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Synthesis and Analysis of Optical Transmission/ Capacitance Bridge System for Oil Deterioration Identification

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Abstract This paper is aimed to design the circuit of optical transmission system oil sensor, for monitoring the deterioration in the edible oil, for example, Sunflower, Palm and Ground nut oil etc. due to moisture react and heating condition. The device packaged to the edible oil, which let every mankind who prepared food at home or hotel to optimize the time for the exchange of edible oil for cooking. By applying the principle of the deterioration of edible oil can be expressed in terms of absorption intensity along with dielectric constant. The capacitance bridge circuit and the optical transmission integrator circuit designed for edible oil to monitor the change due to deterioration because of humidity and varying temperature. In this study, the range of operating temperature of edible oil is experimentally recommended within 80 - 90^{o}C for the stability of a sensor designed. It is concluded that the characteristics of output voltage converted from the dielectric constant are linearly distribute in support of optical absorption/transmission data. Three different samples of edible oil, namely Sunflower, Palm and Ground nut oil at room temperature are studied.

Keywords Optical Transmission, Oil Deterioration, Capacitance

1. Introduction

Vegetable oils are used in salad, cooking, and as ingredients in several foods. The price of vegetable oil may vary considerable from time to time, depending on production costs and availability. Due to economic importance of oil and fats, it is vital to develop methods to confirm authenticity, to define the composition of blends and to detect adulteration. The biggest problem with deterioration of edible oil is rancidity and the main cause of rancidity is oxidation. The most common analytical assessments of oxidation are provided in terms of Peroxide value, Anisidine value etc. It is now generally agreed that the deterioration (decomposition) of oil and fats, due to the action of air, light and moisture, or the action of micro-organisms, is an oxidative process subsequent to partial hydrolysis. In these two forms of rancidity of pure fats (where the absence of nidus prevents bacterial or mould growth) and that caused by micro-organisms; the course of the oxidation is not the same. Much has been written on the deterioration of pure oil when exposed to atmospheric conditions acquires the characteristic odor. But not any specific instant technique to identify deteriorated oil is reported in the literature[1-4]. When subjected to decomposition, it gives rise to a pungent "perfume" or ester-like odor which is quite different from the pure one.

In the present work, the absorption coefficient of vegetable oil was determined using Spectrometer. The variation of the absorption coefficient of vegetable oil with the wavelength is studied. Data indicates that the absorption coefficient of the vegetable oil varies with wavelength. It can be observed that the palm oil has the highest absorption coefficient variation among the oils tested, followed by groundnut oil and sunflower oil. The variation of the absorption coefficient in the range of wavelength studied was maximum for the palm oil compared to the sunflower and groundnut oil.

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2. Experimentation

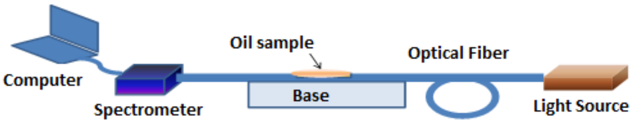


Figure 1. Experimental set up of Optical absorption/transmission measurement system

Deterioration of edible oil can be determined by measuring absorption/transmission intensity and capacitance. To study this, we have used a liquid dielectric constant measurement device by adopting the principle of cross capacitance measurement[1-7]. This study is based on the principle of Mie's theory (based on the variation of reflective index) and Thompson-Lampard theorem of electrostatics (for the variation of dielectric variation) of oil due to polarization. The measurement device in oil installed the thermostat in order to maintain insulation between measurement poles and keep the temperature of measured liquid at a constant level[7-9]. Fig.1 shows the measurement principle adopted for this study. This study uses the fact that any change in edible oil characteristics changes the optical absorption/transmission along with dielectric constant, which measures the changes in optical absorption /transmission intensity value. The control is done by PC based microprocessor system.

This method measures the oxidative deterioration in terms of absorption coefficient. The absorption coefficient of vegetable oil was determined using Spectrophotometer and the variation of the absorption coefficient of vegetable oil with the wavelength is studied.

