# Multimode Optical Fiber Extrinsic Sensor – Determination of Adulteration of Certain Edible Oils

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## ABSTRACT

*Purity of edible oils play an important role with reference to the hygiene and health condition of the consumers. In the present work a multimode intensity modulated fiber optic extrinsic evanescent wave sensor is developed for the determination of the purity of groundnut oil and coconut oil mixed with cheap oils available commercially. The experimental setup of the sensor consist of, two plastic fibers of 200/230μm diameters, operated at the wavelengths of 820nm and 850nm. The sensing region is created by using a U-shaped glass rod as an extrinsic element between the two multimode plastic fibers. The macro bend of the sensing element (U-shaped glass rod) will enhance the sensitivity of the sensor. One end of the input fiber is connected to the light source and the other end of it is connected to U-shaped glass rod. Similarly one of the ends of the output fiber is connected to a power meter and the other end of the fiber is connected to the remaining end of the U-shaped glass rod. Oil mixtures of pure oil mixed with cheap oils at different mixed ratios are introduced into the sensing region one by one. When power launched into the sensor a sharp decrease in the output intensity is observed in the power meter as the mixtures of increased cheap oil ratios are introduced into sensing region. The intensity variations in the observed output power can be co-related to the volume of cheap oil adulteration in pure samples. Since the groundnut oil and coconut oil are used as edible oils in large volumes in different states of the country, investigation of adulteration of these oils is under taken using multimode optical fibers. The sensor so developed is, inexpensive, portabl, easy to fabricate and exhibits high resolution.*

***Key words:*** *Adulteration, Cheap oil, Coconut oil, Groundnut oil, Edible oils, U-shaped glass rod.*

## I. INTRODUCTION

The use of optical fiber systems for sensing of various environmental parameters has taken technology advancement in the recent years in terms of its design, fabrication, geometry and constitution [1–6]. Comparing with other modulation schemes such as phase modulation, wavelength modulation, frequency modulation it is easy to develop intensity modulated fiber optic sensor which are compatible with the multimode optical fibers [7–9]. To encode the information, optical fiber sensors act as transducers, which describes the non optical external perturbation into an optical signal. The various features exhibited by the optical fiber based sensors permit the measurement and monitoring of various environmental parameters. The groundnut oil and coconut oil are widely used as edible oils in most of the regions across the country. These oils are much prone to adulteration due to their high demand, high cost and low supply throughout the year. Some of the oils that are available in the market and most commonly used as adulterants are cheap oils like paraffin oil, palm oil etc.

 ISSN No.: 2279-543X
UGC Journal No.: 64650

## II. EXPERIMENTAL DETAILS

When light is launched from a source into an optical fiber a fraction of the radiation penetrates to a small distance from the guiding medium into the liquid medium of lower index of refraction that surrounds the core medium. The evanescent wave penetrated into the liquid cladding medium attenuates there, because of the refractive index difference and hence a fractional energy will be absorbed and another fractional energy scattered.

**Power Output:** The relation for the output power '$P_{out}$' is given by [10].

$$P_{out} = \frac{P_{in}\,[n_1^2 - n_l^2]}{[n_1^2 - n_2^2]}$$

…………..……..…………………..……………… (1)

Where: $n_1$ – Refractive index of the core

$n_2$ – Refractive index of the cladding

$n_l$ – Refractive index of liquid cladding surrounding the core

$P_{in}$ – Total power injected into the fiber from the source

$P_{out}$ – Total power from the sensor end of the fiber

From equation (1) it is clear that the power coupled into the output fiber decreases linearly with increase in the square of the refractive index of the liquid surrounding the U-shaped glass rod [11]. The relationship so formed can be exploited to construct a refractive index based fiber optic sensor to determine the adulterant present. The dependence of the amplitude E[z] of the evanescent field with distance 'z' from the core-cladding interface can be expressed in the form of an equation.

