Qualitative Assessment of Cooking Oil using Diffuse Reflectance Spectroscopy Technique

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***Abstract*— In this study, reflection spectroscopy technique has been used in determining the oil quality. Conventional methods such as chemical testing consumes some costs and time and not accurate enough. The samples used were bottled palm cooking oil, subsidized cooking oil, and recycled cooking oil from different brands and collected area. Two different sample condition were applied which is different type of cooking oil and different concentration of recycle cooking oil mixture that were used for analysis and their reflection spectrum were measure at 200 nm – 900 nm. The computer simulation was used to process the data based on their pattern recognition. From the analysis, it is found that reflection spectrum is influenced by concentration of foreign compound in the cooking oil sample. This indicate the reflection spectroscopy technique can be used to detect the present of foreign compound in the palm cooking oil, thus providing the difference of quality assessment of cooking oil.**

Keywords—palm oil, reflectance, spectroscopy

I. INTRODUCTION

Malaysia is one of the world's major exporters of palm oil. Quantitative analysis results show that 90 percent of consumers choose palm oil as cooking oil based on factors such as popular brand, nutrition and quality content [1]. This finding shows that many consumers in Malaysia prefer to use palm oil in food preparation. In addition to that, Ministry of Domestic Trade and Consumer Affairs had created subsidized cooking oil to promote Malaysia's palm oil usage [1].

Recycled cooking oils are cooking oils that have been used and in the process of being resold to consumers. The Malaysian Islamic Consumer Association (PPIM) has detected more than 90 percent of restaurants and food premises in Malaysia using recycled packaged cooking oils in foods that can cause various diseases including cancer [2]. It affects on human health, therefore this matter should be resolved.

Fig. 1 shows three types of cooking oil which is bottled palm cooking oil, subsidized cooking oil and recycled cooking oil which were used as samples in this project. The similar colour for this three types of cooking oil becomes an issue when it does not guarantee the purity of cooking oil. The current issue that occur when companies that produce recycle oil will collect waste oil from restaurants or sewer and conduct refineries and colour bleaching to make it look like new oils.

Fig. 1. Bottled palm cooking oil, subsidized cooking oil and recycled cooking oil

It is not easy to distinguish between original cooking oil and recycle cooking oil. Recycled cooking oil is not the same as the original cooking oil in term of nutrition content, heating temperature, chemical structure and more. Furthermore, recycled cooking oils will be packaged in new packages to be delivered to customers since subsidized palm cooking oil is limited to plastic packaged only with the latest subsidy adjustment. There are also oil companies which mix the recycled oil in subsidized oil to gain more profits. This will cause confusion among customer with the purity of subsidized cooking oil.

The quality of cooking oil can be determined by the presence of foreign compound. Common harmful foreign compound that present in waste cooking oil is peroxide compound and acid compound. Peroxide compound has chemical reaction when the oil reacts with hydrogen by repeated heating. Lower number of peroxide value indicates good quality of oil and a good preservation status. The European Union has set standards for testing the foreign compound contained in cooking oil should be maximum at the level of 25% [2]. If the level exceed 25%, it is not suitable to be used.

There are several methods that can be used in determining the quality of cooking oil such as using a conventional method and chemical test. A simple way to identify recycled cooking oil is by letting the cooking oil in the refrigerator for two hours. If it has foaming, it is recycled cooking oil. However, this method does not use a scientific method that makes it unable to determine the real percentage of foreign compound. Thus, this method is not accurate enough. Another method is to send a sample of cooking oil to a laboratory to carry out an investigation. This laboratory system need much time consuming and can be very costly.

In recent years, the spectroscopy technique provides an alternative to the old methods and they have increased in importance in validating the quality of cooking oil. In this respect, a lot of methods have been proposed based on Near-Infrared spectroscopy [3], Ultraviolet and Visible Light Spectroscopy [4-6], Fluorescence spectroscopy [7], Ionization mass spectroscopy [1],[8],[9], and Fourier Transform near infrared Spectroscopy [10-12].These spectroscopic methods now have the potential to replace or at least complement the old methods. Conventional methods such as chemical testing in the laboratory may consume some weeks to produce the analysis and results which is not only time consuming but also quite expensive to test for each sample [7].

