Fiber optic displacement sensor for honey purity detection in distilled water

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A simple fiber optic displacement sensor is employed for sensing a purity of honey in distilled water. Concentration of honey is varied from 75% to 100% of honey purity. Prior that, the performances of sensor is first demonstrated by sensing output signal in air. The front slope has a sensitivity of 2.7116 mV/mm while the sensitivity of the back slope is 0.5323 mV/mm. Both of slopes have more than 99% of linearity in range between 0.05 - 0.50 mm and 1.05 - 2.90 mm respectively. By increasing honey concentration, the peak light intensity is linearly increases and gives the measured peak voltage sensitivities about 0.02 mV/%. A real-time measurement, low cost, stability, high sensitivity and simplicity of design promote a well-developed sensor in providing useful parameters in detecting purity of honey.

(Received February 26, 2013; accepted July 11, 2013)

Keywords: Fiber optic, Fiber optic displacement sensor, Honey detection

1. Introduction

Recently, the higher demands for honey rise due to health claims and also as a well chosen for desirable ingredient in a range of different foodstuffs [1]. The high demand of the honey tends to have a lot of honey available in the commercial market. Unfortunately consumer getting confused about the purity since the taste does not meet their wishes. Purity of honey can be skeptical whenever it turns up to be added with different materials [2]. Adulteration or the foreign substances such as molasses, starch solution, glucose, sucrose, water and inverted sugar added to honey had been studied [2]. In honey, determination of moisture is very significant as it a frequent analysis to determine the quality and the marketability of honey. Thus, addition of distilled water into pure honey to vary the concentration can be tested for determining the purity.

The fiber optic displacement sensor (FODS) is approached as a new technique in detecting honey purity instead of common techniques such as Fourier Transform (FT) Raman spectroscopy, Stable Carbon Isotope Ratio Analysis (SCIRA) and Near Infrared Transflectance (NIR) spectroscopy [4]. In line of fiber optic sensors evolvement, fiber optic technology extends the possibility for developing of a variety of sensors in a wide range of applications [5]. There are many quantities can be measured using this sensor for instance light intensity, vibration, temperature, pressure, calibration of accelerometers, strain, liquid level, pH, chemical analysis, concentration, density, refractive index of liquids and etc. [6-11]. The applications in terms of displacement and concentration analysis are important parameters in this paper. The output from the signal is measured for increasing displacement with different honey concentrations.

2. Experimental setup

The schematic diagram of fiber displacement sensor experimental setup for honey purity detection is shown in Fig. 1. The setup consists of He-Ne laser (λ = 633 nm), fiber optic transmitter, fiber optic receiver, fiber optic probe, silicon detector, lock-in amplifier and voltmeter for output voltage display. The fiber optic probe consists of 2 m long bundled fiber which is the transmitter core with diameter, d = 1.0 mm and 16 receiver cores with d = 0.25 mm. The He-Ne laser beam enters the transmitting fiber to the end of the probe and then emitted towards flat mirror. The receiving fiber collected the reflected light and transmitted to silicon photodetector. Silicon photodetector was chosen based on high speed detection and also optical response extends from 400 nm to 1100 nm. This making it compatible with a wide range of visible which is comprised of 633 nm visible He-Ne laser used in this experiment.

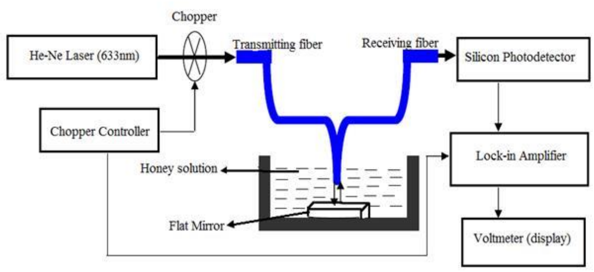

Fig. 1. Schematic experimental setup of FODS for honey detection.