**Electric field**: Electric field with respect to distance 'z' E[z] is given by

$$E[z] = E \exp\left(\frac{-z}{h_p}\right)$$

…………………..……...………...…………… (2)

Where: E[z] – Electric field with respect to distance 'z'

z – Distance from the core-cladding interface

$h_p$ – Height of the penetration (penetration depth)

The depth of the penetration describes the distance from the interface, where the intensity of the evanescent field decreases to 1/e times of the initial intensity 'E'.

**Height of the penetration:** The magnitude of the height of the penetration '$h_p$' is given by

$$h_p = \frac{\lambda}{2\pi n_1}\left[\sin^2\theta - \right.$$

n2n12−1/2………………......………………. (3)

Where: $h_p$ – Height of the penetration

$\theta$ – Angle of incident

$\lambda$ – Wavelength of the light

$n_1$ – Refractive index of the core

$n_2$ – Refractive index of the cladding

From the equation (3) the height of the penetration ‘$h_p$’ increases with refractive index of the cladding refractive index, indicating an increase in electric field present in the cladding and hence reduction of electric field in the core.

**Normalized frequency:** The normalized frequency ‘V’ is given by

$$V = \frac{2\pi a}{\lambda} [n_1^2 - n_2^2]^{1/2}$$

…………………….……………....…….. (4)

Where: V – normalized frequency

a – Radius of the core

λ – Wavelength of the light

$n_1$ – Refractive index of the core

$n_2$ – Refractive index of the cladding

The actual number of modes that propagate within the fiber becomes proportion to square of the normalized frequency (V). But according to equation (4) ‘V’ parameter decreases as refractive index of the cladding increases. Therefore an increase in the refractive index of the cladding reduces the number of modes that are propagating within fiber. Hence we may conclude that the adulteration of edible oils and the changes in the corresponding refractive index will affect the higher order modes prevented from the propagation through the core, thereby measuring the higher order modes can be used to sense the presence of the adulterant of oils in the edible oils [12–16].

The experimental arrangement consists of a laser diode (operated at wavelength 820nm & 850 nm) and two multimode plastic fibers of 200/230µm diameters of core and cladding respectively and a bench mark power meter. The light launched from a laser diode enters into the core of the input plastic optical fiber at one end, then the power transmitting through input end of the U-shaped glass rod which will be coupled out into the output fiber from the other end of the U-shaped glass rod. The light transmitting through the output fiber will enter into the power meter which in turn can be measured and can be recorded. The cladding of the fiber is made up of a thin layer of fluorinated polymer and core of the fiber is made with a PMA (Polymethyle methacrylate). The experimental setup is shown in fig. [1].

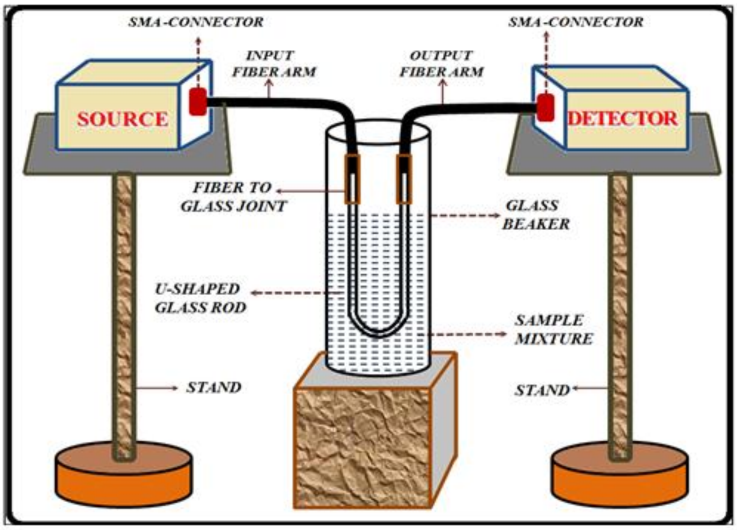
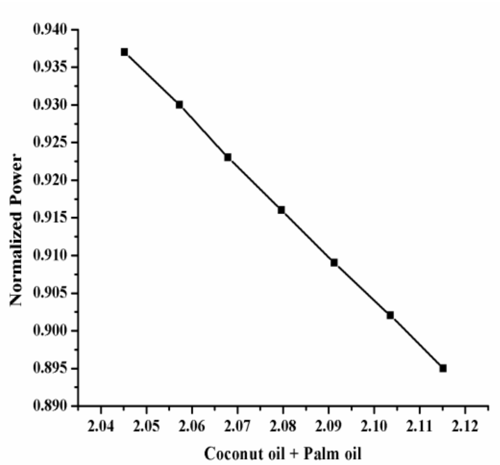



