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U-bent plastic optical fiber for lard adulteration sensor in edible oil

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ABSTRACT

A plastic optical fiber with the structure of U-bent was utilized as a sensor to detect lard adulterants in olive oil. The macro bending was formed on the plastic optical fiber with a bending radius of 10 mm, 12.5 mm, and 15 mm. The output spectra and intensity were measured to detect the existence of lard substance in olive oil. The U-bent plastic optical fiber sensor with a bending radius of 12.5 mm has the optimum performance to detect the lard adulterant substance in olive oil. It has a sensitivity of 4.6 a.u/% with 855 nm LED source and 10.07 a.u/% with 940 nm LED source in intensity-based measurement and 0.50 nm/% in spectrum-based measurement. The proposed sensor is the potential to give rapid detection on lard adulterant in edible oil.

Keywords: *Edible oil, Food safety, Halal detection, Optical fiber sensor.*

1 Introduction

Optical fiber is immensely applied as chemical/biosensors [1-6]. Its ease of fabrication and implementation, lightweight, high sensitivity, low cost, and immunity to electromagnetic interference are the main advantages of optical fiber as a sensor in comparison to conventional sensors [7]. As a chemical/biosensor, an optical fiber acts as both a sensing element and a collecting element [8]. It provides efficiency to a detection process. The presence of analyte on the optical fiber surrounding changes the properties of optical fiber and enabling detection. By utilizing its advantages, an optical fiber sensor was designed to detect lard adulteration in olive oil.

As reported by food and drug associations of some countries for the last three decades, some edible oil products were found adulterated by cheap substances including lard or other animal fats, and mislabeled [9-12]. The presence of the lard in edible oil products gives concern to Muslim and Jews consumers in choosing food products. Since it is prohibited for Muslims and Jews to consume products that contain pig or pig derivatives [13].

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In our previous study, some structures of optical fiber sensors were applied to detect lard adulteration in edible oils and they showed great performance [14-17]. However, it is important to explore the potency of other structures of optical fiber sensors to obtain better performance of the optical fiber sensor. In this paper, a U-bent structure will be formed in a plastic optical fiber with various bending radius. The U-bent structure enables evanescence waves from the optical fiber to interact with the surrounding medium. Hence, it allows the detection.

2 Materials and methods

2.1 Sample Preparation

The pig fat provided in a local market was heated up and melted. The liquid phase of pig fat is then called lard. Then lard was filtered to remove the residual chunks of fat which cannot melt and another unwanted particle. The purified lard was added to olive oil which was purchased from the local store with a concentration of 0 – 5% (v/v). The lard and olive oil mixed by using ultrasonic bathing for 30 minutes to get the homogenous mixture.

2.2 Experiments

The U-bent optical fiber sensor is fabricated by forming a macro bending to a multimode polymethyl methacrylate (PMMA) optical fiber with a certain bending radius. A plastic optical fiber from Super Eska TM, SH-4001 has core diameter and cladding thickness of 980 µm and 20 µm, respectively. The jacket of the plastic optical fiber was removed by using an optical fiber jacket cleaver. Then its coating was removed by using acetone with a concentration of 99%. The uncoated part of the plastic optical fiber acts as the sensing element as shown in Fig.1(a). The plastic optical fiber has a refractive index of the core of 1.49 and a numerical aperture of 0.50. The bending radius was varied (10, 12.5, 15 mm) to evaluate the performance of the sensor. The experimental setups are presented in Fig. 1(b)-(c). The U-bent plastic optical fiber was immersed in the sample for both measurements. The spectrum-based measurement as shown in Fig.1(b) will measure the output spectrum of the proposed optical fiber sensor at the wavelength range of 350 – 1000 nm as the change of lard concentration in olive oil. The output spectrum was measured for 5 repetitions using *Ocean Optics Spectrometer*. While, for intensity-based measurement, the infrared LED with the wavelength of 855 nm and 940 nm was used as the light source as illustrated in Fig.1(c). The LED sources were driven by Arduino to give stable voltage. The output intensity of the U-bent plastic optical fiber sensor was recorded for 100 seconds using *Thorlabs* optical power meter. All the experiments were conducted at a room temperature of 20^{o}C. Since the room temperature affects the properties of the samples and the sensor performance [18].

