International Journal of Engineering Applied Sciences and Technology, 2022
Vol. 7, Issue 8, ISSN No. 2455-2143, Pages 130-134
Published Online December 2022 in IJEAST (http://www.ijeast.com)

DETECTION OF ADULTERANT TRACES IN EDIBLE OIL BASED ON FIBER OPTIC SENSOR TECHNOLOGY

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Abstract—**Low-cost multimode fiber (MMF) optic sensor for detection and determination of adulterant traces of palm oil in coconut oil is experimentally demonstrated. The fundamental principle of detection is the sensitive dependence of the wavelength shift on the refractive index changes of the surrounding medium of multimode fiber cladding. The transmission spectral changes due to variation of adulteration levels have been investigated. Building up of this low-cost multimode fiber optic sensor is helpful in prevention of adulteration. This technique has resulted in 20% adulteration for coconut-palm oil binary mixture.**

Keywords—**Adulteration, coconut oil, palm oil, Refractive index, fiber optic sensor.**

I. INTRODUCTION

Fiber optic sensors technology is one of the most emerging techniques due to its high sensitivity and low-cost [1-3]. Different techniques that have been employed for detection of adulterant traces in food products such as FT-IR, Raman Spectroscopy, NIR Spectrometric, Chemometrics etc. are not cost-effective and are chemically processed [4-6]. Fiber optic sensor technology has shown an effective sensing mechanism as various type of sensors; namely gas sensors, strain sensors, temperature sensors etc. In the proposed report, we have been developed chemical sensor using multimode fiber (MMF) for detection of adulterant traces in edible oil. Hence, chemical sensors have been developed for detection water contaminants and many others [7-10]. Fuel adulteration detection has been developed based on fiber optic sensor technology [11-12]. Here we are developing multimode fiber (MMF) sensors, which is of low-cost and less complexity compared to Fiber Bragg Grating (FBG) and Long Period Grating (LPG) sensors. As multimode fiber has a large diametric core that allows multiple modes of light to propagate. Whereas the earlier work was performed to build sensors using FBG and LPG [13], but it lacks, due to its high cost compare to multimode and single mode fibers. Multimode fiber is usually 50/125µm and 62.5/125 µm in construction and due to its larger diametric core, it allows multiple modes of light to propagate. This means that the core to cladding diameter ratio is 50 microns to 125 microns and 62.5 microns to 125 microns [14].

Early time, fats and oils have been liable to adulteration, either intentionally or accidentally. Since its first appearance, coconut oil has gained wide attraction among the public and scientific community as functional food oil [15]. It has a high gelling temperature (22-25 ^{o}C) and its smoke point is 177 ^{o}C (351 ^{o}F). Quality assurance methods for the determination of fatty acid contents in edible oil and some foodstuff at a certain

level is an important aspect. The detection of adulteration is an attractive issue for researchers, because, food producers do not wish to be subjected to unfair competition from devious processors who would get economical profit with affecting health.
Over past two decades, the use of fiber optic sensors has become an important tool in the adulteration detection of many food products. The detection of adulteration is more difficult, especially when the adulterant has the similar chemical composition to that of the original. Households account for the highest consumption of coconut oil since it is used as the traditional cooking medium in that area. The adulterated coconut oil is widely being sold during Onam season in southern part of India. Apart from cooking purposes, coconut oil is also used more in the field of medical and industrial in South East Asian countries. Coconut oil has been traditionally used to enhance the beauty and promote the growth of our tresses. It refines and moisturizes our skin conditions and is used as ailments for illnesses such as diarrhea and skin inflammations etc. Lans reported that Cocos nucifera was also used as an "ethnomedicine" to treat gastrointestinal problems and minor cuts, injuries, swelling etc. Adulteration of oil with cheaper oils has become a profitable business due its odourless, colorless, and tasteless property. In the present report, we adopted palm oil as an adulterant in the coconut oil, which is one of the less expensive vegetable oils in the market, and are not good for our health. Fiber optic sensor principle is based on a change in refractive index of the medium surrounding its core and the corresponding change can be studied due to the variation in the output power as well as in the wavelength of transmitted light. Surface Plasmon resonance (SPR) is very sensitive refractive index based technique is widely used as detection principle for many sensors that operates in different areas [16].

