Optical interaction at the boundary layer of Oil-Water-Saltwater

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***Abstract*: The purpose optical properties (transmittance, absorbance, and reflectance) of solidified cubes of water, soybean oil, and saltwater, single and layer wise studies experimentally for water, soybean oil and saltwater. The transmittance properties decrease with an increase in wavelength however the absorbance and reflectance values increase with the increase in wavelength. The salt and water have a maximum transmittance value of 100 at the wavelength of 454.5nm and 553.2nm respectively. The authors found the absorbance deep values of oil, water, and saltwater are 0.166 a.u., 0.173 a.u., and 0.211 a.u. at the same wavelength of 634.6nm and Water- Soybean Oil-Saltwater, Soybean Oil- Water –Saltwater, and Saltwater-Water-Soybean oil are 0.218 a.u., 0.208 a.u., and 0.158 a.u. at the wavelength of 363nm. Whereas the reflectance deep values of oil, water, saltwater, Water- Soybean Oil-Saltwater, Soybean Oil-Water –Saltwater, and Saltwater-Water- Soybean oil are -7.981%, -7.925%, -7.695%, -7.679%, -7.735%, and -8.022% are to be found respectively at the same wavelength of 636nm. The result also shows the transmittance of saltwater and soybean oil are depend on transmittance of water which means water, saltwater and soybean oil a strong correlation in statistical term.**

***Keywords*: Absorbance, Transmittance, reflectance, water, saltwater, soybean oil, wavelength etc.**

I. INTRODUCTION

Water is transparent to electromagnetic radiation wavelengths that are within the visible spectrum, but opaque to wavelengths above and below this band. However, visible light is refracted and attenuated once it enters the water. The intensity of accessible solar radiation decreases with depth due to a combination of water molecules, dissolved salts, organic compounds, and suspended particles. The intensity of solar radiation decreases with depth, however the wavelengths contained in the solar spectrum are not attenuated at the same rates, according to observations of light attenuation in ocean waters. Due to their biological qualities, edible oils are complex combinations of organic chemicals of enormous commercial relevance in the food, pharmaceutical, perfume, and cosmetic sectors. Some optical properties of edible oils used in Sudan oil were investigated using UV-VIS spectroscopy (190-1100) nm without flip, which demonstrates that transmittance increases with increasing visible light wavelength [1]. In the spectral range from 500 to 1100 nm, the index of absorption of all brands of nine edible oils decreased as the temperature increased. The characteristic of overtones and combinations of CH stretching vibration of distinct chemical groups are related to the absorption peaks of all analyzed edible oils [2].

When light flows through pure water and seawater in an optical path of 25 cm to 100 cm, the intensity change is on the order of 10^{-4} to 10^{-3}, according to Lee et al. [3]. Around 410–420 nm, the total absorption coefficient exhibits a flat minimum, roughly double that of pure water. At 310 nm, the overall absorption coefficient could be half of what is commonly accepted for pure water [4]. The reflectance of the rocks or the microbial mats growing on the rocks beneath the water, as well as optical absorption and scattering in the water, are the key wavelength-dependent characteristics that produce the widely variable pool hues. The nature of the absorbance coefficient determined by Shaw demonstrates that it increases with light wavelength [5].

When the wavelength is chosen where reflectance equals reflectance at the red chlorophyll an absorption peak, chlorophyll a retrieval becomes completely insensitive to spectrally flat reflectance errors, which are typical of imperfect atmospheric correction, and is completely decoupled from backscatter retrieval [6]. The absorbance of extra virgin olive oil and virgin avocado oil decreases with wavelength with various bumps, as observed by transmittance and absorbance measurements [7]. Because the interaction of light with molecules is one of the most fascinating aspects of materials and has a wide range of applications as well as an active research field, the authors of this paper investigate the absorbance, transmittance, and reflectance at the medium/materials' boundary and inside the medium/materials of soybean oil, drinking water, and saltwater. Because impurities, as well as molecular rotation and vibration, are determined by transmittance and absorbance. As a result, the authors of this paper attempted to investigate how visible photons interact with water, saltwater, and soybean oil molecules.