**Fig.1: Experimental Arrangement of Multimode Optical Fiber Extrinsic Sensor**

The mixtures of the cheap oil and edible oil with increasing index of refraction are prepared by increasing the concentration of paraffin oil or palm oil in edible oil samples. The refractive indices of these mixtures with different concentrations are determined by using Digital Refractometer (RX 7000i).

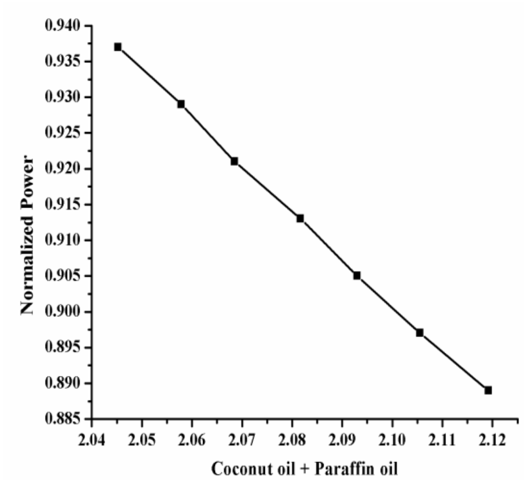
## III. RESULTS AND DISCUSSION

The plots for normalized optical power outputs as function of refractive index of square of the liquid cladding of different volumes of adulterant in pure oils (pure coconut oil & pure groundnut oil) are shown in fig. [2–5] using a wavelength of 820nm.