II. MATERIALS AND METHODS:

2.1 Selection of samples:
Different oil samples were collected. Sample A is pure coconut oil (traditional oil) extracted from dried copra under the cold condition and hydraulic press without any chemical process. It has been reported coconut oil (traditional oil) extracted under cold conditions preserves several thermally unstable antioxidants and better beneficial qualities expected, but in the case of hot conditions, there is a formation thermally stable phenolic antioxidants in the coconut oil [17]. Calculation of extracted oil recovery by formula, which results in the percentage of oil extracted from coconut (Cocos Nucifera) milk [18].

$$\%\ \text{oil extraction} = \frac{\text{weight of oil extracted}}{\text{weight of cocnut milk used}} \times 100$$

Sample B and C were branded (commercial oil) products, sample C is non-packaged oil (commercial oil) purchased from shops, sample E is a palm oil used as an adulterant. Sample A was prepared of different concentrations with palm oil (A+E). The preparation of oil sample to find adulterant traces in coconut oil were taken in the percentage as shown in **Table.1**.

Table-1: Binary mixture of coconut oil and palm oil.

Sample	**Coconut oil in ml**	**Palm oil in ml**
A+E (5%)	4.75	0.25
A+E (10%)	4.5	0.5
A+E (15%)	4.25	0.75
A+E (20%)	4.0	1.0

III. EXPERIMENTAL AND DESIGN OF SENSORS:

The refractive index of a medium is such an optical property that it manages the interaction of electromagnetic radiation incident onto it. Thus when an electromagnetic radiation passes through a medium, it starts interacting with the electrons present in it and the electric field component of the wave makes them vibrate. Thus, forced oscillations of the electrons make them radiate light offering the secondary source of radiation. However, the speed of new waves changes accordingly to the optical properties of the medium and it is always less than the speed of light in vacuum. All materials are characterized by their ability to slow down the waves, classified as an optical refractive index.
A Multimode optical fiber is more suitable for Evanescent field sensor than a single mode fiber because it allows multiple modes of light to propagate and hence the available evanescent power will be sufficient for it to interact with the sensing region. When the evanescent field is made to interact with the test sample solution, the effective refractive index of the waveguide mode or the fiber mode is directly affected by the refractive index of the sample solution. Hence there will be the modulation in the light intensity propagated through the fiber and there will be a shift in wavelength of the propagated light and change in total output power.
To build sensor 2 m long multimode fiber was taken and outer jackets were removed in the middle portion. Then the fiber was stripped (about 2 cm) as a sensing portion. Optical spectrum analyzers work on diffraction grating principle or interferometry principle. Optical Spectrum Analyzer measures the power distribution (spectrum) of optical wavelengths. One end of the multimode fiber is connected to the broadband source and another end to the optical spectrum analyzer. The stripped portion of fiber was mounted on the wax for etching. Some amount of 40% HF solution was used to etch the fiber and readings were noted. The fiber was etched until the there was a considerable shift in wavelength (fiber was etched for 43 mins). The diameter of the etched fiber found using High-Resolution Optical Microscope was 55.5 µm and the image is shown in **Fig.1**.

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Fig 1. Image of etched fiber from optical microscope

The etched fiber was then washed using distilled water to remove the impurities. The middle portion of the etched fiber was dipped in the solution. Experimental setup for detection of adulterant traces in coconut oil as shown in **Fig.2**.

