THE DETECTION OF SUGAR IN HONEY BY TRANSMISSION FIBER OPTIC DISPLACEMENT SENSOR

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THE DETECTION OF SUGAR IN HONEY BY TRANSMISSION FIBER OPTIC DISPLACEMENT SENSOR

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Dedicate, with love,

To my beloved family especially my parents

Hamsinah binti Bahudin & Zainuddin bin Yazid

To all my lovely my friends,

Thank you for understanding and support through my endeavour till the end.

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ABSTRACT

A fiber optic displacement sensor (FODS) using a transmission technique was developed to determine the purity of honey. This was achieved by detecting the output signal of pure honey and adulterated honey with different addition percentage volume of sugar (fructose and glucose). Five types of honey from several retail shops were selected as specimens and labeled as *A*, *B*, *C*, *D* and *E*. Each honey sample was adulterated with different percentage of fructose and glucose ranging from 0-10%. Prior to sensor development, an absorption band for honey was determined by using the UV-Vis spectrophotometer. Blue diode laser at 435 nm was found to be an appropriate light source to be used in this FODS. The performance of sensor was calibrated by sensing the output signal without any honey sample. The displacement was verified within the range of 0 mm to 5.0 mm and 0 mm displacement was found to be the optimized distance for this beam through technique. The output voltage was found to be inversely proportional to displacement. The sensitivity was found to be 32.65 mV/mm with a correlation coefficient of 99%. 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% adulteration (pure honey). The highest sensitivity with adulteration was found in honey *E* with a sensitivity of 3.17 mV/% for fructose and 4.94 mV/% for glucose. Thus, FODS based on transmission technique has a potential to detect sugar content in adulterated honey for a particular honey type.

ABSTRAK

Pengesan sesaran gentian optik (FODS) menggunakan teknik penghantaran dibangunkan untuk mengesan keaslian madu. Ini dapat dicapai melalui pengesanan isyarat keluaran bagi madu asli dan madu yang dicemari dengan peratus jumlah tambahan isipadu gula (fruktosa dan glukosa) yang berbeza. Lima jenis madu daripada beberapa kedai runcit dipilih sebagai sampel dan dilabelkan sebagai *A*, *B*, *C*, *D*, dan *E*. Setiap sampel madu dilancungkan dengan pelbagai peratusan fruktosa dan glukosa dalam julat antara 0–10%. Sebelum pemasangan pengesan, jalur penyerapan untuk madu ditentukan menggunakan spektrofotometer ultralembayung-cahaya nampak. Laser diod biru pada panjang gelombang 435 nm didapati sebagai sumber cahaya yang sesuai digunakan dalam FODS. Prestasi pengesan telah dikalibrasikan dengan mengesan isyarat keluaran tanpa sebarang sampel madu. Sesaran disahkan dalam julat 0 mm hingga 5.0 mm dan sesaran 0 mm adalah jarak optimum untuk teknik penghantaran ini. Voltan keluaran adalah berkadar sonsang dengan sesaran. Sensitiviti ialah 32.65 mV/mm dengan pekali korelasi 99%. Keputusan daripada prestasi pengesan terhadap madu asli dan madu dicemari menunjukkan sensitiviti tertinggi untuk semua sampel dicapai pada kepekatan 10% pencemaran dan sensitiviti paling rendah diperoleh pada kepekatan 0% pencemaran (madu asli). Sensitiviti tertinggi untuk pencemaran didapati pada madu *E* dengan sensitiviti 3.17 mV% untuk fruktosa dan 4.94 mV/% untuk glukosa. Oleh itu, FODS berdasarkan penghantaran berpotensi untuk mengesan kandungan gula dalam madu tercemar untuk madu tertentu.

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LIST OF SYMBOLS

A	-	Central of the transmitting fiber
c	-	Concentration
cm	-	Centimeter
d	-	Distance
eV	-	Electron volt
g	-	Gram
hv	-	Photon
Hz	-	Hertz
I	-	Output intensity
m	-	Meter
mA	-	Milliampere
mm	-	Millimeter
mV	-	Millivolt
nm	-	Nanometer
O	-	Virtual vertex light source
P	-	Normalized output power
r	-	Core radius
s	-	Seconds
v	-	Voltage signal of fiber sensor
V	-	Volt
w/w	-	Weight/weight
z	-	Axial displacement
α	-	Divergence angle of the light source
α	-	Absorption coefficient

β	-	Refraction angle
%	-	Concentration percentage
η	-	Coupling efficiency
A'	-	Central of the receiving fiber
O'	-	Virtual vertex refracted light
n^+	-	N-type
p^+	-	P-type
°C	-	Degree celcius
E_c	-	Energy conduction band
E_{Fn}	-	Energy Fermi level n
E_{Fp}	-	Energy Fermi level p
E_g	-	Energy gap
I_0	-	Initial intensity
n_2	-	Refractive index of medium
z_α	-	Distance from *A* to *O*
z_β	-	Distance from *A* to *O'*
θ_i	-	Angle of incident ray
θ_r	-	Angle of refracted ray