II. LITERATURE REVIEW

The extinction coefficient is a measurement of a substance's ability to absorb light at a certain wavelength per unit of mass density. It is possible to discern between particle and dissolved matter extinction by examining the extinction coefficient of unfiltered and Berkefeld-filtered samples of sea water. The transparency of the sea can be utilized to identify a water mass, and particle absorption, like yellow material absorption, has a selective effect on the transmitted light [8]. The broadband UV absorption cross section of KCl vapor published by Leffler et al. was used to construct the absorption cross-section curves of NaCl, NaOH, and KOH, as well as the accompanying observed spectrally resolved absorbance spectra (2017). When the temperature varied between 1200 K and 1850 K, there were no noticeable variations in the spectrum structures of the absorption cross-sections, with the exception of NaOH at around 320 nm [9].

Although Raman spectroscopy is used to investigate oil optical characteristics, it is limited by its modest scattering cross-section. To advertise it as an alternative and simple instrument for investigating thermally stressed edible oils, it must be linked to a quantitative measure and then calibrated. Thermal deterioration of edible oils can be evaluated utilizing a new quantification platform that is independent of optical transmission and Iodine value measurements, according to the associated data [10]. The Cauchy equation was used to calculate the dispersion characteristics of a variety of edible oils. The current technology, which uses a twofold light path transmission mechanism, is more precise and user-friendly. In addition, the Cauchy refractive index matrices of different oils show a significant difference [11].

The fundamental rotational and vibrational modes of the water molecule are related to the spectrum properties of light absorption by water in the visible to infrared spectral region, but electronic absorption plays a role only at shorter wavelengths. In the gaseous state, molecular rotation is unrestricted, resulting in a plethora of rotational-vibrational combinations and millions of absorption lines. These rotations are constrained in the liquid state by hydrogen bonding in the water molecule cluster. Combinations and harmonics of these fundamental vibration and libration modes cause spectral absorption patterns in liquid water at wavelengths outside of these fundamental vibration and libration modes. Although ion absorption in the spectral region is usually minor, temperature and ion concentration modify the amount of water molecules per volume via changing density and partial density, respectively, and hence change the absorption coefficient of water [12]. Quino et al. found that absorbing both pure and salt water reduced stiffness, yield stress, and hardness, but had only a little impact on the sensitivity of the reaction to the imposed strain rate and tensile ductility. The samples were immersed in pure distilled water at 50°C for rapid absorption, which is lower than epoxy [13].

Because water has no magnetic properties, the permeability can be assumed to be the same as the free space value at all frequencies. The conductivity of pure water ranges from $\sigma \sim 4 \times 10^{-6}$ Siemen m^{-1} ($4 \times 10^{-6}\ s^{-1}$) to $\sigma \sim 4.4$ Siemen m^{-1} for sea water at low frequencies. Seawater is a far greater conductor of electricity than pure water because of the ions formed by the dissolved salts. At most wavelengths, these ions have little effect on absorption. Sea water, on the other hand, has a substantially higher absorption at very long wavelengths than pure water due to its conductor characteristic [14]. Electromagnetic interference shielding for visual observation applications, such as windows used in military or aerospace, is crucial yet difficult to achieve due to the inability of traditional materials to achieve sufficient transparency and shielding at the same time. The observed optical transparency of both acrylic/salt water/acrylic and glass/salt water/glass structures was greater than 90% with essentially uniform light transmission, implying that optical observation was unaffected.