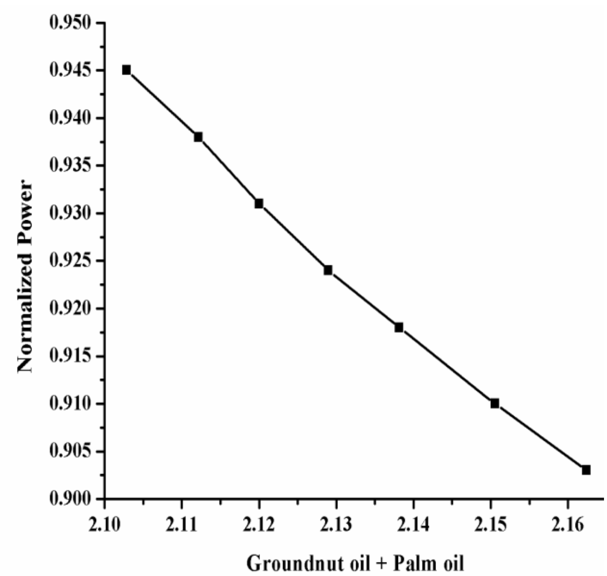

**$n_l^2$ at 820nm**

**Fig.2: Coconut oil + Palm oil ($n_l^2$) Vs Normalized Power($P_N$) at 820nm**



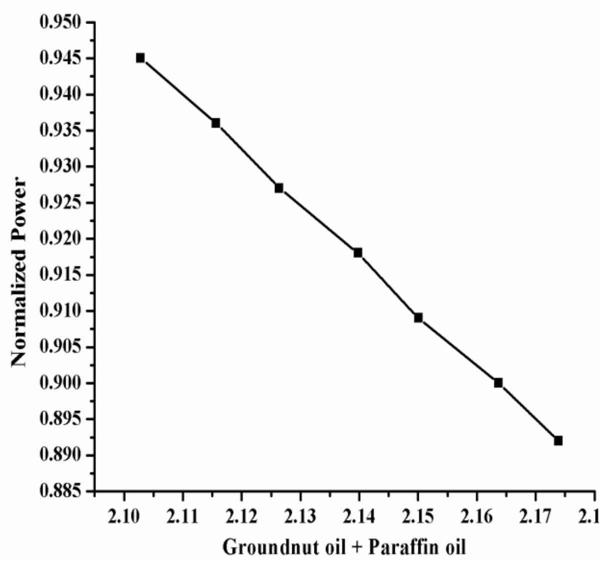

**$n_l^2$ at 820nm**

**Fig.3: Coconut oil + Paraffin oil ($n_l^2$) Vs Normalized Power($P_N$) at 820nm**




**$n_l^2$ at 820nm**

**Fig.4: Groundnut oil + Palm oil ($n_l^2$) Vs Normalized Power($P_N$) at 820nm**

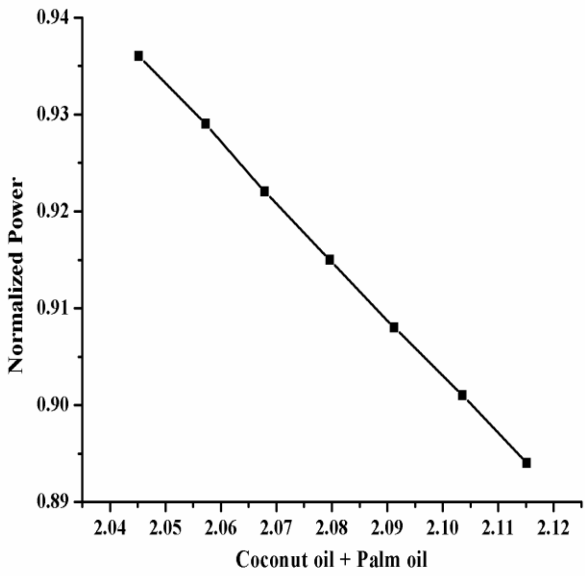



**$n_l^2$ at 820nm**

**Fig.5: Groundnut oil + Paraffin oil ($n_l^2$) Vs Normalized Power($P_N$) at 820nm**

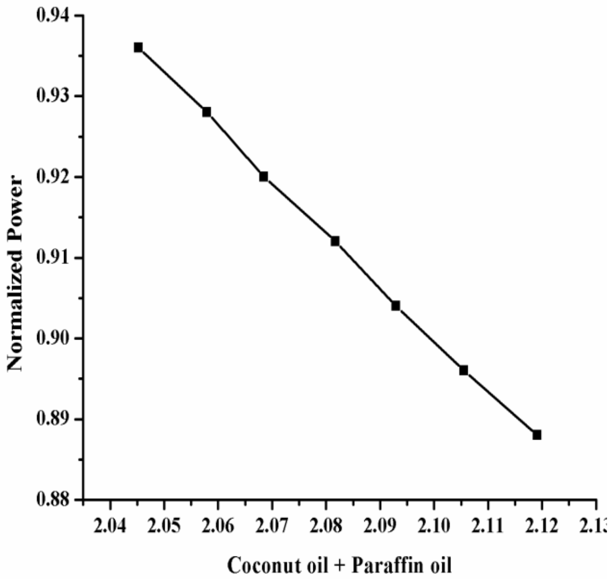
The experiment is repeated with source wavelength of 850nm and graphs are plotted in fig. [6–9].