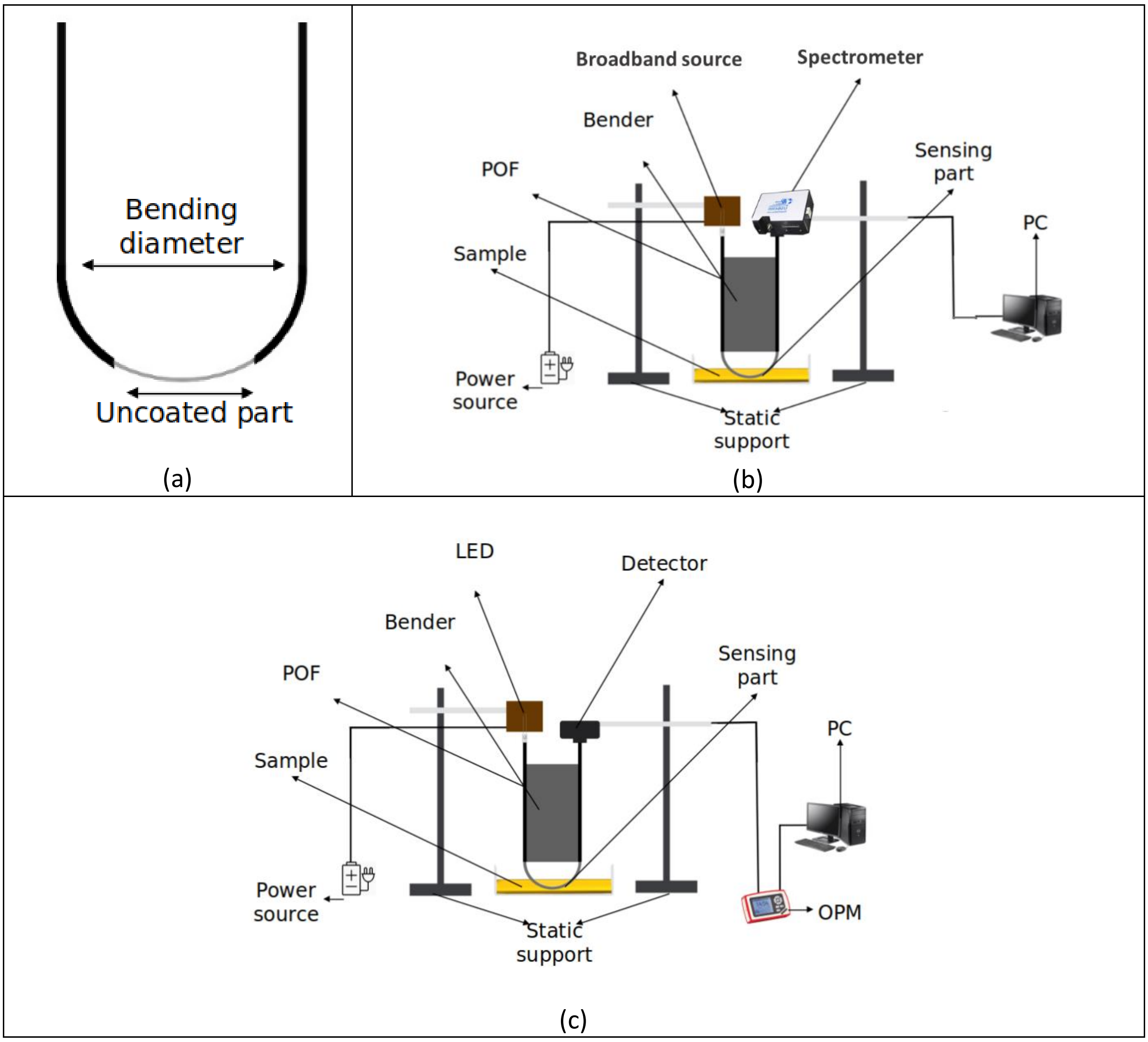

Fig. 1 (a) Schematic diagram of U-bent optical fiber (b) Experimental setup for spectrum-based measurement (c) Experimental setup for intensity-based measurement.

3 Results and discussion

The measured output spectra of U-bent plastic optical fiber sensor with various bending radius are presented in Fig. 2. One can see, the U-bent plastic optical fiber transmitted light which has wavelength peaks at 855 nm and 940 nm. The change in bending radius of plastic optical fiber does not cancel any wavelength of the light source. However, it has a different response toward a variation of lard concentration in olive oil.

The change of lard concentration in olive oil shifted the peak wavelength of the light source which is transmitted in the U-bent plastic optical fiber at all variations of bending radius. In Fig. 2(a), as the lard concentration increased, the measured spectra at the peak wavelength of 855 nm experience blue-shifting with the sensitivity of 0.5 nm while the peak wavelength of 940 nm does not shift. On the contrary, a U-bent plastic optical fiber sensor with a bending radius of 15 mm. It has a blue-shifting response at the wavelength peak of 940 nm with a sensitivity of 0.5 nm, yet it does not shift the wavelength peak at 855 nm as depicted in Fig. 2(c).