Salinity and absorbance correlations have previously been generated with varied degrees of linearity, but they have not been tested to saturation. The correlation between spectral observations and concentrations of NaCl and KCl in water can be extended up to the saturation point of both salts, allowing for the differentiation of solutions of these salts with unknown concentrations. With an average inaccuracy of 0.9 percent, these correlations were able to accurately identify the solution type for all solutions in the test set and estimate their concentrations. Absorption in the mid-infrared band of the light spectrum is caused by stretching and bending vibrations between water hydrogen and oxygen. The concentration of water lowers when NaCl and KCl are added to it, causing the volume of water molecules to decrease. As a result, visible light absorption bands are diminished, as are absorption harmonics in the near infrared. This helps to explain why light transmission through a salt water sample improves in specific wavebands when salt concentration rises [15].

The following basic connection defines the transmission of light through media: $T = 1 - A - R$. The transmission, absorption, and refection coefcients are T, A, and R, respectively. A salt-water layer with thickness (t_{sw}) is sandwiched between two identical transparent substrate layers with thickness (t_{sub}) in the multilayer structure. The absorption of light in each layer can be calculated using Beer-law, Lambert's which is A_s = t, where t is the layer thickness and an is the absorption coefficient. $A = 2\alpha_{sub} t_{sub} + \alpha_{sw} t_{sw}$. can be used to calculate the overall absorption of light in a multilayer system. The absorption coefficients of the clear substrate and saltwater, respectively, are α_{sub} and α_{sw} [16].

III. INSTRUMENTATION AND METHODOLOGY

The Lambert-Beer law is based on the passage of a monochromatic parallel light beam that irradiates the tested substance's surface [17]. It is a device that detects the intensity of light. The basic sketch is shown in Figure 1.

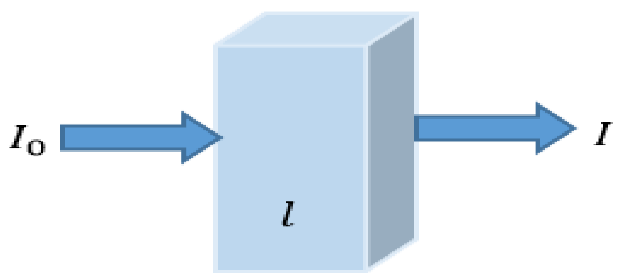

Figure 1: Schematic diagram of the Lambert-Beer law

Mathematical expression of the Lambert-Beer law is as follows:

$$A = \log\left(\frac{1}{T}\right) = Kal \qquad (1)$$

Where A is the absorbance, T is the transmittance, which is the ratio of the intensity of the outgoing light (I) to the intensity of the incident light (I_0); K is the molar absorption coefficient, which is related to the nature of the absorbing substance and the wavelength (λ) of the incident light; a is the absorbing substance concentration in mol/L; and l is the absorbing layer thickness in cm [18]. According to the rule of energy conservation, the reflectivity spectrum was estimated from the absorption and transmittance spectra [1].

$$R(\text{Reflectivity}) = -\sqrt{Texp(A)} \qquad (2)$$

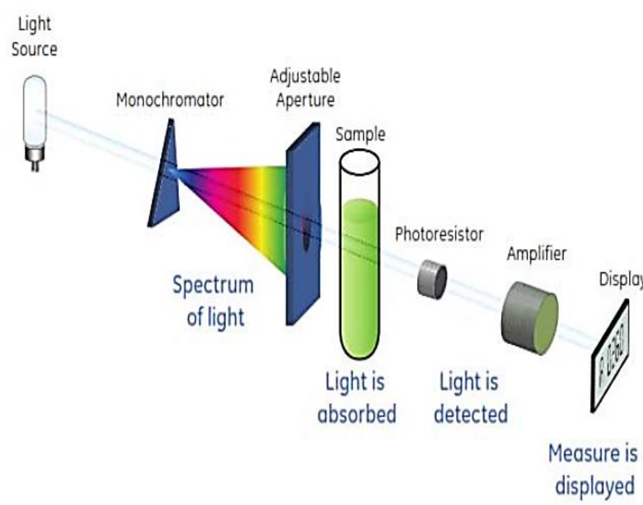

Figure 2: Experimental diagram of spectrophotometer to measure transmittance without cuvet calibration.

