Jurnal
Teknologi

Full Paper

Fiber Optic Displacement Sensor for Honey Purity Detection using Glucose Adulterant

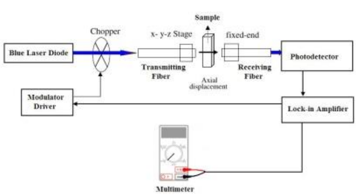
N. Hida[a], M. Abdullah[a*], M. Yasin[b]

[a]Advance Photonic Science Institute, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
[b]Department of Physics, Airlangga University, Surabaya, Indonesia

Article history
Received
10 October 2014
Received in revised form
10 December 2014
Accepted
13 January 2015

*Corresponding author
mundzirabdullah@yahoo.com

Graphical abstract



Abstract

A fiber optic displacement sensor (FODS) using a transmission technique was developed to determine the purity of honey using glucose adulterant. This was achieved by detecting the output signal of pure honey and adulterated honey with different addition percentage volume of glucose. The honey sample was adulterated with different percentage of glucose ranging from 0-10%. Prior that, the performances of sensor is first demonstrated by sensing output signal without any sample in a quartz cell. The linearity obtained is more than 99% in the range of 0 mm to 2.5 mm and the sensitivity is 32.65 mV/mm. The result from performance of sensor towards pure and adulterated honey showed that the highest sensitivity of all samples was achieved at 10% concentration of adulteration and the lowest sensitivity was obtained at 0% concentration (pure honey). Thus, FODS based on transmission technique has a potential to act as honey purity sensor by detecting the contamination of adulterant substances present in pure honey. The faster, simpler and cheaper devise is a promising technique to be employed in food industrial sector. Fiber optic displacement sensor in detecting honey purity for glucose adulteration.

Keyword: Fiber optic, fiber optic displacement sensor, honey sensor, honey purity

Abstrak

Sensor sesaran gentian optik (FODS) menggunakan teknik penghantaran telah dibangunkan untuk menentukan ketulenan madu menggunakan glukosa bahan asing. Ini dicapai dengan mengesan isyarat keluaran daripada madu asli dan madudicemari dengan peratusan yang berbeza. Selain jumlah glukosa, sampel madu telah dicemari dengan peratusan yang berbeza glukosa antara 0-10%. Sebelum itu, prestasi sensor mula menunjukkan dengan mengesan isyarat output tanpa apa-apa sampel dalam sel kuarza. The kelinearan diperolehi adalah lebih daripada 99% dalam julat 0 mm hingga 2.5 mm dan sensitiviti adalah 32,65 mV/mm. Hasil daripada prestasi sensor terhadap madu tulen dan kebezaan menunjukkan bahawa sensitiviti yang tertinggi semua sampel telah dicapai pada kepekatan 10% daripada pencemaran dan kepekaan yang paling rendah adalah pada kepekatan % 0 (madu tulen). Oleh itu, FODS berdasarkan teknik penghantaran mempunyai potensi untuk bertindak sebagai sensor madu kesucian dengan mengesan pencemaran bahan bahan asing pada madu tulen. Lebih cepat, merangka mudah dan murah adalah satu teknik yang menjanjikan untuk diambil bekerja dalam sektor industri makanan. Sensor sesaran gentian optik sensor anjakan dalam mengesan ketulenan madu untuk pencemaran glukosa.

Kata kunci: Serat optik, sensor gentian optik anjakan, sensor madu, madu kesucian

1.0 INTRODUCTION

Nowadays the purity of honey is doubtful since there are a lot of parties either food manufacturers, retailers, or importers boldly sold the fraud honey in market. The parties widely practiced to adulterate honey by mixing the foreign substances to honey such as molasses, starch solution, variants of sugar like glucose, sucrose and fructose, water, etc. [1]. This situation is assumed to be illegal as mention in honey standards of the Codex Alimentarius (CA) the essential composition and quality factors, "honey sold as such shall not have added to it any food ingredient, including food additives nor shall any other additions be made other than honey" [2]. Since glucose syrup is most common adulterants because of their colorless, odorless, and sweetness makes it perfect candidates for adulteration to confuse the consumers. Therefore, this study focuses to discover fraud whenever additional glucose was added into pure honey.