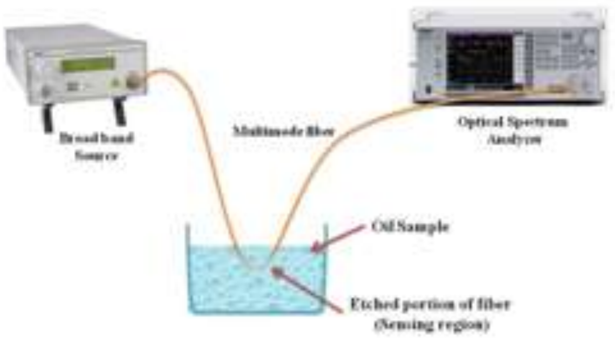

Fig. 2: Experimental arrangement

Four different coconut oil samples were taken viz A, B, C and D with A as a reference (pure) coconut oil. B, C was the packaged coconut oils with different brands and D was the non-packaged oil. The etched fiber was then dipped in one of the coconut oil samples and the respective wavelength and the output power were recorded. Then the dipped fiber was washed by ethanol solution to remove the oil coated on the fiber. Here we used the ethanol, isopropanol solution to remove the oil content because oil is easily soluble in the ethanol then again washed with the distilled water until the oil on the etched portion was removed. Similar procedure was followed for different samples of oil (A, B, C, D, and E), the shift in wavelength and output powers were recorded for all the mentioned samples. To detect the percentage of adulteration of palm oil in the pure coconut oil, the sample was prepared with pure coconut oil (A) and palm oil (E), i.e. (A+E) of different concentration and respective data were recorded.

Table-2: Refractive index of different oil samples.

Sample	**Refractive Index (R.I)**
A	1.4556
A+E (5%)	1.4564
A+E (10%)	1.4571
A+E (15%)	1.4572
A+E (20%)	1.4585
A+E (25%)	1.4587
B	1.4559
C	1.4557
D	1.4564
E	1.4657

Here, we use Abbe's Refractometer to find the refractive indices of the different oil samples. The refractive index of the adulterated coconut oil samples along with the other oils i.e., A, B, C, D and E were measured using Abbe's Refractometer as in **Table 2**. Due to different concentration of oil, increase in the refractive index in the core that guides the light in an optical fiber and variations in refractive index that reduces the reflectivity of a surface treated with an anti-reflective coating. The refractive index of different oil sample can conclude the phase velocity of light in the medium (V).

$$V = \frac{c}{n}$$

c- Speed of light,n- Refractive index of given medium
Wavelength in that medium $\boldsymbol{\lambda}$,

$$\lambda = \frac{\lambda_0}{n}$$

λ_0- Wavelength of that light in vacuum.
The refractive index is a very important property of the components of any optical instrument that uses refraction. However, when light passes through a medium, some part of it will be attenuated, complex refractive index

$$\underline{\mathbf{n}} = \mathrm{n} + \mathrm{ik}$$

n- Refractive index & indicates the phase velocity
k- Extinction coefficient
Also, refer to the mass attenuation coefficient. However, fiber loss parameter is expressed as attenuation in dB/km as

$$\text{Loss} = -10 \log\left(\frac{P_2}{P_1}\right)$$

Where, P_2 - light power output,
P_1 - light power input

Many oils (such as olive oil) & ethyl alcohol are examples of liquids which are more refractive, but less dense than H_2O. It determines generally the path of light through the optical fiber. Refined, bleached and deodorized (RBD) oil is made from copra [19].

IV. RESULTS AND DISCUSSION:

Etching of small portion of the fiber (Sensing portion) with 40% HF solution responds to change in wavelength and output

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power, as shown in **Fig.3** which describes the comparison before and after etching of fiber and shows a shift in wavelength with respect to output intensity.

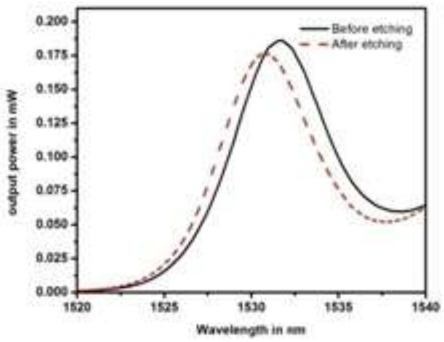

Fig.3: Output power versus Wavelength comparison of etching

The output power from the Optical fiber decreases after etching indicating that there is a loss of power outside the core region after etching. The wavelength also decreases after etching.