For initial testing, sample holder (oil container) is filled with different types of edible oil and its Spectroscopic measurements are taken. Basically, three-four cycles are taken for each sample to get the accurate deterioration value. The light passes through the oil samples and measures the absorption coefficient of samples over a wide range of wavelength. Which results, the absorption coefficient is observed minimum for sunflower, ground-nut oil and maximum for palm oil may be because of more absorption taken place in palm oil. The purpose was to review the advances in the oil moisture measuring techniques and to consult on the procedures for adopting oil adulteration measurement techniques in the future research.

3. Results and Discussion

Fig. 2(a), (b), (c) and table 1 shows that the variation in absorption coefficient for Sunflower oil is minimum and for Palm oil is maximum over a wide range of wavelength.

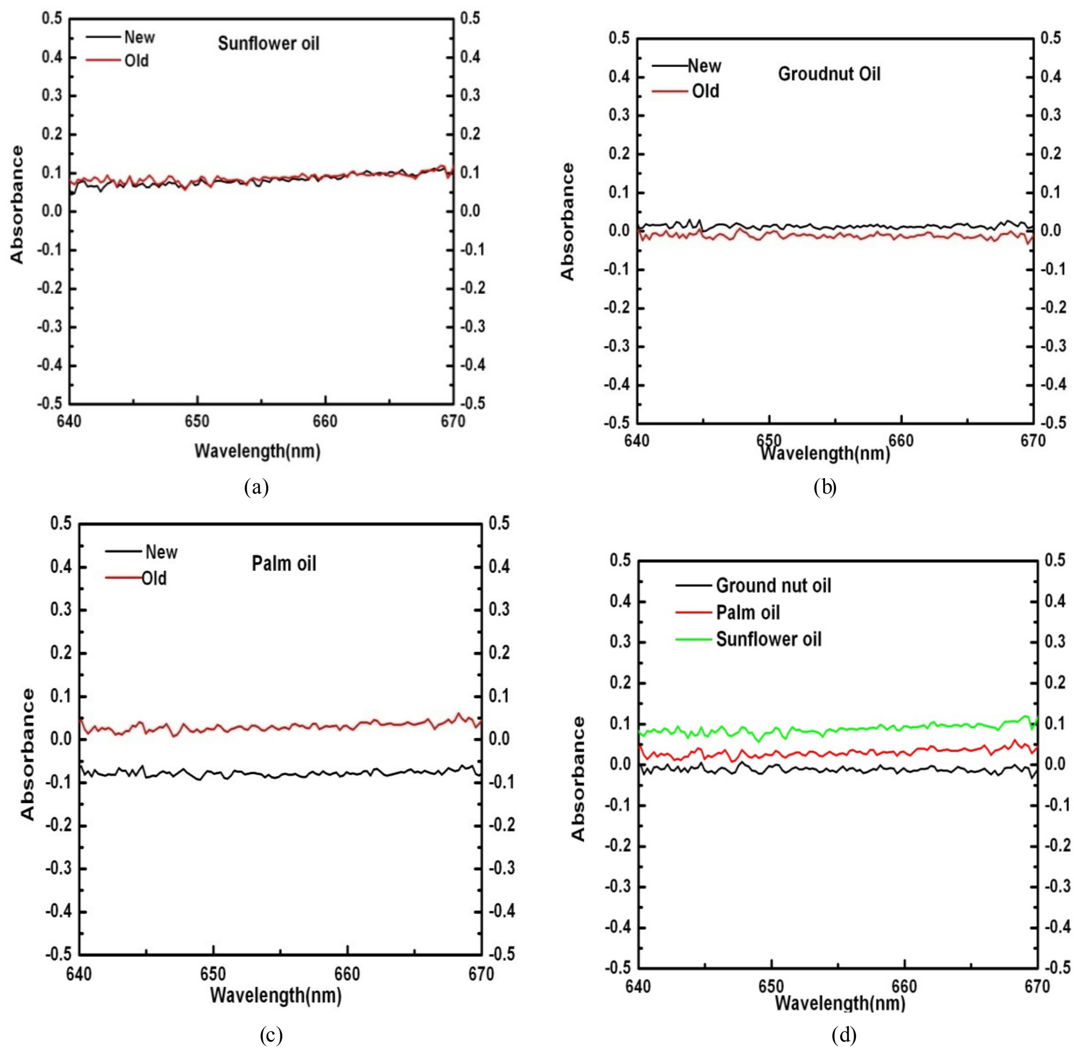


Figure 2. Variation of Absorption coefficient w.r. t. wavelength for Sunflower (a), Ground nut oil (b) and Palm oil (c) for all three samples (d)

Similarly Fig.3, (a), (b), (c), and table 1 shows that the variation in intensity (a. u.) for Sunflower oil is minimum and for palm oil is maximum over a wide range of wavelength.