ISSN No.: 2279-543X
UGC Journal No.: 64650



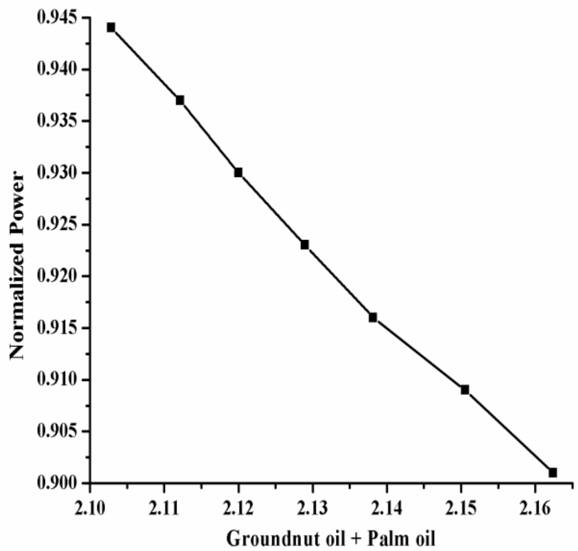

**$n_l^2$ at 850nm**

**Fig.6: Coconut oil + Palm oil ($n_l^2$) Vs Normalized Power($P_N$) at 850nm**



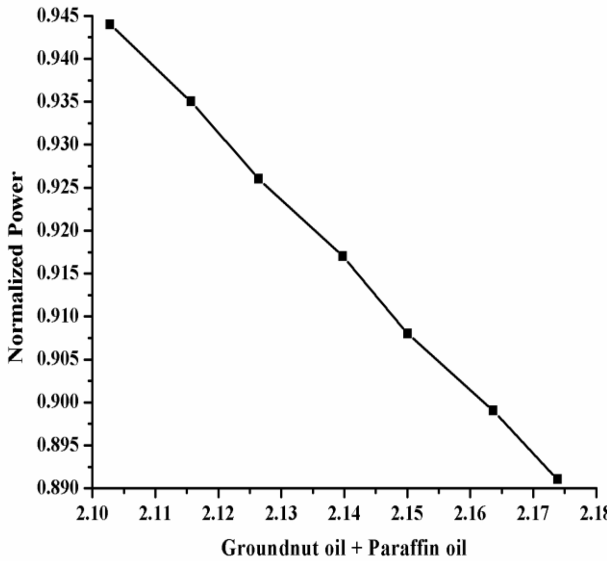

**$n_l^2$ at 850nm**

**Fig.7: Coconut oil + Paraffin oil ($n_l^2$) Vs Normalized Power($P_N$) at 850nm**




**$n_l^2$ at 850nm**

**Fig.8: Groundnut oil + Palm oil ($n_l^2$) Vs Normalized Power($P_N$) at 850nm**




**$n_l^2$ at 850nm**

**Fig.9: Groundnut oil + Paraffin oil ($n_l^2$) Vs Normalized Power($P_N$) at 850nm**

As expected from equation (1) the normalized power exhibits a linear relationship with square of the liquid cladding surrounding the U-shaped glass rod. The variation in index of refraction with volume percentage of adulterant in groundnut oil and coconut oil are shown in fig. [10–11].