Among these spectroscopy technique, ultraviolet and visible light (UV-VIS) spectroscopy has desirable advantage and is suitable for analysis the cooking oil quality such as analysis time, high sensitivity to liquid, easier to handle and user friendly compare to other technique. In addition, few reports have been recorded on simulation of reflective spectroscopy used as a technique for monitoring the quality of palm cooking oil. A cheaper test which is foaming test that can be done at home do not use a scientific method that can't determine the real percentage of the foreign compound such as chemical test. So this method actually not accurate enough. Another way is to send a sample of cooking oil to a laboratory to carry out an investigation.

This work involves determination of the quality of cooking oil based on spectroscopy technique by comparing the reflectance spectrum of bottle palm cooking oil, subsidized cooking oil and recycled cooking oil. Then, the presence of foreign compound of cooking oil at wavelength 350 nm – 600 nm is estimated. This method may provide quick and easy method to test for oil quality in the industry and can prevent the used of contaminated oil among the society that may affect their health.

II. Methodology

A. Sensor Probe using Polymer Optical Fiber

Polymer optical fiber probes were optimized for measuring diffuse and specular reflectance, colour, fluorescence, and backscattering of solid, liquid, and powder samples. This work will focus on reflection spectrum from a liquid. The probe used have separated fibre cables with a leg to carry light from a source to a sample and a leg to carry light reflected by the sample to a spectrometer. Each bundle uses 200 μm core multimode fibre bundles with either a high hydroxyl ion (OH) content are for use in the 200 nm - 1200 nm range, respectively.

One cable receives signal from the light source and another cable is connected to the spectrometer to get reflection spectrum measurement. Reflection probes consist of six bundle light source leg and a single read-out fibre. This probe sample legs are available with two different configurations that is ideal for maximizing light delivered to the sample and are suitable for general applications. Single read-out fibre reflection probe is multi-purpose function and for this project to gather the optical reflected signal from the oil sample.

Beside, this probe is intended for samples that are sensitive to light exposure or heating [13] caused by absorption. Fig. 2. shows the cross-section of the separate fibre cable leg of Fiber Bundle Probe.

Fig. 2. Cross section of the separate fibre cable leg of Fibre Bundle Probe.

B. Sample Preparation

The preparation of the sample has been divided into two groups. First group is a sample from different type of cooking oil which is bottled palm cooking oil, subsidized cooking oil and recycled cooking oil. Second group is a sample with different concentration of recycle cooking oil mixture. Five different brand of bottle palm cooking oil and subsidized cooking oil samples will be used in this work. That sample are purchased as commercial product from a local market in Malaysia. Next, recycle cooking oil sample collected from five different restaurants.

Second group sample consists of different concentration of recycle cooking oil mixture. The 100 ml bottle palm cooking oil is mixed with 25 ml, 50 ml and 75 ml of recycle cooking oil using stirred machine in a laboratory show in Fig. 3. Five samples in second group have been prepared which has concentration of 0%, 25%, 50%, 75% and 100% of recycled cooking oil mixture. Each mixing process is fixed at rotational speed of 18 RPM (rotation per minute) with a time of 10 minutes.

Fig. 3. Stirred the cooking oil sample

The temperature of cooking oil has an important influence on the radiation it reflects and absorbs. Thus, the last phase in sample preparation is by testing all the sample with thermometer to make sure the oil sample in room temperature is fixed at 24°C.

C. Experimental Setup

Fig. 4 shows the experimental setup in this project. Basically, there are four main elements for the measurement of the reflection of light spectrum in the sample which are light source, reflection probe, spectrometer and analysis for data acquisition. Fiber optic is additional elements as light source connectors and spectrometers. Next is the petri dish that was used to place the sample.