Fiber optic displacement sensor (FODS) as new system honey purity detection is developed a part of others sensor systems like biomimetic sensor which are Electric Nose (E-Nose) measurement and Electric Tongue (E-Tongue) measurements [3-4]. Over the past two decades, the use of fiber optic sensors for contaminant detection in food stuff has need widely exploited. Fiber optic sensor offer simplicity, low cost and non-contact type sensing which able to perform without contacting the sample [5]. The honey sensor is applied using the beam-through technique whereby light is transmitted through transmitting fiber to a receiving fiber and the received light is measured by a photodetector [6].

The output signal is measured for all the honey samples either pure honey or various concentration of adulterated honey. The output grant a crucial distinctive signal to meets the requirement on development and application of a honey purity references on glucose level. The finding on measurement glucose level of honey is a critical issue on controlling its natural level since glucose in a food gives a very significant effect to human health. Moreover, excessive intake of glucose may cause the high blood glucose in body which then leads to diabetes.

2.0 EXPERIMENTAL

2.1 Sample Preparation

The honey sample employed is obtained from local market in Malaysia. It was used as reference samples. The adulterated honey samples were prepared by adding the glucose solution from 2%, 4%, 6%, 8% and 10% concentration into each type of honey in volume ratio. The mixture were stirred for one minute and were placed into water bath at 35°C to be kept for 20 minutes in order to prepare homogeneous glucose adulterated honey samples.

2.2 Experimental Setup

The experimental setup for the characterization of the honey sensor in detecting honey fraud is schematically shown in Figure 1. The setup concept is launched based on beam-through technique whereas the fiber optic is split into transmitting fiber which is connected from a light source and receiving fiber is connected to detection system. The blue wavelength 457 nm compatible with the result ofdiode laser is function as light source operating at wavelength 457 nm compatible with the result ofhoney absorbance tested. It was modulated externally by a chopper with a frequency of 150 Hz in order to avoid the harmonics line frequency which is about 50-60 Hz.

The modulated sources are used in conjunction with a lock-in amplifier to reduce the dc drift and interference of ambient stray light. A 10 mm quartz cell is used to contain the honey samples solution and is fixed between the common ends of the transmitting fiber and receiving fiber. Once the light source is feed into transmitting fiber, the light is scattered after travelling out towards sensing region. The refracted light intensity is yield after it enters the honey samples solution and is then collected by receiving fiber to transmit into photodiode detector whereby the intensity is measured.

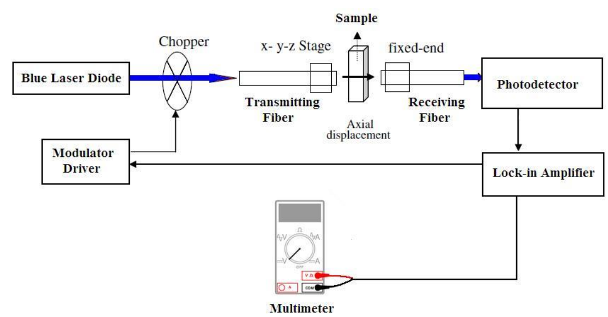


Figure 1 Schematic diagram of fiber optic displacement sensor

3.0 RESULTS AND DISCUSSION

The sensor calibration is first carried out to observe the formation of the output voltage pattern. The calibration was investigated without any sample in a quartz cell. Figure 2 shows the sensor performances as a function of axial displacements. The output voltage obtained from receiving fiber is related to the displacement movement of transmitting fiber.

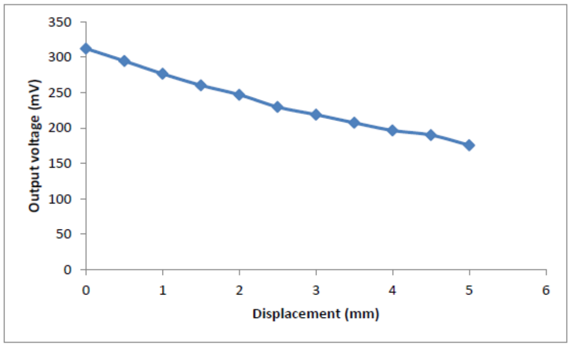


Figure 2 The output voltage against displacement

As expected, the output voltage is found to be highest at zero displacements and as the axial movements of transmitting fiber away from receiving fiber resulted in a reduced output voltage. This behavior of the power drop pattern is agreed with the theoretical analysis from Van Etten and Van Der Plates, (1991) whereby the output transmission function is given as:

$$n \approx 1 - \frac{z}{r}\frac{2}{\pi(NA)^2}\left(\arcsin(NA) - NA\sqrt{1-(NA)^2}\right) \quad (1)$$