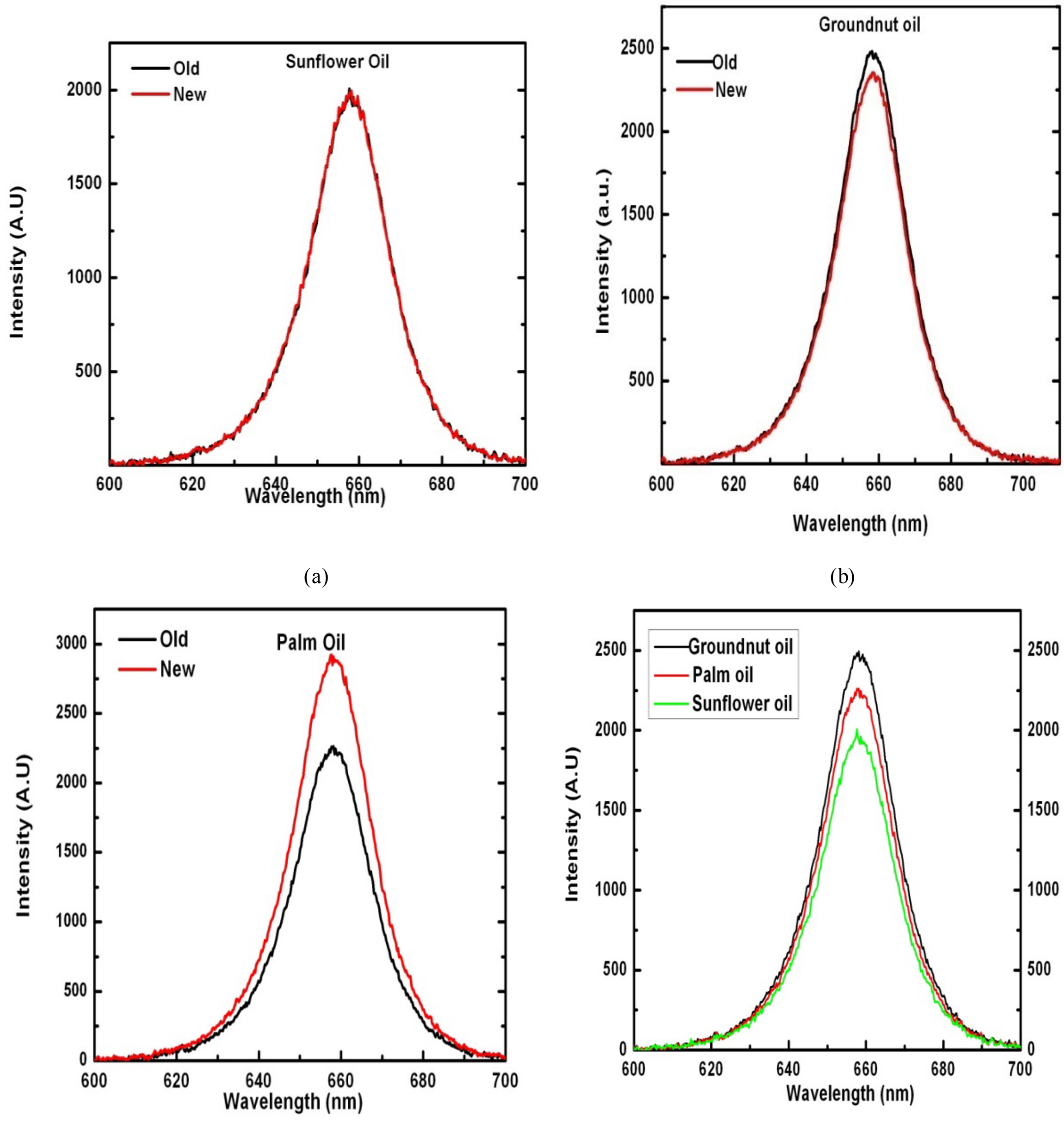