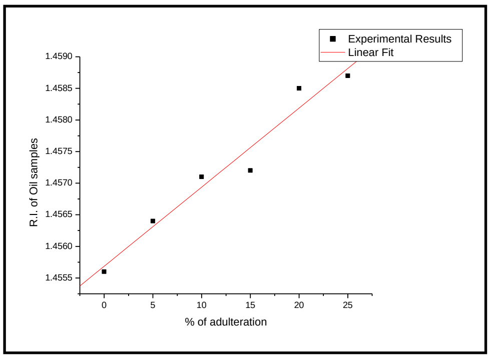

Fig.4: Plot of R.I. versus Adulteration % in Coconut oil

From the graph, it is clear that Refractive index of the pure coconut oil increases linearly with increase in concentration of Palm oil i.e., % of adulteration. As the concentration of Palm oil in pure coconut oil increases, the density of the oil increases which leads to the increase in refractive index as shown in **Fig.4**. The output power versus % of adulteration in A fits linearly. This shows that as the adulteration % in A increases the power transmitted through the fiber increases as R.I. increases with increase in adulteration.

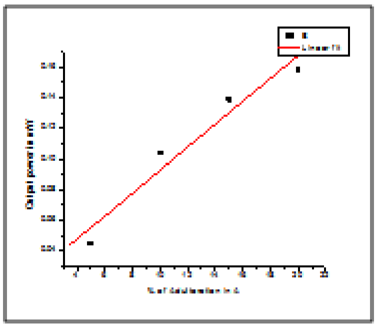

Fig.5: Output power versus different concentrations of adulterated oils

From the **Fig 5**. It is clear that with the change in the RI of the different oil samples, there is a change in the wavelength and change in power.

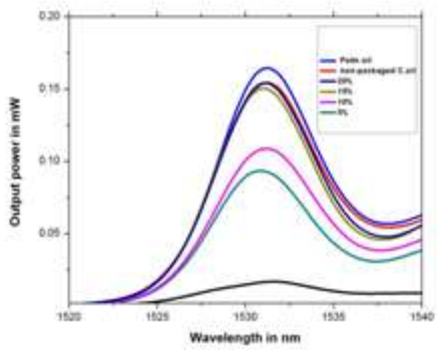

Fig.6: Optical Spectrum for different oil samples

The Spectral response for non-packaged Coconut oil and different Palm oil concentrations shown in the **Fig.6**. 20% adulteration of palm oil in the coconut oil, which causes diseases which effect on health**.**
The resultant adulteration of palm oil in coconut oil is 20%, where the refractive index at the same medium is 1.4585 leads to phase velocity 2.0555 m/s. Hence, 20 % of adulteration of palm oil in coconut oil which effects human health.

V. CONCLUSION:

The author have developed a Fiber optic sensor using Multimode fiber to detect and determine adulterant traces in Coconut oil, which is one of the most commonly used edible oils in South India. Use of multimode fiber for sensors is more economic than the Fiber Bragg Grating or Long Period Grating; hence, it may be referred to as low-cost Fiber optic sensor. Coconut oil is much prone to adulteration due to its high cost and it is often used by the people. Phase velocity in the resultant medium of refractive index 1.4585 is 2.0555 m/s. The spectral response for Coconut oil adulterated with 20% Palm oil matches with that of the non-packaged Coconut oil. This sensor may be employed for other liquids too due to its efficiency.

VI. ACKNOWLEDGEMENT:

This work was supported by VGST, Department of Science and Technology; Government of Karnataka has commissioned the project at Karnatak University, Dharwad. (VGST-KFIST (Level-II). Author Mangesh Jadhav and Balesh Mastiholi are also thankful to J S S Arts, Science & Commerce College, Gokak for providing an opportunity to continue the research. Authors are also thankful to Dr. Pradeep Chavan, BLDEA's S. B. Arts & K. C. P. Science College, Vijayapur for their valuable suggestions on this work.

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