ISSN No.: 2279-543X
UGC Journal No.: 64650

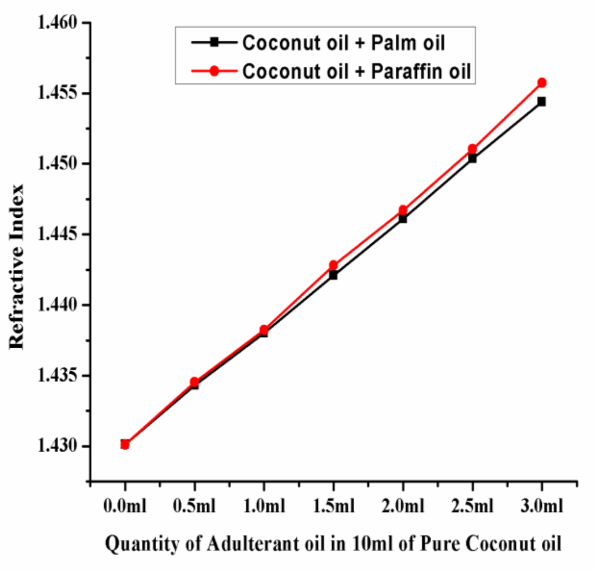



**Fig.10: Quantity of Adulterant oil (Palm oil, Paraffin oil) in Pure Coconut oil Vs Refractive Index**

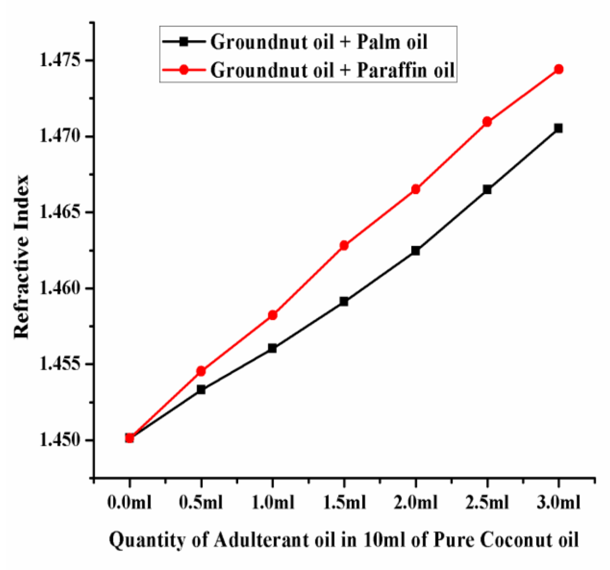



**Fig.11: Quantity of Adulterant oil (Palm oil, Paraffin oil) in Pure Groundnut oil Vs Refractive Index**

The influence of the adulterant leading to the corresponding decrease in the intensity output is shown in fig. [12–13] using the wavelength of 820nm.

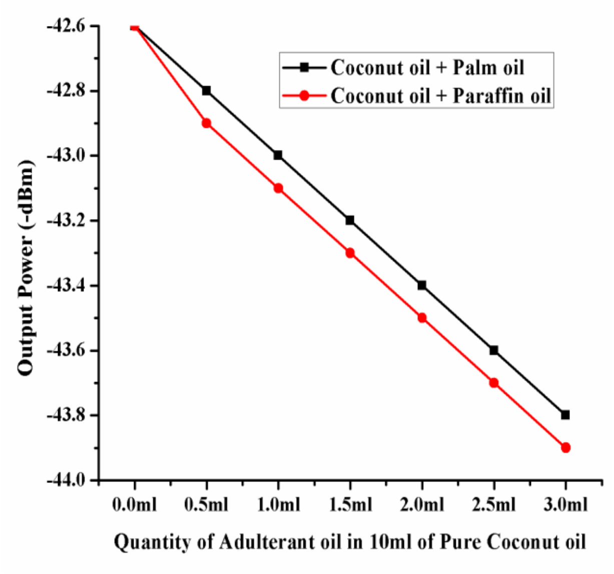



**Fig.12: Quantity of Adulterant oil (Palm oil, Paraffin oil) in Pure Coconut oil Vs Output Power (-dBm) at 820nm**

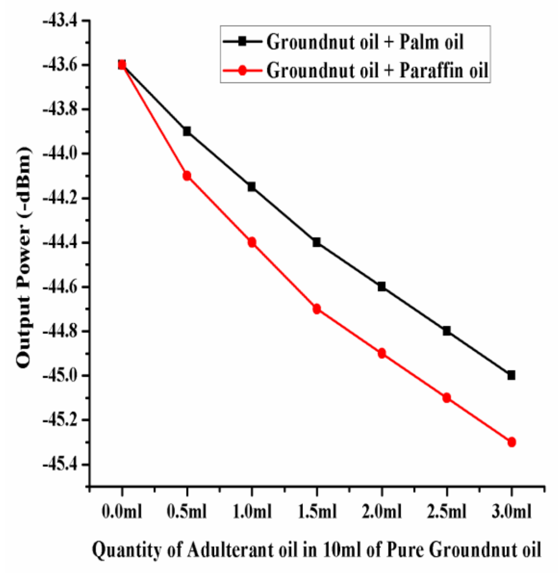



**Fig.13: Quantity of Adulterant oil (Palm oil, Paraffin oil) in Pure Groundnut oil Vs Output Power (-dBm) at 820 nm**

The experiment is repeated with a wavelength of the source at 850nm and graph is plotted in fig. [14–15].

