TELKOMNIKA, Vol.17, No.5, October 2019, pp.2445~2450
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v17i5.12813

Optical fiber tip sensor for glucose-adulterated honey detection

Nazirah Mohd Razali[1], Aimi Najwa Mazlan[2], Mohammad Farizuddin Salebi[3], Habibah Mohamed[4], Sumiaty Ambran*[5]
[1,2,4,5]Department of Electronic Systems Engineering, Malaysia-Japan International Institute of Technology,
Universiti Teknologi Malaysia, 54100, Kuala Lumpur, Malaysia
[3]Advanced Membrane Technology Research Centre, 81310,
Universiti Teknologi Malaysia, 54100, Kuala Lumpur, Malaysia
*Corresponding author, e-mail: sumiaty.kl@utm.my

Abstract

Honey, a natural sweet substance and also a high-value foodstuff has been a target for adulteration. This paper reports the early stage development of optical fiber tip sensor using a standard single mode fiber for adulterated honey detection. The development of simple, sensitive and low-cost sensor for direct detection of adulterated honey is a considerable interest in this context. A pure stingless bee honey was mixed with glucose adulterant at different volume ratios for the adulteration process. By changing this chemical composition, the refractive index of the adulterated honey varied and Fresnel reflection occured at the interface between the fiber tip and the adulterated honey solution also changed. The average sensitivity achieved by this sensor is 0.29 dBm/% with linear regression value up 0.97. This shows that, the sensor has a potential in adulterated honey detection.

Keywords: *adulterated honey, fiber optic sensor, fresnel reflection, glucose adulterant, refractive index*

1. Introduction

Honey is the natural sweet substance produced by honey bees from nectar of plants or can be obtained from the living parts of plants. Honey has been part of an important nutritional food product worldwide. Currently, there is a high market demand for pure honey and it became an expensive food product. To obtain more profit and due to insufficiency of pure honey in the market, irresponsible sellers started to produce and sell adulterated honey which is cheaper and easier to produce compared to the unadulterated honey [1]. Honey adulteration has become a common problem due to the difficulties in distinguishing pure honey from adulterated honey [2]. Foreign substances such as glucose syrup, corn syrup, sugar syrup and inverted syrup are used as adulterants and added directly to pure honey at certain ratios after production to increase the honey sweetness to recover more honey from the bee hives [3]. Although these adulterants increase the quantity of honey, they decrease the nutritional properties, thus degrading the quality. Considering these limitations, this study proposes an alternative method by applying fiber optic sensor in adulterated honey detection. Fiber optic sensor has attracted considerable attention in the new sensor systems as it offers numerous advantages due to its small and thin size, biological inertness in nature and the safeness due to absence of electric current at the sensing point [4-6]. Fiber optic sensors are being widely used as chemical sensor in measuring the concentration of ethanol [7-10], sucrose and sodium chloride solution [11], glucose [12-15], preservative in milk [16], adulterated edible oil [17] and determination of nitrate [18], cadmium [19], fluoride [20], copper [21], magnesium [22] and lead ions [23] based on their concentrations in water.

Recently, fiber optic sensor has been introduced as one of the interesting techniques to detect adulterated honey but still in the primary stage of development. In 2016, Bidin et al. [24] presented a fiber optic displacement sensor to detect sugar content in honey. The honey samples were adulterated with different percentage of fructose and glucose ranging from 0% to 10%. The sensor performance showed that the voltage signal linearly increases with the concentration of adulteration of sugar. In 2017, Irawati et al. [25] fabricated polymer and silica microfiber optic sensor for the detection of honey adulteration. The honey samples

Received July 17, 2018; Revised March 14, 2019; Accepted April 27, 2019

(Acacia) were adulterated with different percentage of glucose ranging from 1% to 6%. The sensitivity achieved by these sensors is 0.49 μW/% and 1.37 μW/% respectively. Thereby, we determined that it is feasible to detect the adulterated honey samples with a fiber optic sensor. Therefore, in this work, optical fiber tip sensor is proposed as a new technique in detecting adulterated honey. This work employs the optical sensing technology using a fiber tip sensor to determine the purity of honey at percentage level. The main interest is the application of fiber optic sensor as a chemical sensor where the reflected light intensity changes by changing the chemical composition of measured solution around the sensing region.