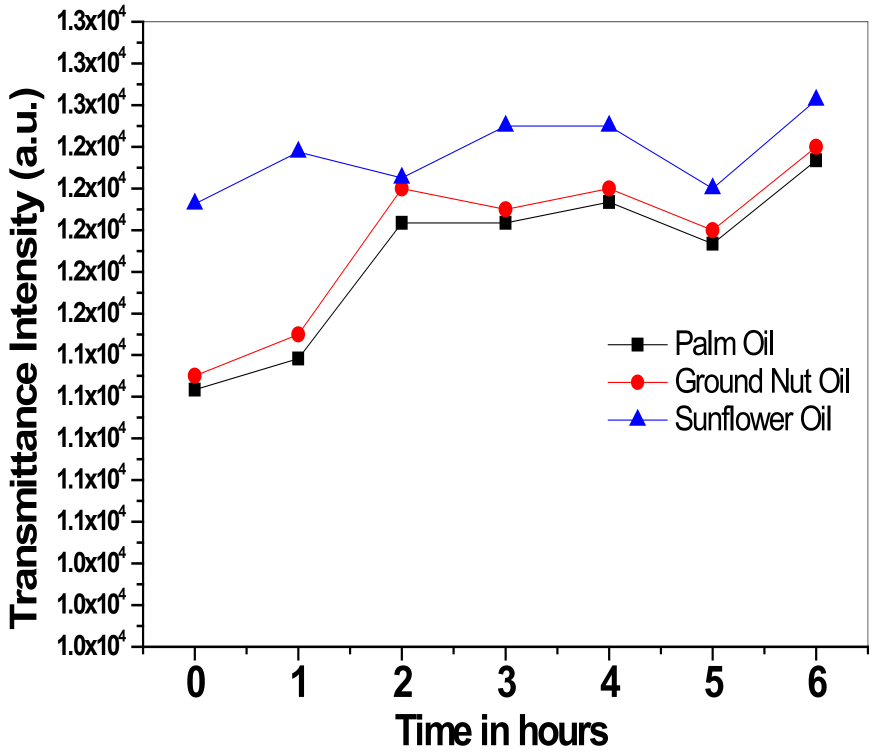