Where n, r, and NA are coupling efficiency, axial displacement, core radius and numerical aperture, respectively. n is defined as the ratio of output voltage over the maximum voltage

Therefore, the blueprint of probe sensor is set to be reduced output voltage for higher displacement measurement so that all samples should have similar trends to validate the testing. The sensor performance is investigated for its sensitivity. The sensor sensitivity is acquired by finding the slope of a straight line portion of the graph. Based on Figure 1, the negative straight line portion with linearity more than 99% is obtained in the range of 0 mm to 2.5 mm and the sensitivity is 32.65 mV/mm. The performance of the sensor is summarized in Table 1.

Table 1 Performances of fiber optic displacement sensor

Parameter	Value
Sensitivity (mV/mm)	32.65
A linear range (mm)	0 - 2.5
Linearity (%)	More than 99

Figure 3 highlighted the performances of FODS towards glucose adulteration in honey samples. The results illustrate the transmitted light intensity against displacement of the beam-through technique with certain concentration of glucose solution addition. In line with the sensor calibration, the behavior of output signal also anticipated highest at zero displacement and as the displacement of the transmitting fiber away from the quartz cell is then lead to reducing output voltage.

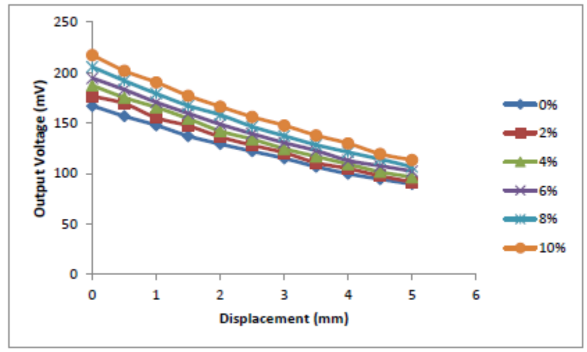


Figure 3 The output voltage against displacement for various concentration of glucose adulteration

The sensor sensitivity on every displacement position is studied. The sensor sensitivity in this context is the slope of the output voltage against adulteration concentration for various displacements [8]. Figure 4 show the output voltage against the adulteration concentrations at positions of 0, 1.5, 3.0 and 4.5 mm. It is observed as the displacement position increases, the concentration line decreases. At displacement positions of 0, 1.5, 3.0 and 4.5 mm, the sensitivities are 4.9357 mV/mm, 3.7857 mV/mm, 3.1357 mV/mm and 2.5829 mV/mm respectively. The reducing trend is because of the displacement curves (Figure 2) follow an almost inverse square law relationship whereby the slope becomes less steep as the displacement increase. It concludes that the sensor have its optimum output voltage at distance of zero displacement as it indicated the maximum sensitivity value than other displacement position.

The curves characteristics in Figure 2 such as sensitivity, linearity and the linear range are analyzed for every straight line portion in curves of adulterated honey samples tested as summarized in Table 2. The linear range is observed to be fixed for different amount of adulteration. The sensitivities of the negative slopes for each curve is gradually increased with the increase of adulteration concentration. Therefore, the performances conclude that the highest sensitivity of all samples achieved for a concentration of 10% of adulteration concentration and the lowest sensitivity is obtained at 0% adulteration (pure honey).

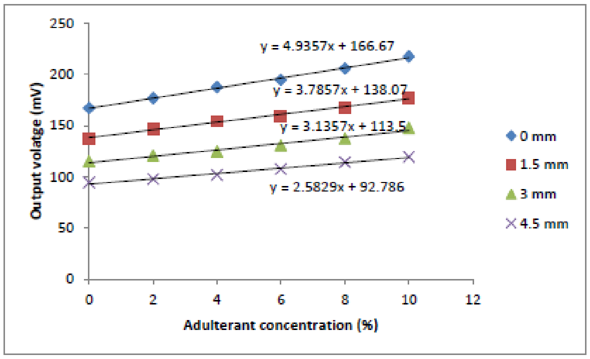


Figure 4 Optimum output voltage against glucose adulteration concentration

The higher sensitivity for honey sample increased linearly for higher adulteration is due as the transmitting light enters the air–liquid interface, refraction occurs due to the difference in their refractive indices. The refraction angle could increase with the higher addition glucose solution into honey samples. The larger refracted beam of laser source is obtained after strikes the quartz cell and eventually increases the portion of light to be collected by the receiving fiber.