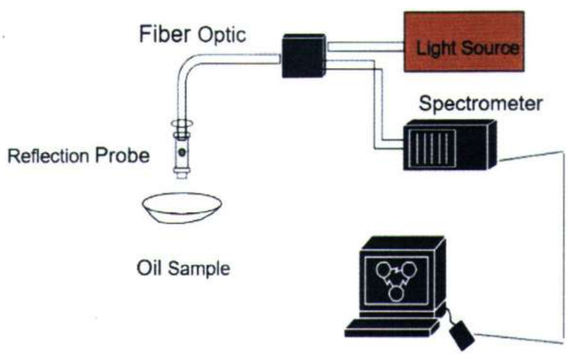

Fig. 4. Experimental Configuration

The light source will transmit the UV-VIS spectrum to the reflection probe through the fiber optic medium. In this study, the light source used is DH-2000-BAL which is a balanced light source that was produced from the halogen and deuterium produced by OceanOptic. This source of light uses innovative filtration technology to produce a smooth spectrum across the entire range of the spectrum.

The light then will propagate to the oil sample and the reflection spectrum will absorb back to the reflection probe [14]. This probe consists of a six bundle light source leg and a single read-out fiber to gather the optical reflected signal from the sample oil. The collected spectrum are going to be measured with spectrometer when it assess and analyze the characteristic of the oil samples employing a computer. The spectral suite is a spectrometer data software used to process data through the computer and the results are reproducible.

HR4000CG-UV-NIR spectrometer uses a gradient that can be altered and reproducible. This grating has been specially designed to deliver a complete spectrum output across the wavelength range of 200 nm - 1100 nm, with maximum efficiency between 200 nm -1050 nm. Next, SpectraSuite is a spectrometer data software used to process data.

III. Measurement Process

A. Data Collection

Two major experiments were conducted. First, comparing the reflection spectrum from the 15 samples different type of cooking oils. Next, comparing the reflection spectrum from 5 samples the different concentration of recycling cooking oil mixture.

The spectrometer is placed in a stable and locked state using a screw to ensure a fixed position to prevent any vibration that may cause grating to shift and consequently resulting in the error in the light spectrum reading as shown in Fig. 5. Percentage of reflection is measured as the ratio of light reflected from a sample to the reflection probe. When measuring the specular reflectance, it is commonly expressed in a percentage scale (%R). Reflection probe holder uses to fix the reflection light angle and allowing to the measurement of specular like mirror angle.

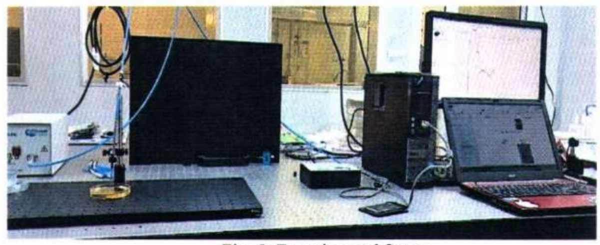

Fig. 5. Experimental Setup

Reflection probe set is placed 90° on the oil sample with a distance of 1cm from the sample as shown in Fig. 6.

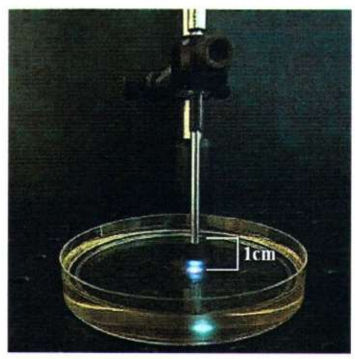

Fig. 6. Distance of reflection probe from sample is 1cm

B. Regression Analysis

Regression analysis is a very useful statistical technique that will be used to analyze the results obtained in this work. Regression analysis can be used to build a model to predict the precise of data. For correlation coefficient, R^2 can be used to determine the precise or of in the straight line. When the $R^2 = +1$ shows the true positive corollary, so the value is exactly on the straight line. In practice, calibration graph often gives R^2 values less than 0.99, and R^2 appreciates the value of less than normal which is 0.90. The typical example of calculation R^2 may describes some significant information that will utilized in this work.