2. Research Method

In this experiment, a standard single mode fiber of length 30 cm with core and cladding diameter of 9 μm and 128 μm respectively was used to fabricate the tip sensing probe. The small part of the fiber tip was stripped and cleaned by ethanol and dry tissue. Then, the tip was cleaved to produce a flat end surface to provide approximately 4% reflectivity. The pure stingless bee honey sample was obtained from a beekeeper in Pahang, Malaysia. Initially, glucose adulterant with 10% concentration was prepared by dissolving glucose powder [Chemically Pure Grade, R&M Chemicals] in distilled water. In the adulterating process, the glucose solution was added individually into six different beakers with various volume percentage ranging from 0% to 40%. Subsequently, the mixtures were stirred for 10 minutes to ensure homogeneity. Table 1 shows the percentage of honey purity after adulteration for labelling purpose.

Table 1. Glucose Content in Adulterated Honey Sample

Percentage of Honey Purity (%)	Percentage of Glucose (%)
100	0
90	10
80	20
70	30
60	40

The refractive indexes of all the samples were determined using a digital refractometer. Before measurements, the refractometer was calibrated using distilled water in accordance with the instrument’s instructions. The experimental setup for the proposed sensor is shown in Figure 1. Amplified Spontaneous Emission (ASE) [FiberLabs] was used as the light source. The passive optical circulator was used to direct the reflected light from the sensing surface to the detector in one direction. The reflected optical spectrum was monitored and recorded using optical spectrum analyser (OSA) [Yokogawa -0.02 nm resolution]. Throughout the experiment, the sensing probe was compeletely immersed in the solutions. At the end of each sample measurement, the sensor was cleaned with distilled water repeatedly, followed by drying properly to return to the initial state condition. The experiment was repeated for three cycles and conducted at standard room temperature.

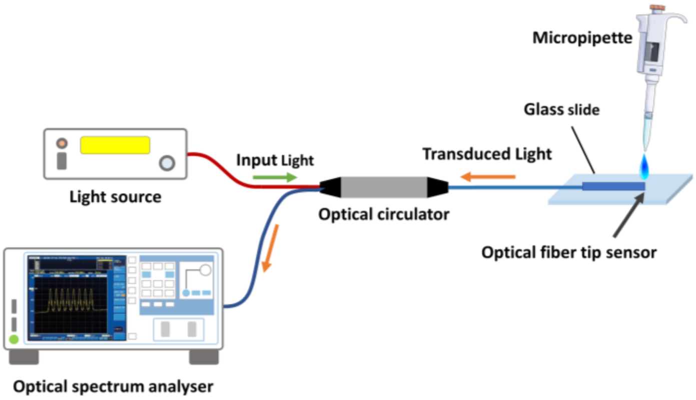


Figure 1. Experimental setup

3. Results and Analysis

In the experiment, the optical power was monitored while honey samples with different percentage of purity were in contact with the sensing surface. The refractive index of the adulterated honey samples was recorded for reference and the optical sensing response is subjected to studies to evaluate the sensor performance.

3.1. Sensing Response

Figure 2 shows the refractive index of adulterated honey samples against the percentage of honey purity. As the percentage of purity increases from 60% to 100%, the refractive index of solution also increases from 1.4049 to 1.4561 with total changes of 0.512. Based on the plotted graph, by changing the chemical composition of the solution, the refractive index will also change.

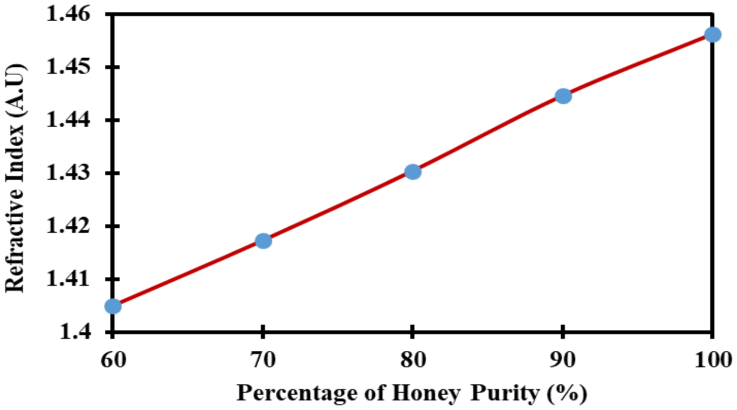


Figure 2. Refractive index of adulterated honey samples

The tip probe sensor was exposed to different adulterated honey samples of increasing order from 60% to 100%. The optical response of the sensor for various concentrations were recorded as shown in Figure 3. The spectrum becomes narrower with the decrement of percentage of purity in honey samples due to the change in the refractive index. The pure stingless bee honey shows the smallest spectrum size and lowest reflected optical power which indicates more light loss occurs during sensing. It can be seen, when the refractive index of the measured solution increases, the light intensity reflected to the fiber core decreases.