Sample preparation

First saltwater was prepared by adding 3gram of NaCl to 150ml of drinking water because authors only try to study the effect of salt in absorbance and compare its effect with water. For this research, we prepared three different pure solid cubes such as water, oil, and saltwater to study of transmission, absorption, and reflection properties. In addition, we also prepared a solid cube with three layers of different liquids (water=1.5cm, oil=0.5cm, and saltwater=2cm) by solidification of one by one such as water to soybean oil to saltwater, oil to water, and third is saltwater to water to soybean oil, to study the boundary transmittance properties. Example, soybean oil-saltwater-water cube is prepared by placing oil initially cube port and freeze it for 30 minutes after freezing the oil at -10 ^{o}C salt water is added on the surface of formed cube and leave for 30minutes again at -10 ^{o}C and solid cube of saltwater is also formed, finally the water is added to the surface of saltwater and leave for 30minutes to -10 ^{o}C. The formed cube at this temperature is test with the help of theremino spectrometer whose principle is based on figure 2.

IV. RESULT AND DISCUSSION

Comparison of transmittance properties of the soybean oil, water, and saltwater:

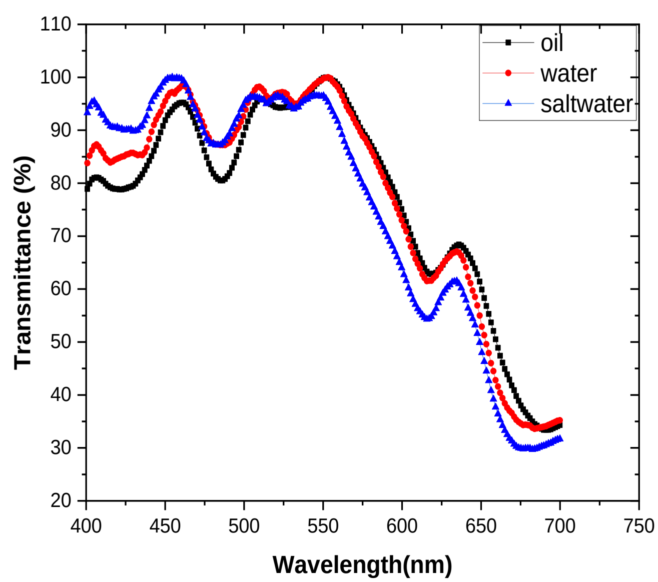

Figure 3: Transmittance properties of the soybean oil, water, and saltwater at room temperature.

The above figure 3 represents the variation of transmittance properties of the oil, water, and saltwater with the wavelength. The transmittance ranges from 20% to 100%. The different deep and bump is observed with wavelength. The oil, water, and saltwater have a deep (lower transmittance nearby wavelength) value of 62.9%, 61.6, and 54.4 at the same wavelength of 617.1nm, similar other bumps are observed above and below 617.1nm. The transmitted light shows almost the same pattern in the three medium oil, water, and saltwater solid cubes of thickness 0.5cm, 1.5cm and 2cm respectively. The thickness is consider different because of lack of experiment apparatus and difficulties to control the thickness of oil and water with smooth surface. The maximum transmission of the wavelength of 454.5nm and 553.2 of radiation on the saltwater and water cube respectively.