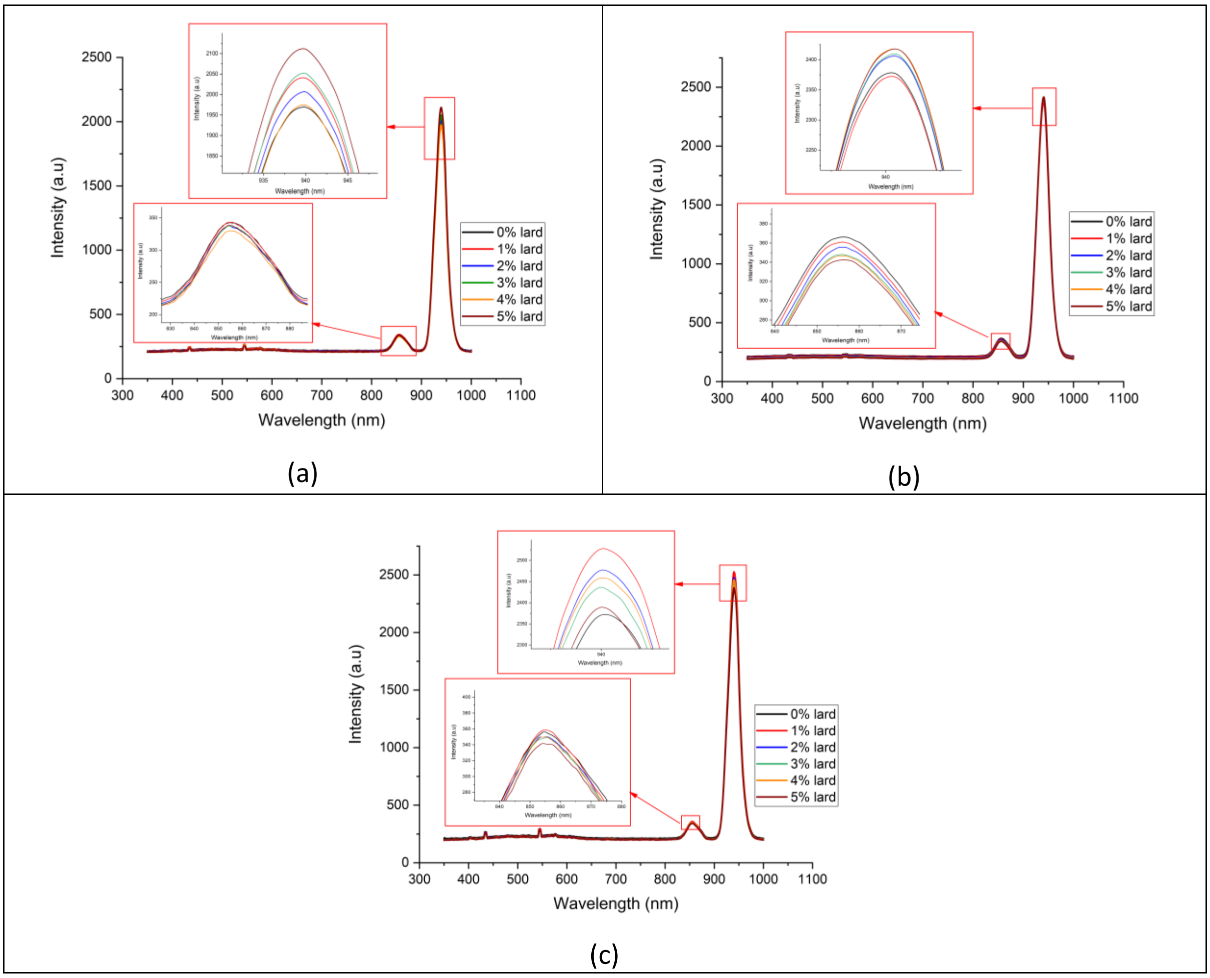

Fig. 2 Measured output spectra of U-bent optical fiber with the radius of (a) 10 mm (b) 12.5 mm (c) 15 mm.

A different response showed by U-bent plastic optical fiber with a bending radius of 12.5 mm. The wavelength shifting occurred in both peaks. It shifted to the shorter wavelength at the peak of 855 nm with the sensitivity of 0.5 nm while at the peak of 940 nm is shifted to a longer wavelength with the sensitivity of 0.5 nm.

The addition of lard substance in olive oil changed its refractive index. The change of medium refractive index surrounding the U-bent plastic optical fiber leads to the change of effective refractive index of the light propagation inside the optical fiber. It yields the shifting of the transmitted light wavelength which the results agree with the previous studies [19-21].

The intensity-based measurement was carried out as well to provide a compact-designed measurement. As shown in spectrum-based measurement that the wavelength of 855 nm and 940 nm gave a point of interest to be explored in an intensity-based measurement. Hence, the wavelength of 855 nm and 940 nm were utilized to investigate the sensor performance. One can see in Fig. 3(a), with an 855 nm LED, the measured intensity of U-bent plastic optical fiber decrease as the lard concentration in olive oil increased. While, with a 940 nm LED, it increased as the lard concentration increased. U-bent plastic optical fiber with a bending radius of 12.5 mm has the highest sensitivity in both wavelengths. It has a sensitivity of 4.6 a.u/% and 10.07 a.u/% at the wavelength of 855 nm and 940 nm, respectively.

