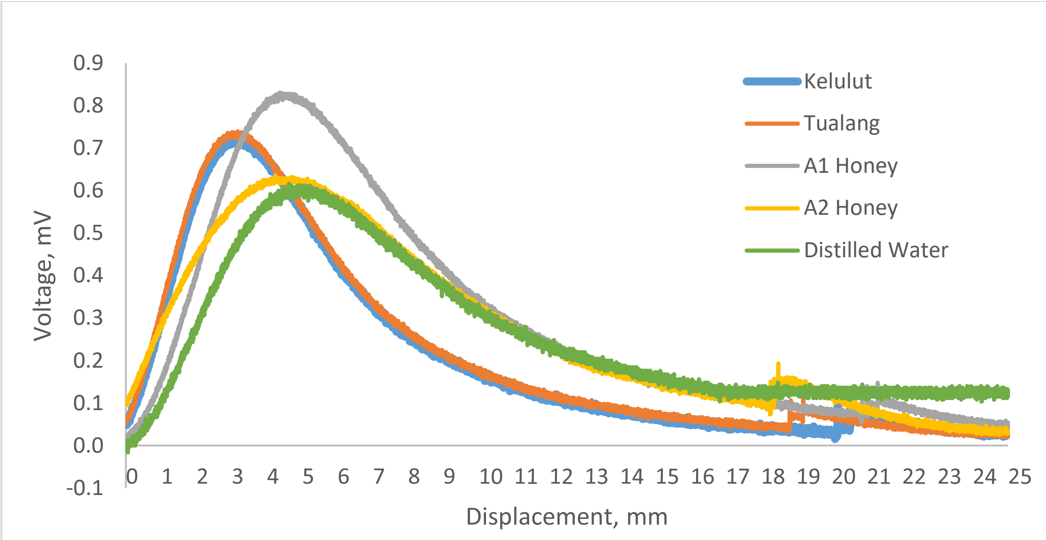


Figure 2: Output voltage with displacement sensor at 100% concentration of honey

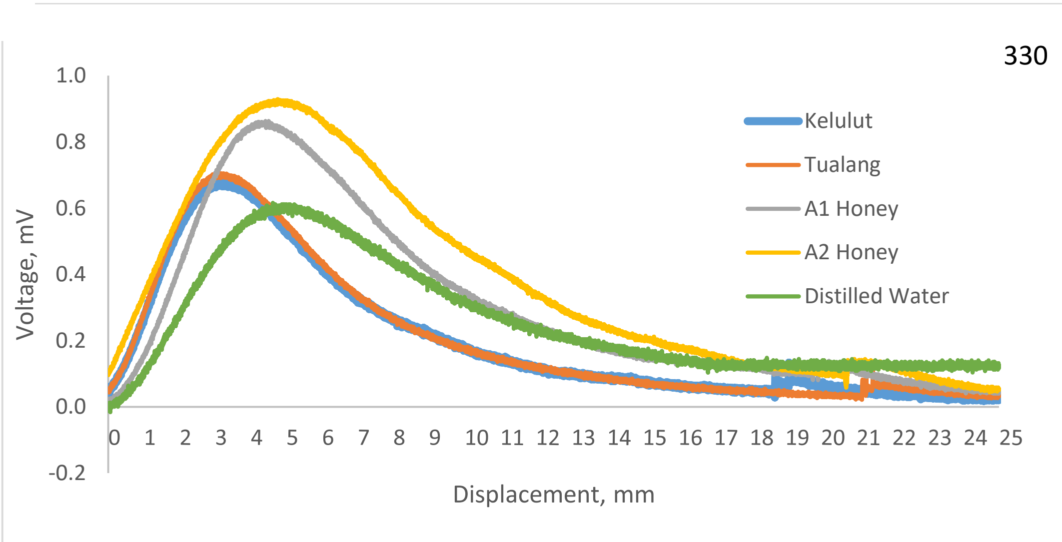
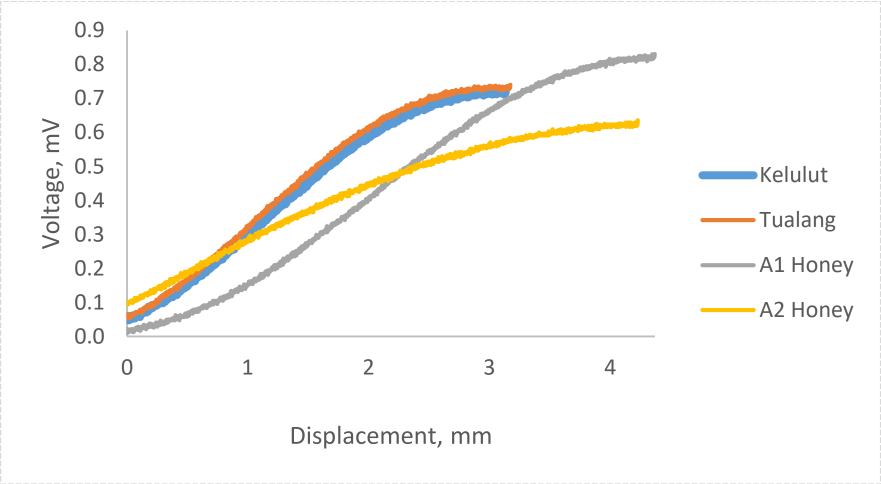