Figure 3. Variation of Intensity (a. u.) w.r.t. wavelength for Sunflower (a), Ground nut oil (b) Palm oil (c) and for all three samples (d)

Table 1. The variation of Absorption Coefficient and Intensity variation data of Sunflower, Groundnut and Palm oil in arbitrary units (a.u.)

Sr. No.	**OIL SAMPLE**	Absorption coefficient Exposed samples (a. u.)	Absorption coefficient Unexposed Samples (a. u.)	Absorption coefficient Difference	Intensity Exposed samples (a.u)	Intensity Unexposed Samples (a.u)	Difference in intensity (a.u)
1	**Sunflower oil**	0.075	0.05	**0.025**	2000	2000	**ZERO**
2	**Groundnut oil**	-0.025	00.00	**-0.025**	2500	2375	**125**
3	**Palm oil**	0.5	-0.75	**-0.25**	2000	2750	**750**



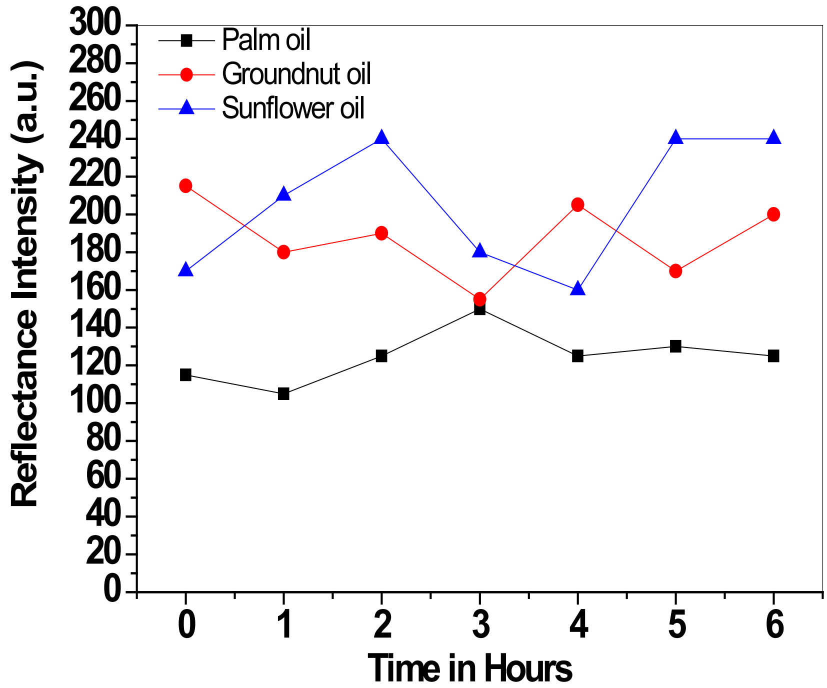


Figure 4. Variation of Intensity (a. u.) w .r. t. heating time of Sunflower, Ground nut oil and Palm oil

Fig.4 (a) shows that, over wide range of a heating period, variation in transmittance intensity is minimum for sunflower oil and maximum for palm oil. The oxidation of Sunflower oil is more in term of intensity ($0.06 x10^4$ a. u.), as compared to both Ground nut oil ($0.11 x10^4$ a.u) and Palm oil ($0.17 x10^4$ a.u). Similarly, Fig.4 (b) shows that, variation in reflectance intensity with respective heating time is maximum for sunflower oil and minimum for palm oil. The oxidation of Sunflower oil is more (70 a.u.), as compared to both Ground nut oil (20 a.u.) and Palm oil (10 a.u.) oils. This can be verified and confirmed from the photographs (not shown) of both unexposed (fresh) and exposed (moisture reactive) oils that the deterioration of sunflower oil is more by completely opposite change in the colour. However, it is less in case of both ground nut and palm oil. This indicates that the moisture react more with sunflower oil as compared to the Ground nut and Palm oil. In a quantitative analysis of the optical spectra of oil samples, one can address the applicability of various size-dependent corrections to the optical properties derived from unexposed oil samples. These include the effects of surface scattering (mean-free path correction), surfactant effects on the core electron density, and quantum size effects. In addition, one may obtain a quantitative way to provide molecular information independent of mass, by XRD, or FTIR analysis. In general, solutions to Maxwell's equations for this geometry yield an expression for the absorption cross section, which is a sum over electric and magnetic multipoles (spherical vector harmonics and Legendre polynomials). When the size of a particle is much smaller than the wavelength of the exciting radiation, the absorption is dominated by the dipole term. Auto-oxidation of oils and the decomposition of hydroperoxides increase as the temperature increases. The formation of auto-oxidation products during the induction period is slow at low temperature. The concentration of the hydroperoxides increases until the advanced stages of oxidation. The content of polymerized compounds increases significantly at the end of the induction period of auto-oxidation (Marquez-Ruiz and others 1997). It indicates that the effect of moisture and temperature on edible oil may change the molecular structure of the edible oil and may cause the change in absorption coefficient and dielectric constant.

4. Conclusions

It is concluded that:

(1) The variation of absorption coefficient of oil sample over wide range of wavelength which is observed to be minimum for sunflower oil, and maximum for palm oil.

(2) The intensity of transmitted light variation is also minimum for sunflower and maximum for palm oil.

(3) Over a range of a heating period in variation in transmittance intensity is minimum for sunflower oil and maximum for palm oil.The oxidation of Sunflower oil varies more ($0.06\text{x}10^4$ a.u), as compared to both Ground nut oil ($0.11\ \text{x}10^4$ a.u) and Palm oil ($0.17\ \text{x}10^4$ a.u).

(4) Over a range of a heating period variation in reflectance intensity is maximum for sunflower oil and minimum for palm oil. The oxidation of Sunflower oil is more (70a.u.), as compared to both Ground nut oil (20 a.u.) and Palm oil (10 a.u.) oils.

Thus, the most important application of the present method is to verify the quality of edible oil under oxidative Deterioration and heating conditions, to control the adulteration factor and to have the hygienic stability of the oil.

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