IV. Results and Analysis

Reflectance is the return of radiation by a surface, without a change in wavelength λ. Hence, the reflection percentage R_λ is calculated based on the expression shown in equation (1) below:

$$R_\lambda = \frac{S_\lambda - D_\lambda}{Rf_\lambda - D_\lambda} \times 100\% \quad (1)$$

Where S_λ, D_λ and Rf_λ is the sample, dark and reference intensity at wavelength λ, respectively. Several cooking oil from each bottle palm cooking oil, subsidized cooking oil and recycle cooking oil were examined to determine the fundamental optical properties of different concentration of foreign compound.

A. Different Spectrum of Cooking Oil

The spectrum measurement from the five samples of bottled palm cooking oil were depicted as in Fig. 7. Based on the trend, there were two prominent wavelength peaks show in the graph; approximately around 468 nm and 505 nm. The maximum peak not over than 120 (a.u). Others reflectance peaks are lower and consistent.

Fig. 8 shows the measurement spectrum of the five sample of subsidized cooking oil. The trend was similar to Fig. 7 which is two prominent peaks were observed for Sample 1, Sample 2 and Sample 3. The peak is less than 120 (a.u). While, for sample 4 and sample 5 the prominent peak is more than 120 (a.u).

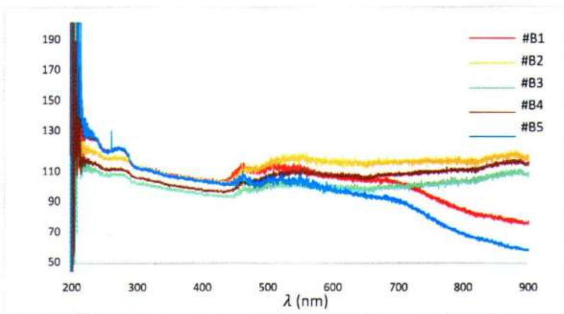

Fig. 7. Result of reflectance spectrum of bottle palm cooking oil

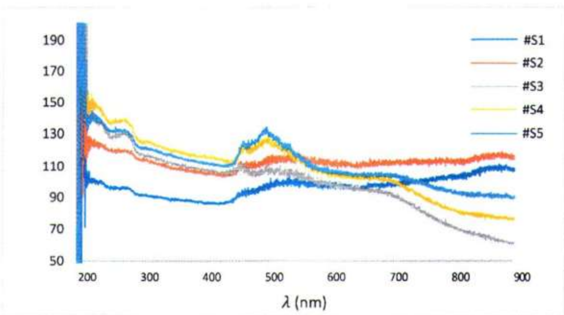

Fig. 8. Result of reflectance spectrum of subsidized cooking oil

Fig. 9 shows the spectrum measurement of the sample of recycle cooking oil. The trend was similar to Fig. 7 and Fig. 8, which they have two prominent peaks observed for each sample, but shows difference spectrum trend of sample 3 and sample 4 which it has one more-high peak extra at 740 nm.

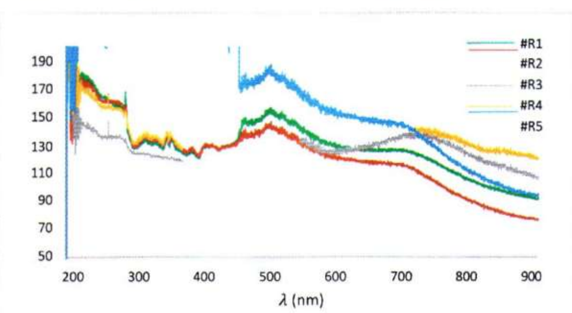

Fig. 9. Average reflectance spectrum of recycle cooking oil

In contrary, for the recycle cooking oil, the trend shows that the peak has more reflectance intensity as compared to Fig. 7 and Fig. 8. Average reflectance peak intensity for recycle cooking oil not less than 130 nm at two prominent peak.

To examine the trend of different type of cooking oil, the average result of each cooking oil was normalized and plotted as shown in Fig. 10. Clearly, there were distinct trend between the bottle palm cooking oil, subsidized cooking oil, and recycle cooking oil. For recycle cooking oil has two clear prominent peak at wavelength 468 nm and 505 nm. While for bottled palm cooking oil and subsidized cooking oil the trend of graph is quite flat and the peak at wavelength 468 nm and 505 nm is not quite prominent but still can be observed.