The displacement was measured by moving the probe away from zero point where the reflective surface and the probe are in close contact in order to gain the signal from the receiving fiber. The chopper modulated externally the light source with a frequency of 200 Hz. A lock-in amplifier was deployed to reduce the dc drift and the interference of ambient stray light.

Initially the fiber optic probe is calibrated without solution in the container (in air). The fiber optic probe is precisely adjusted via a vertical translational state in the range of 0 to 10 mm with an increment of 50 µm. At each increment, the output intensity of the beam was detected via a photodetector. The electrical signal was cascading into multimeter to measure in term of voltage. Immediately after sensor calibration honey solution was prepared. A Tualang Honey manufactured by Ikhtiar Madu Enterprise of Malaysia was employed as a specimen. The honey was dissolved in distilled water at various concentration including 75%, 80%, 85%, 90%, 95% and 100%. The experiment is carried out under atmospheric pressure at room temperature of 25°C.

3. Results and discussions

Initially the fiber displacement sensor was calibrated. The results are presented in Fig. 2. The figure shows the output signal versus displacement of the reflecting target from the fiber optic probe. In a small displacement (the probe is closed to the mirror), the output signal is minima because no light cone is entering into the fiber. When the displacement is increased, the size of the reflected cone of light at the plane of the fibers also increases thus begins to overlap with the core of receiving fiber and gives a small output signal. The rapid increases in the output signal until it reaches maximum resulting from further increases the displacement and leads to large overlapping. The output after reaching the peak value starts to decrease for larger displacements owing to large increase in the size of the light cone. This is due to the power density decreases with the increases of light cone size, which follow the pattern of inverse square law relationship. Thus the displacement exhibits a maximum with a steep front slope, and minimum with a gradually back slope. This is the finger print of the probe sensor, meaning all other sample should have similar fashion in order to validate the testing and follow the rule of thumb for displacement sensor.

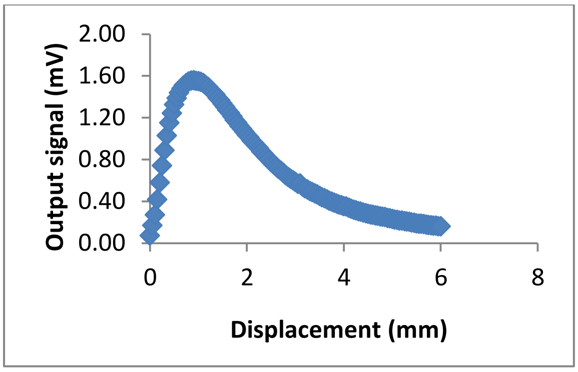

Fig. 2. Calibration curve of fiber displacement sensor in air.

In both front and back slopes, linear range of linearity obtained are more than 99% as shown in Fig. 3. A linear range of front slope is obtained starting from the distance of 0.05 mm until 0.50 mm with a sensitivity of 2.7116 mV/mm while for the back slope from 1.05 mm to 2.90 mm with a sensitivity of 0.5323 mV/mm. Table 1 summarized the performance of the fiber displacement sensor for the front and the back slope region. Both slopes will be an indicator for measurement purity of honey.

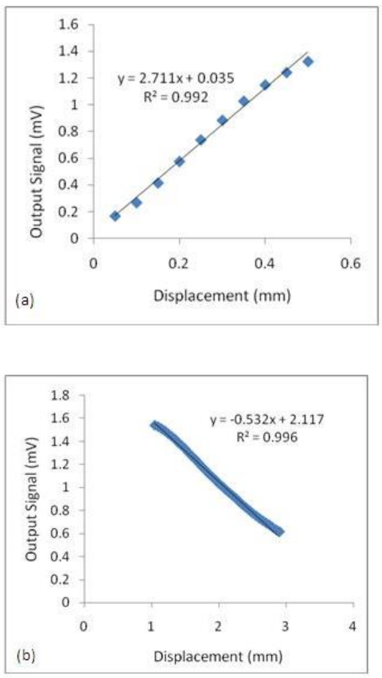

Fig. 3. A linear range for the (a) front slope and (b) back slope.