Table 2 The curves characteristics for various concentrations of glucose adulteration. In the range 0 to 2.5 mm with linearity index close to 1

Concentration %	Sensitivity (mV/mm)
0	17.67
2	20.02
4	21.56
6	22.28
8	23.38
10	24.34

The correlation of honey sensor for indicating honey with glucose adulteration is more than 99%. The high correlation coefficient obtained reveals that the repeatability of the measurement is high. Thus, the proposed idea to discriminate and distinguish the pure honey and adulterated honey is established. The fiber sensor technique is much simple and low cost technique. This device has a higher potential to be used as honey purity sensor in order to detect the glucose adulteration content. The faster, simpler and cheaper devise is a promising technique to be employed in food industrial sector.The whole system is setup by connecting the PI camera module to the CSI port on the Raspberry PI board via ribbon cable while the LCD screen is connected to the board via HDMI cable. The wireless keyboard and mouse is connected to the board using wireless USB adapter. This is only needed when manipulation of code is required. The power is supplied to the board by connecting a micro USB to USB cable to a wall socket USB adapter or power bank.

4.0 CONCLUSION

Fiber optic displacement sensor demonstrated as honey purity sensor to detect the glucose adulteration of pure honey via distinctive amount of adulteration substances. The calibration shows that the sensor has sensitivity of 32.65 mV/mm with linearity 99%. The highest sensitivity of all samples was achieved at 10% concentration of adulteration and the lowest sensitivity was obtained at 0% concentration (pure honey). Therefore, it is able to act as concentration indicator for adulteration of a particular honey. The finding is significant to create potential application of honey sensor. It could promise to be a simpler and cheaper developed sensor without involving any complex chemical process for employment in food industrial.

Acknowledgement

The authors like to express their thanks to Ministry of Higher Education (MOHE) for granting a Fundamental Research Grant Scheme (FRGS) through grant vote Q.J130000.2509.06H45 for the financial support in this project. Thanks also due to UTM through RMC for financial management and monitoring the progress of the project.

References

[1] N. M. El-Bialee and M. A. Sorour. 2011. Effect of Adulteration on Honey Properties. *International Journal of Applied Science and Technology*. 1: 122-133.
[2] S. Bogdanov and P. Martin. 2002. Honey Authenticity: A Review. Swiss Bee Research Centre.
[3] Ammar Zakaria, Ali Yeon, Md Shakaff, Maz Jamilah, Masnan, Mohd Noor Ahmad, Abdul Hamid Adom, Mahmad Nor Jaafar, Supri A. Ghani, Abu Hassan Abdullah, Abdul Hallis Abdul Aziz, Latifah Munirah Kamarudin, Norazian Subari and Nazifah Ahmad Fikri. 2011. A Biomimetic Sensor for the Classification of Honeys of Different Floral Origin and the Detection of Adulteration. *Sensors*. 11: 7799-7822.
[4] Norazian Subari, Junita Mohamad Saleh, Ali Yeon Md Shakaff and Ammar Zakaria. 2012. A Hybrid Sensing Approach for Pure and Adulterated Honey Classification. *Sensors*. 12: 14022-14040.
[5] S. Patil and A. Shaligram. 2013. Refractometric Fiber Optic Sensor for Detecting Salinity of Water. *Journal of Sensor Technology*. 3: 70-74.
[6] M. Yasin, S. W. Harun, W. A. Fawzi, Kusminarto, Karyono and H. Ahmad. 2009. Lateral and Axial Displacements Measurement using Fiber Optic Sensor based on Beam Through Technique. *Microwave and Optical Technology Letters*. 51: 2038-2040.
[7] Van Etten, W. and Van Der Plaats. 1991. *J. Fundamentals of Optical Fiber Communications*. London: Prentice-Hall.
[8] H. A. Rahman, S. W. Harun, M. Yasin, and H. Ahmad. 2012. Fiber Optic Salinity Sensor using Beam-through Technique. *Optik.* 124: 679-681.