ABBREVIATIONS

A/D	-	Analog/digital
AC	-	Alternating current
ADC	-	Analog to digital converter
CA	-	Codex Alimentarius
DC	-	Direct current
DMM	-	Digital multimeter
DVM	-	Digital multimeter in voltage mode
EMF	-	Electromagnetic fields
FAO	-	Food and Agriculture Organization of the United Nations
FODS	-	Fiber optic displacement sensor
FOS	-	Fiber optic sensor
FTIR	-	Fourier transform infrared
HMF	-	Hydroxymethylfurfural
HPLC	-	High-performances liquid chromatography
IC	-	Intergrated controller
NA	-	Numerical Aperture
NaCl	-	Sodium chloride
PMMA	-	Polymethyl methacrylate
R1	-	Resistor 1
R2	-	Resistor 2
SCIRA	-	Stable carbon isotope ratio analysis
UV-Vis	-	Ultraviolet-visible

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CHAPTER 1

INTRODUCTION

1.1 Overview

Since the invention of laser in 1960’s, a great enthusiasm in optical system has motivated researchers to study the potential of fiber optics for data communications, sensing, and other applications (Fidanboylu and Efendioğlu, 2009). Moreover, the advances toward low-loss optical fiber in the 1970s stimulated further scientific advances, both in telecommunications and in optical fiber sensors. The phenomena had been leading many researches to focus on suitable design of fibers. Therefore, it's become a new thoughts aimed at using optical fibers to design sensing systems, which led to the fiber based sensing devices and components (Gholamzadeh and Nabovati, 2008).

Then, due to integration product between the rapid growth of the optoelectronics and fiber optic communications industries, its ultimately create the fiber optic sensor that mostly relies on communication technology to provide a basic component set as the instrumentation of fiber sensors (Culshaw and Kersey, 2008). Soon it was discovered, it able to sense changes in phase, intensity, wavelength and others from outside perturbations of the fiber itself with material loss almost disappearing and the sensitivity for detection of the losses increasing. Hence fiber optic sensing was born (Geib, 2003).

Honey is consumed worldwide, including Malaysia and it is such a crucial natural forest resources due to their nutritional advantages to human health claimed. Hence it gives a high market demand on pure honey. This has resulted in increased sales of adulterated honey claimed as pure honey by irresponsible parties (Subari *et al*., 2012). Many manufactures had 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., (El-Bialee and Sorour, 2011). However, this situation is assumed to be wrong in honey authenticity because according to the 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 (Bogdanov and Martin, 2002). The adulteration of pure honey permits the community a complex problem which it has a serious economic impact in honey market.

1.2 Problem Statement

Recently, people started to realize about the benefits of honey due to its nutritional advantages. Thus, honey of different variety and brand are now available in the commercial market. However, consumers are faced with the difficulty in determining its purity since honey can easily be adulterated with various sugars as cheaper sweeteners in order to get higher commercial profits.

Even though there are various analytical procedures such as high-performances liquid chromatography (HPLC), stable carbon isotope ratio analysis

(SCIRA), Fourier transform infrared (FTIR), protein characterization, microscopic detection, and others can be employed to detect the adulteration in honey but they have their drawbacks such to being time-consuming, requiring highly skilled operators to perform the corresponding chemical separation process and expensive isotope test which is hard to meet in routine monitoring analysis (Roussel *et al.*, 2003).

Thus, a reliable scientifically-based test to identify adulterant or any sugars added to honey is being research. The applications of fiber optic displacement sensor (FODS) in detecting changes of liquid concentration proposed an idea how to distinct pure honey samples from adulterated ones. This can be used to determine the amount of adulterated substances which had been added to pure honey. Therefore, a simple and reliable FODS is considered as a new technique in determining the fingerprint of honey adulteration.

1.3 Research Objectives

The main objective of this project is to detect sugar content in adulterated honey by the addition of fructose and glucose using transmission fiber optic displacement sensor (FODS). This is established by performing the following works;

1. Prepare and characterize the honey samples
2. Develop a transmission fiber optic displacement sensor
3. Calibrate the performances of the fiber optic displacement sensor
4. Analyze the output reading of sensor towards honey adulteration

1.4 Research Scope

This research is focused on the development of sensor that is able to distinct pure honey and adulterated honey. Several honey samples are obtained from retail shops in Malaysia. Fructose and glucose solution are used to prepare the adulterated honey samples. Basically, silica fiber optic is used as a probe. A blue diode laser is used as a source of light. Ultraviolet-visible (UV-Vis) spectrometer is used for determining the absorption band of honey. The intensity modulation is varied via displacement method. HPLC is conducted to analyze the individual sugar composition in honey.

1.5 Significance of Study

This result will show a simple method to determine whether sugar is added to pure honey. The fiber optic displacement sensor is a preliminary screening technique for identification between pure honey and adulterated honey without complexity of chemical process and time-consuming. The identification is based on the physical appearance of honey itself. The amount of adulteration of sugars into pure honey can be screened by the sensor. The demand for finding appropriate methods to validate honey adulteration and to protect consumers against honey fraud can be solved.

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