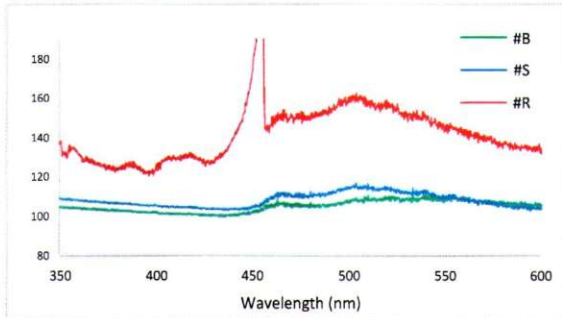

Fig. 10. Average result of the reflectance spectrum of oil sample

The reflectance data shows that bottle palm cooking oil and subsidized cooking oil displays low reflectance characteristic as compared to recycle cooking oil with higher reflectance spectrum. The reflectance characteristics at wavelength 350 nm until 600 nm can be related to peroxide value concentration. This mean that the prominent peak at wavelength 468 nm and 505 nm can be defined as reference point to determine the foreign compound which is peroxide value.

As for the recycled cooking oil, it is expected that the peroxide value is higher because the oil via recycling process require refineries and color bleaching to make it like new oil. But the foreign compound in the recycle cooking oil still present and thus giving reflectance values at wavelength 468 nm and 505 nm becomes higher. Besides, for sample 4 and sample 5 subsidized cooking oil from Fig. 8, the prominent peak is over than 120 (a.u) probability to have the present of peroxide value in the oil sample. While expecting these two cooking oils to have a mixture of recycle cooking oil, it can be expected that the cooking oil has been kept long and unused. This is because the presence of peroxide value is also due to excessive oil storage in inappropriate conditions. A lower number of peroxide value indicates a good quality of oil and a good preservation status.

B. Spectrum of Oil Mixture

Fig. 11 shows the spectrum measurement from the 5 samples of recycled cooking oil mixture. The trend of the graph is similar for each sample but different in the reflectance intensity.

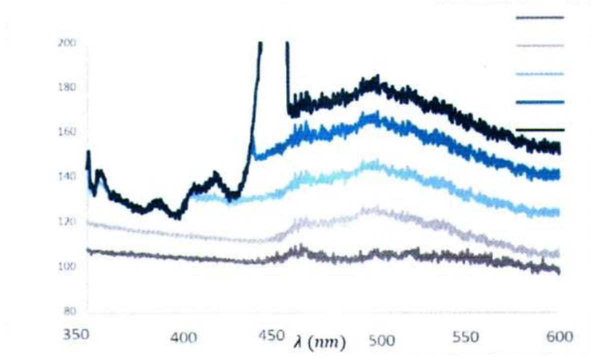

Fig. 11 Spectrum measurement from difference concentration for oil mixture.

An examination of Fig. 11 shows that the reflectance of the sample is strongly related to the present of foreign compound concentration. Obviously, the optimal variation of reflection is monitored at 468 nm and 505 nm for comparison in this study. This two points are the reference point to analyze the present of foreign compound which contained peroxide value.

From Fig. 11, the trend of the graph shown for sample 1 which is from the brand-new cooking oil and did not have mixture with any recycle cooking oil. As the result, the reflectance spectrum of the sample 1 is linearly below 120 a.u. For sample 2, sample 3 and sample 4 the reflectance spectrum increase slightly because the sample have detect the mixture of 25%, 50%, and 75% of recycle cooking oil for each sample. Next for sample 5 the reflectance spectrum is the higher because the sample use totally recycle cooking oil. The reflection spectrum is proportional to increasing concentration of recycle cooking oil mixture.

Fig.12 and Fig.13 show the calibration curve in the form of scattering plotted graph. The graph of concentration recycled cooking oil mixture against reflection (%) at peak wavelength 468 nm and 505 nm, together with the linear regression line and its correlation coefficient.