Figure 3: Output voltage with displacement sensor at 50% concentration of honey

The 100% concentration of Tualang and Kelulut shows an optimum peak voltage as it is realized there is no additional distilled water in honey solution compared to 50% of concentration. It is found that the output voltage is proportional to the concentration of honey due to variation of the intensity of receiving light. The changes in the emitting and acceptable angles between transmitting and receiving fibres change the immersion concentration result. However, for 50% of honey concentration, the figure shows insensitivity toward the sensor, as the increase in refraction angles caused it to reduce the output voltage.

Figure 4 and Figure 5 illustrates the sensitivity and linearity performance of sensors for honey purity in distilled water at the front and back slopes. It shows that both slopes are increased and decreased linearly within certain linearity for different honey concentrations. Thus, it can detect the signal as it is close to the sensitivity in the air. The linearity obtained for the front and back slopes is more than 96%. For pure honey, displacement for the linear range starting from starting point until 0.7053 mm, known as peak voltage with a sensitivity of 0.2221 mV/mm, as shown in Table 2, involved the different honey with different concentrations. Thus, the measurement purity of honey will be indicated by the front slope and back slope.



(a)

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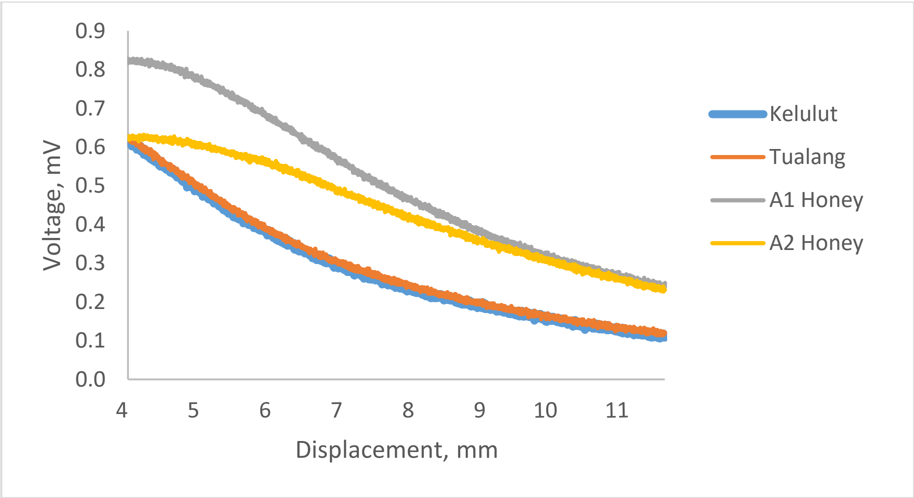
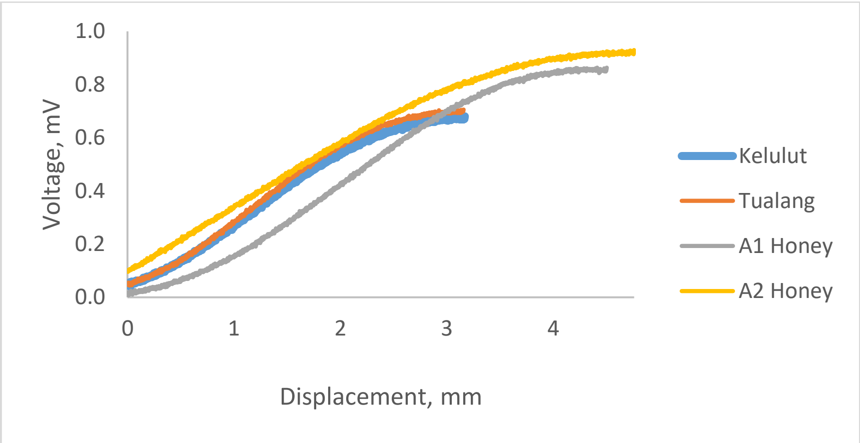


(b)

Figure 4: (a) Front slope and (b) back slope with linearity for 100% concentration of honey



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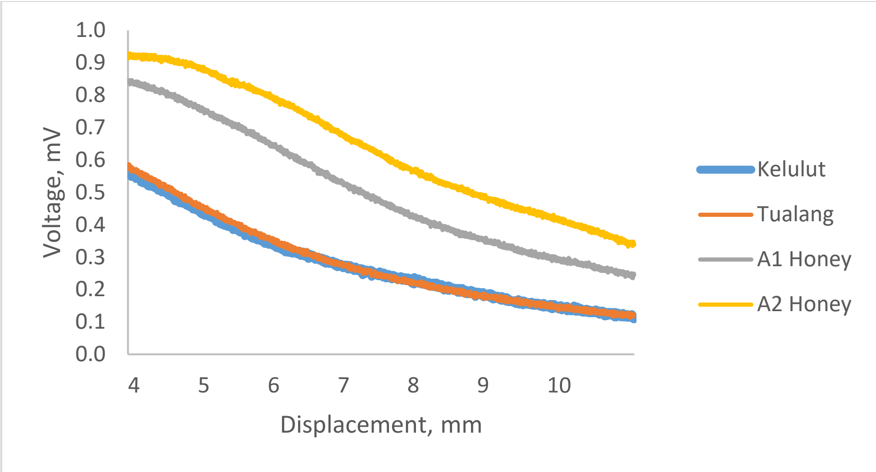

(b)

Figure 5: (a) Front slope and (b) back slope with linearity for 50% concentration of honey

Table 1 shows the output voltage of distilled water against displacement of the reflecting target from the fibre probe. As the displacement increases, the output voltage decreases as the probe tip is far from the flat mirror.

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Table 1: Output voltage in distilled water

Displacement (mm)	Output Power (mV)
5	0.5653
10	0.1813
15	0.0720
20	0.0720
25	0.0240

Table 2: Performance FODS of honey with different concentrations

Types of honey	Honey concentration (%)	Peak voltage (mV)	Front slope		Back slope	
			Sensitivity (mV/mm)	Linearity (%)	Sensitivity (mV/mm)	Linearity (%)
Tualang	50	0.7053	0.2221	97.52	-0.1567	97.20
	100	0.7400	0.2344	96.85	-0.1644	96.85
Kelulut	50	0.6800	0.2145	97.81	-0.1511	97.45
	100	0.7253	0.2312	97.65	-0.1612	97.65
A1 Honey	50	0.8627	0.1916	98.09	-0.1917	98.00
	100	0.8307	0.1901	98.64	-0.1846	98.64
A2 Honey	50	0.9293	0.1953	96.43	-0.2065	96.22
	100	0.6360	0.1504	96.22	-0.1413	99.08