Table 1. The performance of displacement sensor.

Front slope			Back slope		
Sensitivity (mV/mm)	A linear range (mm)	Linearity (%)	Sensitivity (mV/mm)	A linear range (mm)	Linearity (%)
2.7116	0.05-0.50	> 99	0.5323	1.05-2.90	> 99

Honey at various concentrations is tested using the same probe. The results are displayed in Fig. 4. The figure shows the output voltage against displacement of the reflecting target from the fiber optic probe at various honey concentration. The trends of the curves following the same pattern as calibration curve, such as shown in Fig. 2. This indicated that the results are following the rule of thumb for displacement sensor. Hence the results are validated and can be resolved similar fashion as the calibration curve. Furthermore the analysis of front and back slope each of the curves are shown in Fig. 5.

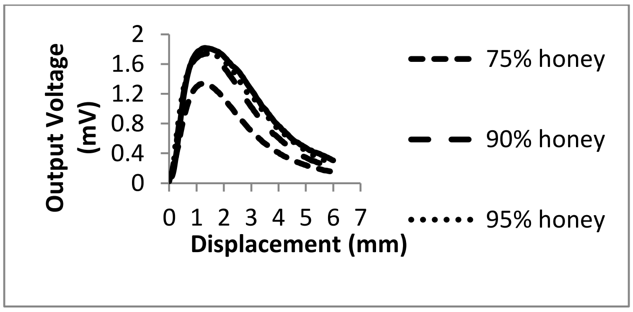

Fig. 4. Output signal versus displacement sensor at different honey concentration.

Fig. 5 illustrates the sensitivity and linearity obtained from the analysis of front and back slopes of honey concentration. Table 2 summarized the performances sensor for honey purity detection in distilled water. From the table, it shows that both slopes are increased and decreased linearly within a certain of linearity for different honey concentration.

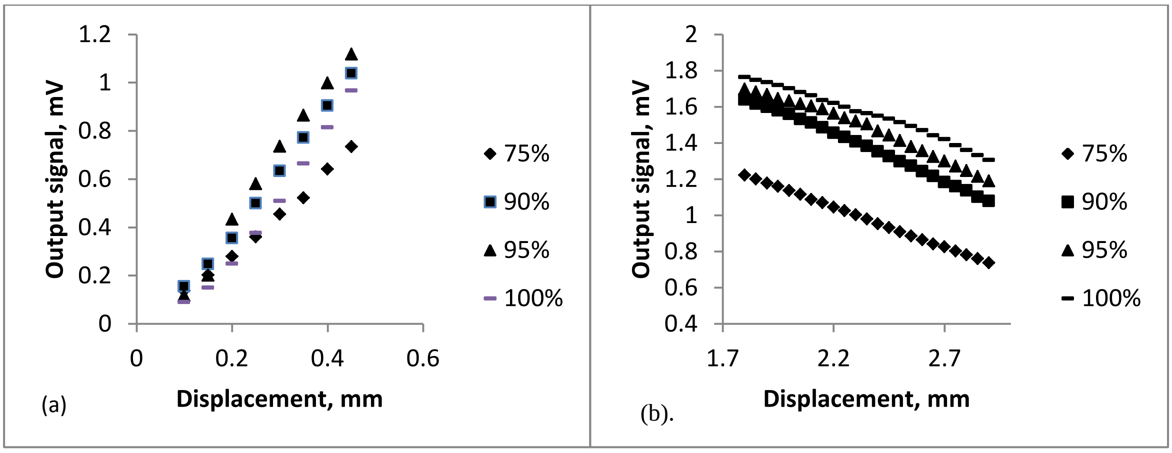

Fig. 5. A linear range of honey profile at different concentration, (a). front slope, (b). back slope.

Table 2. The slopes efficiency for each honey concentration.