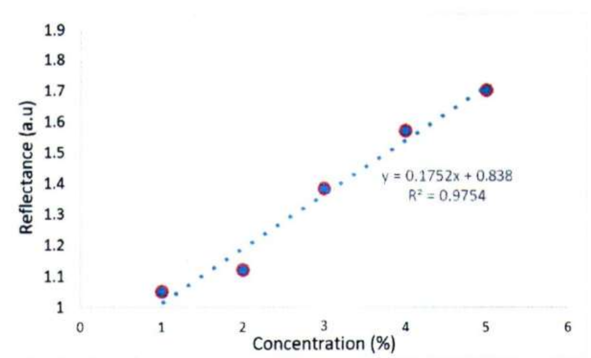

Fig. 12 Average reflectance at wavelength 468 nm

Table I shows the peak wavelength of 505 nm is suitable to analyze the reflectance spectrum than wavelength 468 nm because the correlation coefficient is more approaching +1. It can be said that the reflection spectroscopy technique used in this experiment almost obey the reflectance is linearly related to the concentration with small deviation.

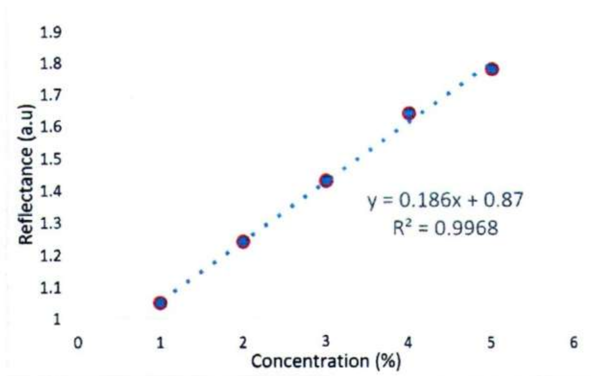

Fig. 13 Average reflectance at wavelength 505 nm

TABLE I. REGRESSION EQUATION FOR WAVELENGTH 468 nm AND 505 nm

Wavelength (nm)	468	505
Regression Equation (y=mx+b)	y= 0.1752x – 0.838	y= 0.188x –0.866
Correlation Coefficient	0.9754	0.9979
Intercept (a)	0.838	0.866
Slope (b)	0.1752	0.188

V. CONCLUSIONS

In Malaysia, the demand and usage of subsidized cooking oil is increasing in the community. There are confusion between the subsidized cooking oil and recycled cooking oil among consumers because of the packaging consumption and production attitude enhancers who mix recycle oil with subsidizes cooking oil. However, theregular assessment done by Kementerian Perdangan Dalam Negeri, Koperasi dan Kepenggunaan (KPDNKK) on subsidized palm cooking oil by using old technique and lab system to analyze the quality of palm cooking oil takes time and very costly. Therefore, besides using chemical analysis, the spectrum analysis also can implement in part of their standard procedure.

This work proposes the effective strategy to characterise the optical properties of the cooking oil. Conventional method such as chemical testing consumes costs and time, therefore, this presented method represents rapid and inexpensive test. From the result, the reflectance spectrum of recycled cooking oil is higher than bottled palm cooking oil and subsidized cooking oil causes by the present of foreign compound in oil sample fulfilling the first objective.

Besides that, the data can be utilized to estimate the quality of the cooking oil, based on the reflective spectroscopy technique to detect the present of peroxide value at wavelength 350 nm – 600 nm reach for second objective. Lastly, according to data analysis, it shows that the reflectance spectrum is directly proportional to concentration of foreign compound accomplished last objective in this study. Therefore, the objectives of this study have been achieved. Future works may include to adapt the method using portable, hand-held device that can ease the analysis of the quality of the samples.

REFERENCES

[1] Syazwany, I., Nasir, M., Rani, N. A., & Choy, E. A, "Malaysia Preference factors for palm oil consumption in Malaysia :An empirical study of Putrajaya consumers, Faktor pemilihan minyak sawit dalam kalangan pengguna : Kajian empirikal di Putrajaya," Society and Space, 8(8), 66–77, 2015.