Transmittance properties at different boundary layer of oil, water and saltwater

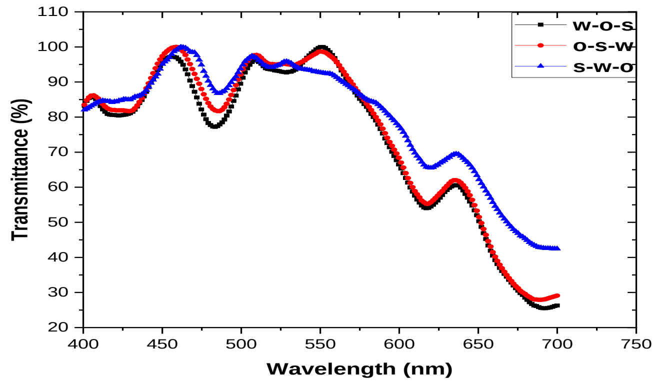

Figure 4: Transmittance properties at different boundary layer of oil, water and saltwater at room temperature.

The above figure 4 represents the variation of transmittance properties of water- soybean oil-saltwater, soybean oil-water-saltwater, and saltwater-water-soybean oil with the wavelength. The transmittance ranges from 20% to 100%. The transmittance of water-soybean oil-saltwater, soybean oil-water–saltwater, and saltwater-water-soybean oil have deep values of 54%, 55.3%, and 65.8% at the same wavelength of 617.1nm, similar other bumps are observed above and below 617.1nm. The transmitted light shows almost the same pattern in the three medium oil, water, and saltwater solid cubes. The maximum transmission of was observed at 551.8nm, 458.9nm, and 461.8nm on the water-soybean oil-saltwater, soybean oil-water–saltwater, and saltwater-water-soybean oil cubes respectively. The cubes formed with three different material oil, saltwater and water with thickness of 0.5cm, 1.5cm and 2cm respectively.

Comparison of absorbance light through properties of soybean oil, water, and saltwater

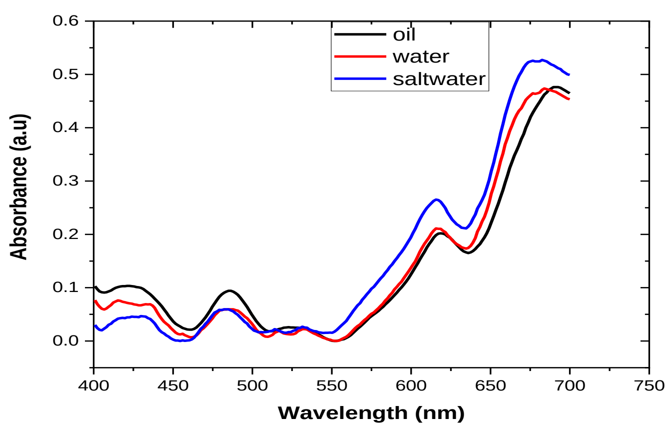

Figure 5: Absorbance properties of the soybean oil, water, and saltwater.

The above figure 5 represents the variation of absorbance properties of the oil, water, and saltwater with the wavelength. The absorbance of light ranges from 0 to 0.55a.u. The oil, water, and saltwater have 0.166 a.u., 0.173 a.u. and 0.211 a.u. deep values at the same wavelength of 634.6nm. In addition, different bumps with different value absorbance are also observed above and below the 634.6nm. The values of absorbance properties increase with the increase of wavelength. The saltwater has minimum absorption property low wavelength and high absorption at high wavelength while water absorbance lies between oil and saltwater.

Comparison of absorbance at different boundary layer of oil, water and saltwater

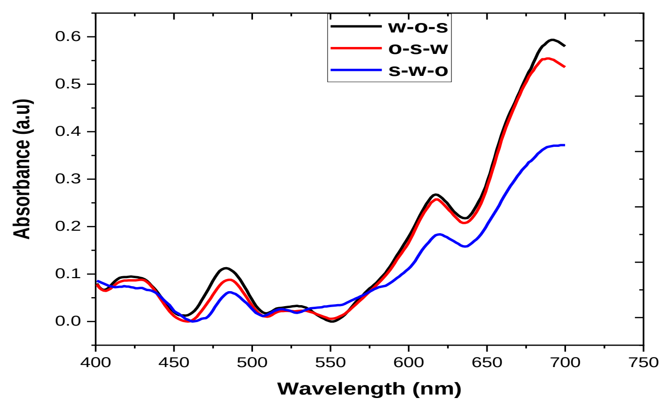

Figure 6: Absorbance properties at different boundary layer of oil, water and saltwater.