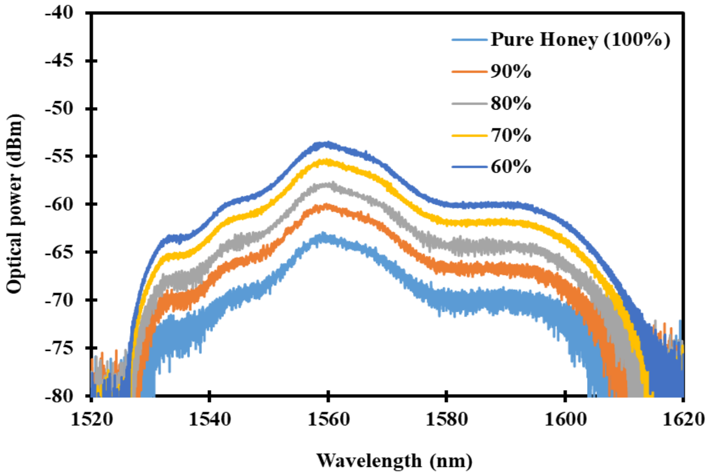
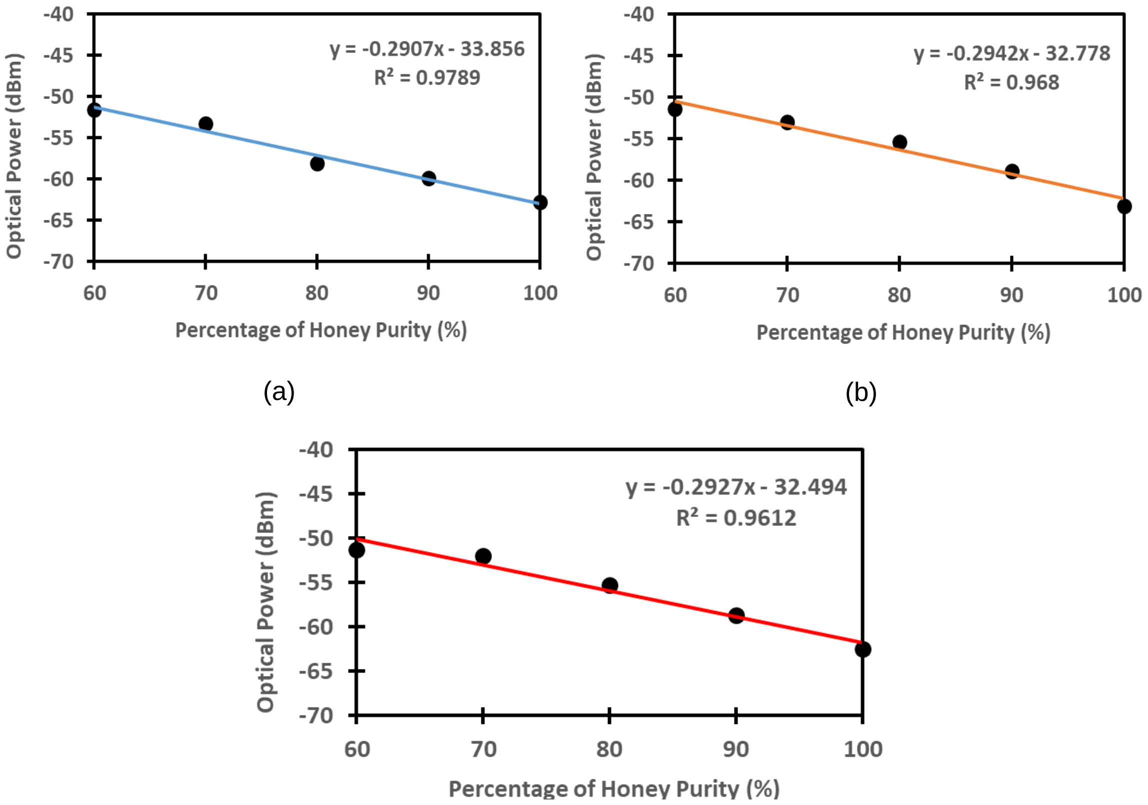


Figure 3. Optical spectrum of honey samples based on percentage of its purity

Figure 4 depicts the graph analysis of the optical power values of the sensing probe as it measures the adulterated honey samples at 1559 nm for three cycles of experiment. As the percentage of honey purity changed from 60% to 100%, the reflected light intensity gradually decreased via energy loss due to light scattering. In the measurements from all three cycels, based on the slope of the graphs, the highest sensor sensitivity was 0.2942 dBm/% which is shown in Figure 4 (b) with linear regression value up to 0.968. Basically, all the experimental data are agreeing well with the fitted straight line. These results indicate that the sensor is an ideal platform for detecting adulterated honey samples. The average sensitivity achieved by this sensor was 0.29 dBm/% and the linear regression value was 0.97. From the three cycles experimental results, the fiber tip sensor can maintain its sensitivity with good signal stability.