[2] Minda. (n.d.). Open Minda. Retrieved from http://baca-blogspot.blogspot.com/2011/12/minyak- masak-plastikpaket-1-kg-mungkin.html

[3] Jinkui, M., Han, Z., Tomohiro, T., Yelian, M., & C, J. Y., "Rapid Determination of Degradation of Frying Oil Using Near-Infrared Spectroscopy," 20(2), 217–223, 2014. http://doi.org/10.3136/fstr.20.217

[4] Rashid, F. N. A., Maamor, H. N., Yusuf, N., Zakaria, N. Z. I., Ismail, S. W. M., Adnan, K. N. A. K., Shakaff, A. Y. M., "Aroma and optical absorption spectroscopy for quality assessment of vegetable cooking oils," 2nd International Conference on Electronic Design, ICED 2014, 339–342. http://doi.org/10.1109/ICED.2014.7015826

[5] Shi, J., Yuan, D., Hao, S., Wang, H., Luo, N., Liu, J., … Chen, Z., "Stimulated Brillouin scattering in combination with visible absorption spectroscopy for authentication of vegetable oils and detection of olive oil adulteration," Spectrochimica Acta - Part A: Molecular and Biomolecular Spectroscopy, 206, 320–327, 2019. http://doi.org/10.1016/j.saa.2018.08.031

[6] Kružlicová, D., Mocák, J. Á. N., Katsoyannos, E., & Lankmayr, E., "Classification and characterization of olive oils by UV-Vis absorption spectrometry and sensorial analysis", 47(4), 181–188, 2008.

[7] Albakri, N., Abdullah, S., Supian, L. S., Arsad, N., Zan, S. D., & Bakar, A. A., "Assessment of Palm Oil Fruit Bunch Maturity based on Diffuse Reflectance Spectroscopy Technique," ICP, 2–4, 2018.

[8] de Oliveira, I., Correa, W., Neves, P., Silva, P., Lescano, C., Michels, F.,Caires, A. , "Optical Analysis of the Oils Obtained from Acrocomia aculeata (Jacq.) Lodd: Mapping Absorption-Emission Profiles in an Induced Oxidation Process. Photonics," 4(1), 3, 2017. http://doi.org/10.3390/photonics4010003

[9] Ng, T., So, P., Zheng, B., & Yao, Z., "Analytica Chimica Acta Rapid screening of mixed edible oils and gutter oils by matrix-assisted laser desorption / ionization mass spectrometry," Analytica Chimica Acta, 884, 70–76, 2015. http://doi.org/10.1016/j.aca.2015.05.013

[10] Khaled, A. Y., Aziz, S. A., & Rokhani, F. Z., " Development and Evaluation of an Impedance Spectroscopy Sensor to Assess Cooking Oil Quality," International Journal of Environmental Science and Development, 5(3), 299–302, 2014. http://doi.org/10.7763/IJESD.2014.V5.496

[11] Shen, Y., Chen, S., & Du, R., "Rapid assessment of the quality of deep frying oils used by street vendors with Fourier transform infrared spectroscopy," (999), 336–342, 2014. http://doi.org/10.1007/s11694-014-9194-3

[12] Cayuela-Sánchez, J. A., & Palarea-Albaladejo, J., " Olive oil nutritional labeling by using Vis/NIR spectroscopy and compositional statistical methods," Innovative Food Science and Emerging Technologies, 0–1, 2018. http://doi.org/10.1016/j.ifset.2018.05.018

[13] XF, L., Ng CY, J. K. and M. M., "Effects of Repeated Heating of Cooking Oils on Antioxidant Content and Endothelial Function," Austin Journal of Pharmacology Ans Therapeutics, 3(2), 1–7, 2015. http://doi.org/10.1145/988772.98881

[14] Divin, Y., Lyatti, M., Poppe, U., Urban, K., & Pavlovskiy, V., "Josephson Spectroscopy for Identification of Liquids", 21(3), 311–314, 2011.