Table 2 summarise the performance of FODS to achieve the objective, which is to characterise the samples at different concentrations of honey. In this experiment, the same probe has been used to test the different concentrations of honey. The increment in displacement from 0 to 25mm is important because if the linear actuator is fixed at a certain displacement, it will cause the reflected power to have a substantial change. Thus, the distance has a slight variation between the tip of the sensor and the interface of the air sample. It shows that both slopes increase linearly within certain linearity for different honey concentrations. For pure honey, the sensitivity of the front slope showed an increasing trend concerning concentrations of honey. Thus, the pure honey with a higher concentration has greater sensor sensitivity as it can detect the signal that is closer to the sensor's sensitivity in the air. The same goes for the sensitivity of the back slope, gradually decreasing with respect to concentrations of honey. Thus, as higher the measurement's repeatability caused the correlation coefficient to become almost greater than 96%. In addition, pure honey has the same trend of slope for 50% and 100%, whereas for adulterated honey, vice versa.

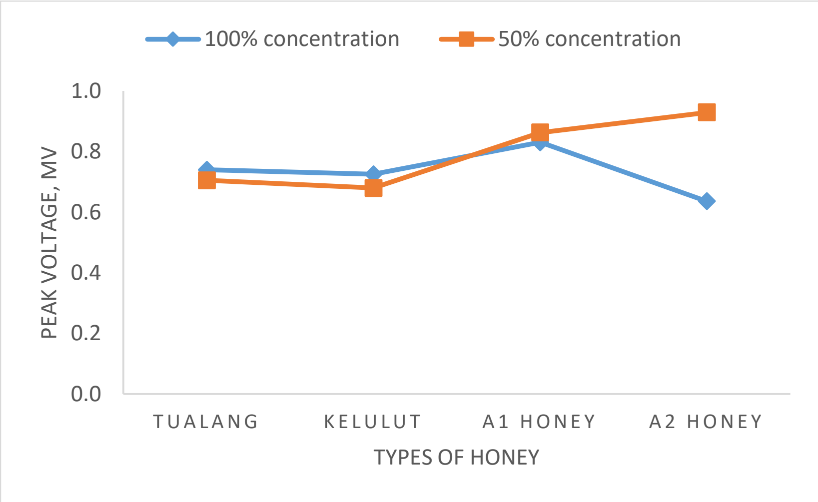

Figure 6: Peak voltage versus honey samples

Figure 6 shows the variation of peak voltage with different types of honey at 100% and 50% of honey concentration. The figure shows that peak voltage linearly increased with a sensitivity for pure honey, whereas linearity for adulterated honey decreased as concentration increased. The peak voltage is used to analyse the fibre optic displacement sensors [16]. The changes of the emitting and angles in the bifurcated fibre are commonly caused by the varying intensity of the receiving light. As the refraction angle reduces with the increase of the concentration, thus the output voltage also increases. The differences of refractive indices make the refraction occur between the material of bifurcated fibre and the honey solution [17].

4. Conclusion

The fibre optic displacement sensor successfully detects pure and adulterated honey with different concentrations. Using He-Ne laser with 633nm wavelength, pure honey samples, Tualang and Kelulut, show a similar trend slope. For adulterated honey, A1 Honey and A2 Honey, the trend slightly decreases and increases at different concentrations. After successfully classifying and analysing the purity of honey using FODS, sensitivity for pure honey decreased as the concentration decreased, whereas adulterated honey increased sensitivity as the concentration decreased. Thus, FODS also successfully shows its ability to differentiate the purity of honey, which does not consume chemical processes, less time-wasting and less preparation for the sample.

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