(a) (b)

(c)

Figure 4. The analysis of reflected light intensity at 1559 nm for (a) first cycles, (b) second cycle and (c) third cycle

3.2. Sensing Mechanism

When immersing the fiber tip sensor into the adulterated honey solution with various percentages of purity from 60% to 100%, the reflected optical power changed due to the changes of refractive index of the surrounding. As previously shown in Figure 2, the change in chemical composition will change the solution refractive index. Fresnel reflection occurs at the coupling interface between the measured solution and the optical fiber core which has different refractive indices thus, a portion of light is reflected into the core [26]. The fraction of optical power (R) that is reflected at the interface is given as [26].

$$R = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)^2 \tag{1}$$

Here, n_1 is the refractive index of the optical fiber core and n_2 is the refractive index of the contact measured solution with the core. Figure 5 illustrates the working principle of fiber tip sensor. By changing n2 with physical parameters, Fresnel reflection arising at the interface between the tip of optical fiber and the contact solution also changed.

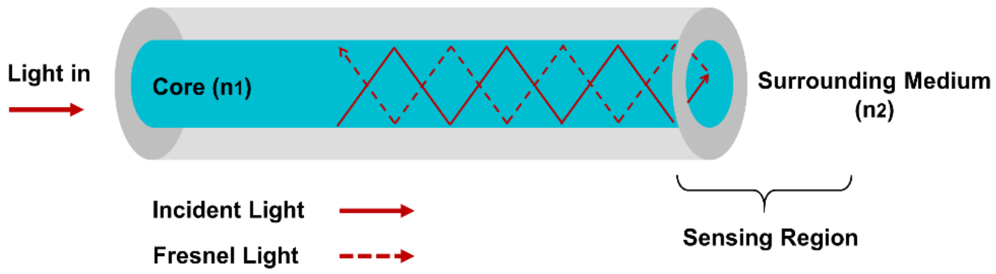


Figure 5. Working principle of fiber tip sensor

4. Conclusion

In this study, we successfully applied the optical fiber tip sensor in adulterated honey detection at different percentages of purity ranging from 60% to 100%. The sensor sensitivity reached up to 0.27 dBm/% and the linear regression value was 0.97 showing that the experimental data fitted well with the straight line. This shows the sensor has a potential in adulterated honey detection. In the future, we suggest improvements to increase the sensor sensitivity and selectivity for high quality detection.

References

[1] S Samat, FK Enchang, AA Razak, FN Hussein, WIW Ismail. Adulterated Honey Consumption Can Induce Obesity. Increase Blood Glucose Level and Demonstrate Toxicity Effect. *Research Gate*. 2018: 47(2): 353-365.

[2] W Korth, J Ralston, Techniques for the Detection of Adulterated Honey, Rural Industries Research and Development Corporation. 2002: 1-16.

[3] Soares S, Amaral JS, Oliveira MBPP, Mafra I. A Comprehensive Review on the Main Honey Authentication Issues: Production and Origin. *Comprehensive Reviews in Food Science and Food Safety*. 2017; 16(5): 1072-1100.

[4] Lee B. Review of the present status of optical fiber sensors. *Optical Fiber Technology*. 2003; 9(2): 57-79.

[5] Alberto N, Domingues MF, Marques C, Andre P, Antunes P. Optical Fiber Magnetic Field Sensors Based on Magnetic Fluid: A Review. *Sensors (Basel).* 2018; 18(12): 1-27.

[6] Sabri N, Aljunid SA, Salim MS, Ahmad RB, Kamaruddin R. *Toward Optical Sensors: Review and Applications.* Journal of Physics: Conference Series. 2013; 423: 012064.

[7] Girei SH, Shabaneh AA, Arasu PT, Painam S, Yaacob MH, editors. *Tapered multimode fiber sensor for ethanol sensing application*. 2013 IEEE 4th International Conference on Photonics (ICP). 2013.