The above figure 6 represents the variation of absorbance properties of water-soybean oil-saltwater, soybean oil-water–saltwater, and saltwater-water-soybean oil with the wavelength. The absorbance of light ranges from 0 to 0.60. The water-soybean oil-saltwater, soybean oil- water–saltwater, and saltwater-water-soybean oil have deep values of 0.218 a.u., 0.208 a.u., and 0.158 a.u. at the same wavelength of 636nm. In addition, different bumps are observed above and below the 636nm. The values of absorbance properties increase with the increase of wavelength. The cube crystal with saltwater-water-soybean has low absorption than other consider crystal layer.

Comparison of reflectance properties of Soybean oil, Water, and Saltwater:

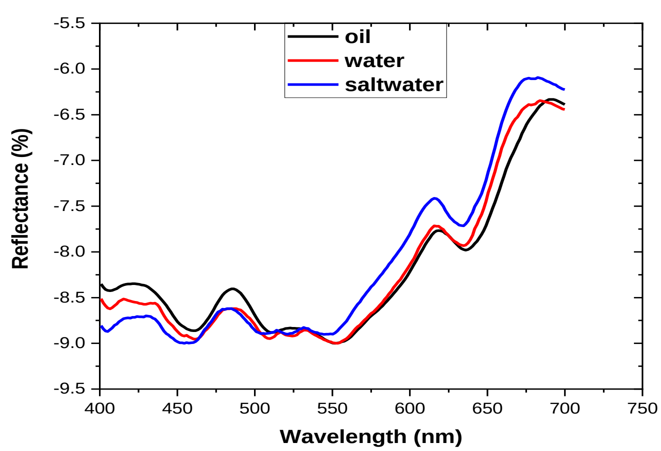

Figure 7: Reflectance properties of the Soybean oil, Water, and Saltwater.

The above figure 7 represents the variation of reflectance properties of the oil, water, and saltwater with the wavelength.

The reflectance ranges from -9.5% to -5.5%. The oil, water, and saltwater have -7.981%, -7.925%, and -7.695% of deep values at the wavelength of 636nm. In addition, the reflectance bumps are also observed above and below 636nm. The values of reflectance properties increase with the increase of wavelength.

Comparison of reflectance properties at different boundary layer of oil, water and saltwater

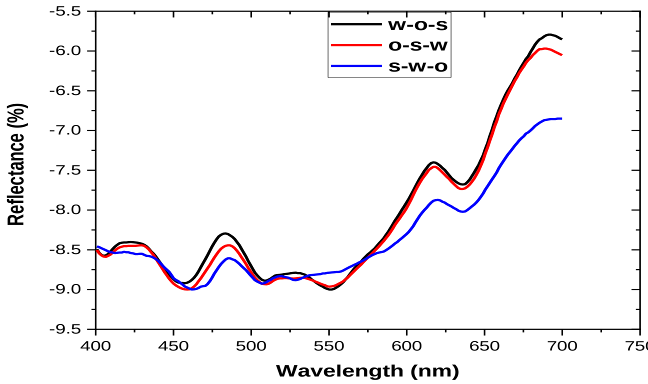

Figure 8: Reflectance properties at boundary of water, soybean oil and saltwater.

The above figure 8 represents the variation of reflectance properties of water-soybean oil-saltwater, soybean oil-water–saltwater, and saltwater-water-soybean oil with the wavelength. The reflectance ranges from -9.5% to -5.5%. The water-soybean oil-saltwater, soybean oil- water–saltwater, and saltwater-water-soybean oil has -7.679%, -7.735%, and -8.022% of deep values at the same wavelength of 636nm. In addition, the reflectance bumps are also observed above and below 636nm. The reflectance increase with the increase of wavelength. The water-soybean oil-saltwater has low absorption at a low wavelength and high absorption at a high wavelength.