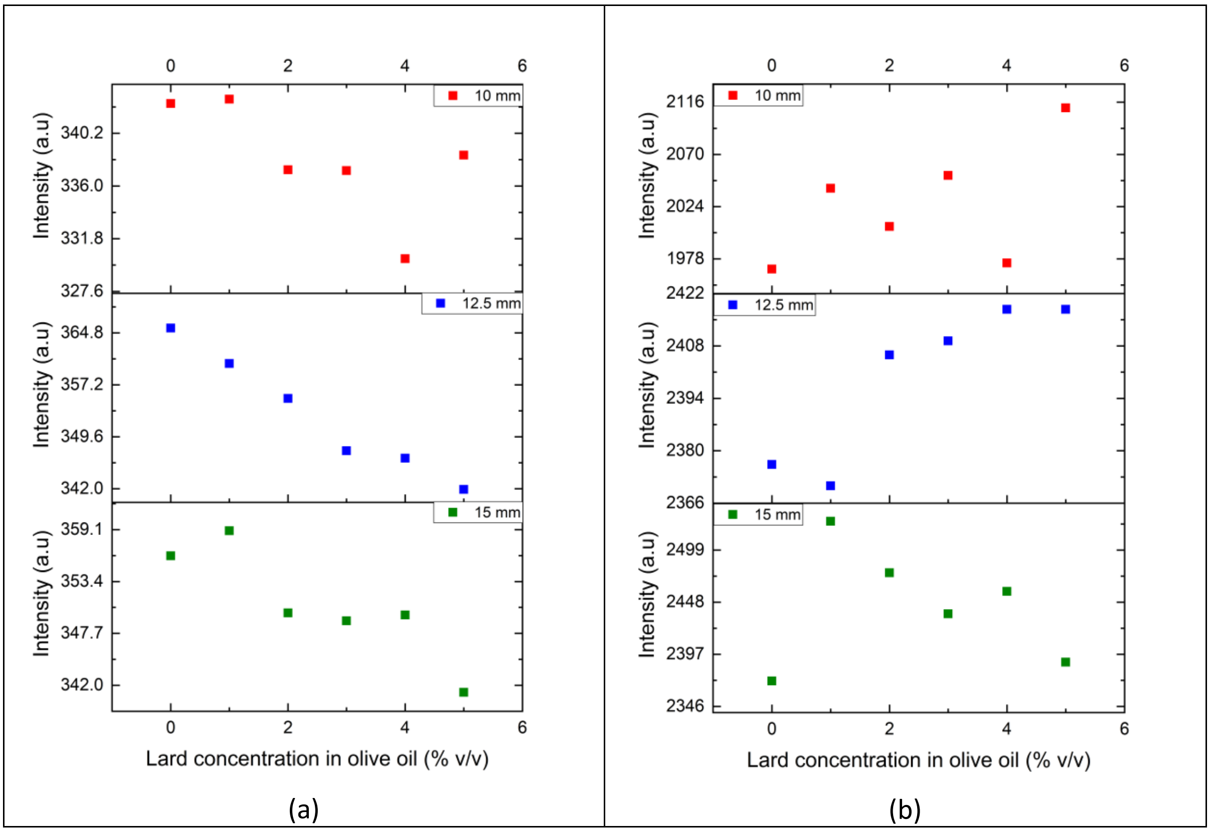

Fig. 3 Measured output intensity of U-bent optical fiber with various radius at a wavelength of (a) 855 nm (b) 940 nm.

The U-bent plastic optical fiber sensor exploits the evanescence phenomenon caused by the macro bending on the optical fiber. The variation of the analyte refractive index varied the evanescent modes and their penetration depth to the analyte which acts as the cladding on the sensing element. The simultaneous variation in bending radius and the analyte refractive index caused the different responses of the U-bent plastic optical fiber sensor.

The results show the potency of the U-bent plastic optical fiber sensor to detect lard adulteration in olive oil. The proposed optical fiber sensor provides high sensitivity, low cost, and ease of fabrication method.

Conclusion

U-bent plastic optical fiber sensor for lard adulteration in olive oil was investigated experimentally. The measured output spectrum and intensity were used to evaluate the performance of the proposed sensor. From all the experiments conducted, the result showed that the U-bent plastic optical fiber sensor for lard adulteration in olive oil has great sensitivity and linearity with a bending radius of 12.5 mm. It has a sensitivity of 4.6 a.u/% by using an 855 nm LED source and 10.07 a.u/% by using a 940 nm LED source. It can be used as the novel rapid and compact alternative to do oil product authentication.

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