[8] Hernaez M, Mayes AG, Melendi-Espina S. Graphene Oxide in Lossy Mode Resonance-Based Optical Fiber Sensors for Ethanol Detection. *Sensors (Basel).* 2017; 18(1): 58.

[9] Sampath U, Kim D, Song M. Aqueous ethanol detection using a fiber-optic sensor based on Fresnel reflection: SPIE. 2017: 6.

[10] Sharifpour-Boushehri S, Hosseini-Golgoo SM, Sheikhi M-H. A low cost and reliable fiber optic ethanol sensor based on nano-sized SnO2. *Optical Fiber Technology*. 2015; 24: 93-99.

[11] Wu Z, Yu X, Gu E, Kong Z, Li W. Characteristics Analysis of Chemical Concentration Sensor Based on Three-layer FBG. *Optics and Photonics* Journal. 2013; 03(02): 268-271.

[12] Corres JM, Sanz A, Arregui FJ, Matías IR, Roca J. Fiber optic glucose sensor based on bionanofilms. Sensors and Actuators B: *Chemical*. 2008; 131(2): 633-639.

[13] Kang JU, Kim D, Waynant RW, Ilev IK, editors. *Non-Invasive Fiber-Optic Glucose Sensor Based on Stimulated Raman Scattering*. LEOS 2007-IEEE Lasers and Electro-Optics Society Annual Meeting Conference Proceedings. 2007.

[14] Lin TQ, Lu YL, Hsu CC. Fabrication of glucose fiber sensor based on immobilized GOD technique for rapid measurement. *Opt Express*. 2010; 18(26): 27560-27566.

[15] Zhang X, Wu Z, Liu F, Fu Q, Chen X, Xu J, et al. Hydrogen peroxide and glucose concentration measurement using optical fiber grating sensors with corrodible plasmonic nanocoatings. *Biomed Opt Express*. 2018; 9(4): 1735-1744.

[16] Saracoglu OG, Hayber SE. Bent Fiber Sensor for Preservative Detection in Milk. *Sensors (Basel)*. 2016; 16(12): 2094.

[17] Jadhav MS, Laxmeshwar LS, Akki JF, Raikar PU, Tangod VB, Raikar US. *Multimode Fiber Optic Sensor for Adulterant traces in Edible Oil using Nanotechnology Technique*. Materials Today: Proceedings. 2017; 4(11): 11910-11914.

[18] Razali NM, Ambran S, Hamzah A, Abdullah N, Mikami O, Hara H, et al., editors. *Etched Fiber Bragg Grating Sensor for Nitrate Sensing Application*. 2018 IEEE 7th International Conference on Photonics (ICP). 2018.

[19] Nguyen TH, Wren SP, Sun T, Grattan KTV, editors. *Development of a fiber-optic chemical sensor for the detection of cadmium*. 2016 IEEE SENSORS. 2016: 2016.

[20] Jadhav MS, Laxmeshwar LS, Akki JF, Raikar PU, Kumar J, Prakash O, et al. Fluoride contamination sensor based on optical fiber grating technology. *Optical Fiber Technology*. 2017; 38: 136-141.

[21] Tran VT, Tran NHT, Nguyen TT, Yoon WJ, Ju H. Liquid Cladding Mediated Optical Fiber Sensors for Copper Ion Detection. *Micromachines (Basel*). 2018; 9(9): 471.

[22] Yasin M, Irawati N, Isa NM, Harun SW, Ahmad F. Graphene coated silica microfiber for highly sensitive magnesium sensor. *Sensors and Actuators A: Physical*. 2018; 273: 67-71.

[23] Ibrahim SA, Ridzwan AH, Mansoor A, Dambul KD. Tapered optical fibre coated with chitosan for lead (II) ion sensing. *Electronics Letters*. 2016; 52(12): 1049-1050.

[24] Bidin N, Zainuddin NH, Islam S, Abdullah M, Marsin FM, Yasin M. Sugar Detection in Adulterated Honey via Fiber Optic Displacement Sensor for Food Industrial Applications. *IEEE Sensors Journal*. 2016; 16(2): 299-305.

[25] Irawati N, Isa NM, Mohamed AF, Rahman HA, Harun SW, Ahmad H. Optical Microfiber Sensing of Adulterated Honey. *IEEE Sensors Journal*. 2017; 17(17): 5510-5514.

[26] Yoo W, Sim H, Shin S, Jang K, Cho S, Moon J, et al. A Fiber-Optic Sensor Using an Aqueous Solution of Sodium Chloride to Measure Temperature and Water Level Simultaneously. *Sensors*. 2014; 14(10): 18823.