Cross-correlation of transmittance of water with saltwater and soybean oil

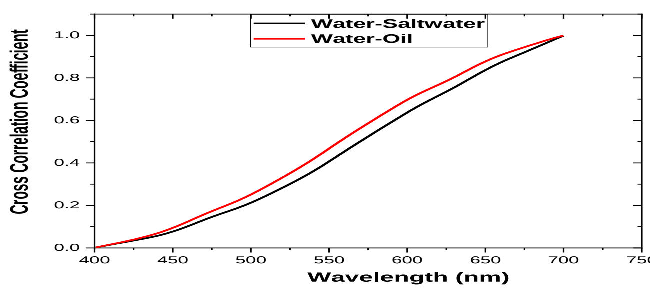

Figure 9: Cross-Correlation of transmittance properties of water with salt water and oil.

The above figure 9 represents the correlation of water with salt water and oil respectively. The above figure shows a strong correlation of +1 at the wavelength of 700nm i.e. there is a strong correlation between water and saltwater/oil. Authors limit the study of refractive index of consider samples in this work. The cross correlation is study to know the dependence of one layer to another layer of consider samples.

Cross-Correlation of transmittance at different boundary layer of oil, water and saltwater

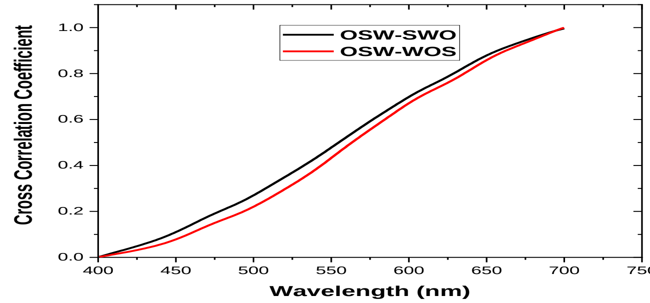

Figure 10: Cross-Correlation of transmittance at boundary layer of oil, water and saltwater.

The above figure 10 represents the correlation of soybean oil-saltwater-water with saltwater-water-soybean oil and water-soybean oil-saltwater respectively. The above figure shows a strong correlation of +1 at the wavelength of 700nm i.e. there is a strong correlation between the soybean oil-saltwater-water and saltwater-water-soybean oil/water-soybean oil-saltwater.

V. CONCLUSION

The transmittance properties are maximum of saltwater and water at the wavelength of 454.5nm and 553.2nm. The water-soybean oil-saltwater, soybean oil-water–saltwater, and saltwater-water-soybean oil all the solid cubes show a maximum transmittance at different wavelengths 551.8nm, 458.9nm, and 461.8nm. The transmittance properties of the solid cubes are decreasing with increasing the wavelength. The oil, water, and saltwater have a 0.166 a.u, 0.173 a.u, and 0.211 a.u deep values at the same wavelength of 634.6nm whereas Water- soybean oil-saltwater, soybean oil-water–saltwater, and saltwater-water-soybean oil have deep values of 0.218 a.u, 0.208 a.u, and 0.158 a.u at the same wavelength of 363nm. The oil, water, and saltwater have -7.981%, -7.925%, and -7.695% whereas water-soybean oil-saltwater, soybean oil-water–saltwater, and saltwater-water-soybean oil has -7.679%, -7.735%, and -8.022% of deep values at the same wavelength of 636nm. The strong cross correlation is found between the transmittance of water to transmittance properties of saltwater and oil and also same strong correlation is found between Soybean oil-Saltwater-water to the saltwater-water-soybean oil and water-soybean oil-saltwater.

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