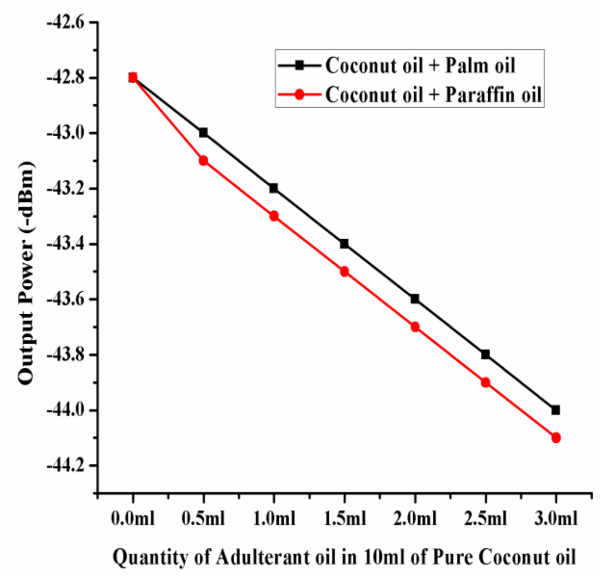



**Fig.14: Quantity of Adulterant oil (Palm oil, Paraffin oil) in Pure Coconut oil Vs Output Power (-dBm) at 850nm**

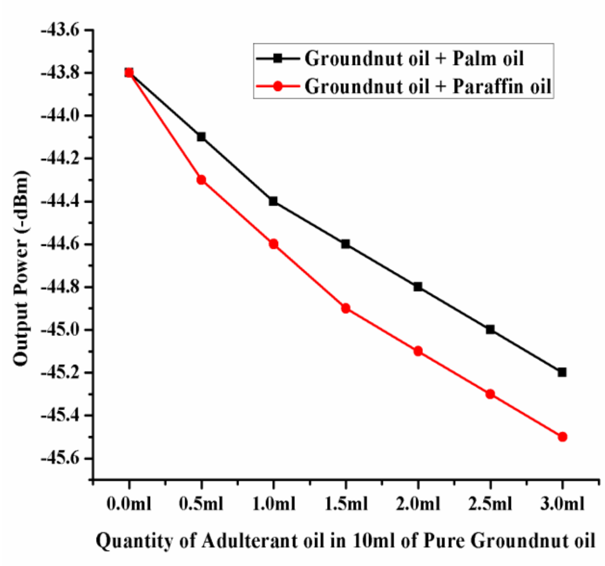



**Fig.15: Quantity of Adulterant oil (Palm oil, Paraffin oil) in Pure Groundnut oil Vs Output Power (-dBm) at 850 nm**

The reduction in the transmitted light intensity is attributed to the refractive index variations of the oil mixtures only. As the adulterant oils used are colourless (low absorbance) at the wavelength of light used. The variations in the index of refraction occur only within the height of the depth of penetration of the evanescent field of the guided wave. The increase in the index of refraction of the medium surrounding the core increases, as the concentration of the impure oil increases.

## IV. CONCLUSION

For the detection of adulterant present in the coconut oil and groundnut oil an evanescent wave multimode fiber optic sensing system using plastic optical fibers is developed. In the mechanism of the sensor the change in the refractive index with the addition of adulterant was determine for the indirect measurement of adulterant by noting down the corresponding power changes in the output. Evanescent field modulation is facilitated by the presence of tunneling rays propagating in large diameter multimode fiber, which contribute for an extra amount of energy available. The sensitivity observed is linear and the limit of detection is 3% of volume of adulterant present in the oil

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