Honey concentration (%)	Front slope			Bacl slope		
	Sensitivity (mV/mm)	**A linear range (mm)**	**Linearity (%)**	**Sensitivity (mV/mm)**	**A linear range (mm)**	**Linearity (%)**
75	1.701	0.10 - 0.65	99.72	-0.4080	1.55 - 3.60	99.70
90	2.442	0.10 - 0.65	99.55	-0.4924	1.60 - 3.95	99.72
95	2.537	0.20 - 0.55	99.30	-0.4537	1.65 - 4.40	99.70
100	2.578	0.15 -0.70	99.42	-0.4756	1.90 - 4.25	99.70

The sensitivity of the front and back slope for each curves showed the increasing trend with respect to the honey concentration. This mean the higher concentration of the honey the greater sensitivity of the sensor to detect the signal which closer to the sensitivity of the sensor in the air. Similarly with the sensitivity of the back slope which gradually decreasing with respect to the honey concentration. In fact the linear ranges become wider with the increasing of honey concentration. The correlation coefficient is almost greater than 99% which mean the repeatability of the measurement is high.

Fig. 6 shows the variation of peak voltage with honey concentration. From the figure, it is found that peak voltage is increased linearly with a sensitivity 0.02 mV/%. The correlation of honey sensor is more than 94%. Therefore, it is useful to detect an unknown concentration of honey in the linear region. The performance of honey sensor is listed in Table 3.

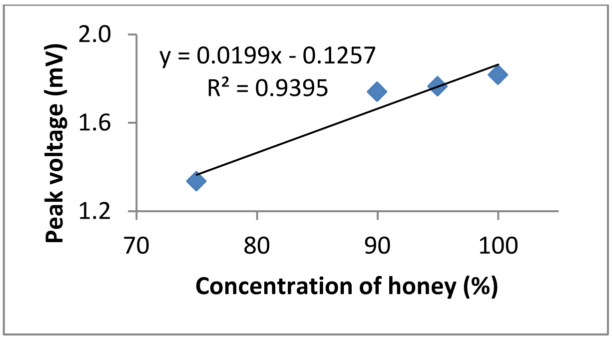

Fig. 6. Peak voltage versus honey concentration.

Table 3. The features of fiber optic honey detection.

Parameter	Value
Sensitivity (mV/%)	0.02
Concentration range (%)	75-100
Linearity (%)	> 94

It is found that the output voltage is proportional to concentration. It is realized that honey without any additional distilled water shows an optimum peak voltage. This is due to the variation of the received light intensity that actually changes the emitting and acceptable angles of the two fibers as the result of the immersion concentration changes. However, for the 80% and 90% of honey concentration the results show insensitivity towards the sensor. With the increasing concentration, reduction of refraction angles occur and therefore showing the increases of output voltage. Refraction occurs because of the difference in refractive indices between the plastic material of the fiber and the honey solution. It can be seen that higher concentration indicates higher refractive index due to more reduction of the refraction angle. Consequently, the area of light cone emitted from the transmitting fiber smaller for each increase in refractive index of the honey solution. Thus, higher output voltage detected by silicon photodetector.

4. Conclusions

The detection of the honey purity is employed using an intensity modulated displacement sensor by detecting honey concentration in distilled water. The sensor illustrates the maximum displacement curves with a steep front slope while the back slope follows an almost inverse square law relationship. The sensitivity of front and back slopes are 2.7116 mV/mm and 0.5323 mV/mm respectively. Based on experimental results, the peak voltages or light intensity are linearly increases with the honey concentration. The highest peak voltage exhibit towards 100% honey concentration. The sensitivity is measured about 0.02 mV/% as the honey concentration is varied from 75% to 100%.

Acknowledgement

The authors like to express their thanks to government of Malaysia through FRGS grant vote 4F110 and GUP grant vote 02H79 for the financial support in this project. Thanks are also due to UTM through RMC for financial management and monitoring the progress of the project. We also like to acknowledge University Airlanggar Surabaya Indonesia for allowing Dr Yasin to be as a visiting researcher in UTM.

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