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Identification of Carbon Dots in Waste Cooking Oil

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Abstract. We found carbon dots (C-Dots) in waste cooking oil. The C-Dots were formed as a result of heating process. The heating process caused carbon chains in the waste oil were cut off and suffered rearrangements (polymerization) of carbon chains that accompanied with the process of carbonization. Luminescence of C-Dots was observed while C-Dots in waste oil were irradiated by UV light and the emission was radiated in the visible light area with yellow-greenish color. The heating process with different temperatures caused changes in the structure and the band gap energy. Structural changes were observed from the FTIR spectra where the intensity of functional groups C — OH, C — H and C = O on a degraded waste oil. While the band gap energy of C-Dots displaces due to thermal processes with different heating temperature. The band gap energy shifted from 0.5 to 2 eV at heating temperature of 300°C. This study showed that we found an alternative raw material for luminescence materials.

Introduction

The content of cooking oil such as unsaturated fatty acid has benefits for the human body as a source of fat. However, due to the heating process, the unsaturated fatty acids are easily damaged and they suffer structural changing to become saturated fatty acids that are harmful for the human body. The residue of the cooking oil that has been used for frying process (known as waste cooking oil) is very dangerous when used repeatedly. Repeatedly heated cooking oil causes the carbon double bonds in the unsaturated fatty acids are more and more disconnected and free radicals as a triggers cancer cells are formed [1]. In addition, the waste cooking oil that has been unused becomes liquid waste that could potentially pollute the environment.

The abundance of carbon-chain bonding in the waste cooking oil was estimated. Carbon dots materials (C-Dots) can therefore be formed by the process of polymerization and carbonization of the waste cooking oil. C-Dots with sizes in the order of nanometers have very good fluorescent properties (photoluminescence), non-toxic, and water soluble [2]. Various carbon sources have been studied to produce C-Dots with good luminescence properties such as from citric acid [3], soy milk [4], and orange juice [5]. Bonding of carbon chains suffers polymerization process, carbonization and formation of C-Dot particles with heating process at low temperatures [6,7]. Currently, C-Dots have a variety of potential use such as biological labeling, bioimaging, photocatalyst and optoelectronics devices [8].

The content of the carbon-chains bonding that are abundant in the waste cooking oil becomes one excellent potential as a base material for C-Dots. This study focused on identifying the formation of C-Dots in the waste cooking oil and it is expected to be one of the ways to tackle the problem of waste liquid and can be harnessed into other products.

Experimental

The investigation of C-Dots in the waste cooking oil was done by heating 20 mL of cooking oil at different temperatures, i.e. 100, 150, 200, 250, 300, and 350°C for 1 h. The heated cooking oil was then characterized by employing a UV-NIR spectrometer (Ocean Optics type USB 4000) to estimate the band gap energy. According to the Tauc plot method, the relationship between the absorption coefficient (σ) and the frequency (f) of light is given by Eq. (1), where h is the Planck constant. This equation is used to extract the band gap energy (E_g) of heated cooking oil.

$$\sigma(f) = A(hf - E_g)^2 \tag{1}$$

Structural changes of the carbon chains were observed by using a Fourier Transform Infra-Red (FTIR) spectrometer (Perkin Elmer FT-IR Spectrometer Frontier). The optical properties and the changes of the structure become a simple foundation to identify C-Dots in waste cooking oil.

Results and Discussion

Visual inspection of the heated cooking oil is shown in Figure 1. As the temperature increases, the color of heated cooking oil becomes darker. This is because the heating process caused the cooking oil suffered a series of processes of dehydration, oxidation, and polymerization, indicating a change in the structure of heated cooking oil. The heating process causes the process of dehydration where the hydroxyl groups (-OH) of glycerol drop out. In addition, the heating process causes the oxidation process where the carbon chains binding the oxygen from the environment to form a new structure. The process of breaking the chains of molecules and form a new arrangement is a polymerization process. The color change as shown in Fig. 1 was also observed in the thermal process to carbon sources of soy milk and orange juice in which C-Dots were obtained [4,5].

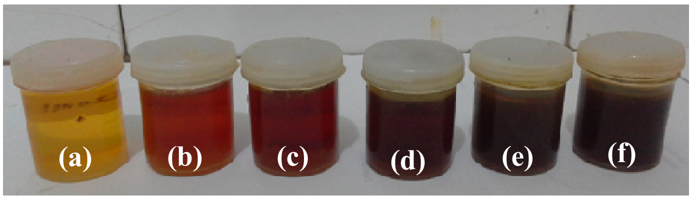

Figure 1. Different colors of heated cooking oil at a temperature of (a). 100°C, (b). 150°C, (c). 200°C, (d). 250°C, (e). 300°C, and d (f). 350°C for 1 h.

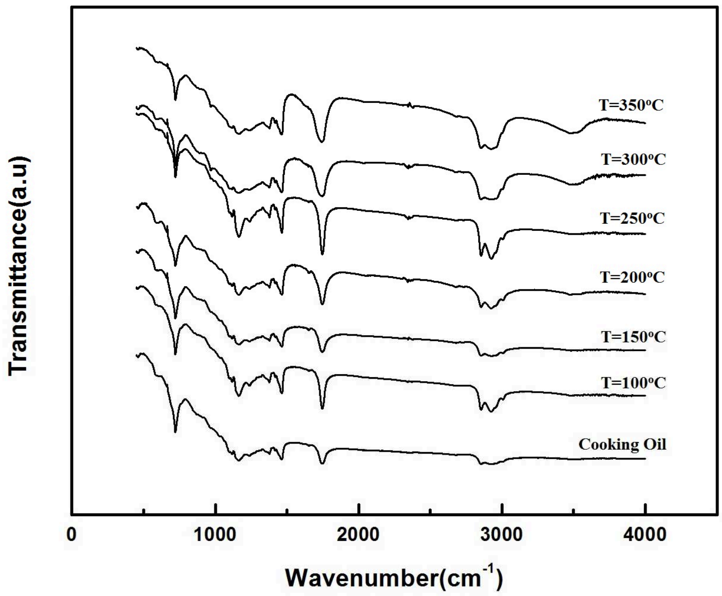

Figure 2. FTIR spectra of cooking oil heated at 100, 150, 200, 250, 300, and 350°C for 1 h.

The changes in the structure of the heated cooking oil were observed from the FTIR spectra as shown in Fig. 2. There are C-OH bending vibrations at 3504 cm^{-1}, C=C and C-H stretching vibrations at 2934.5 cm^{-1} and 2857.5 cm^{-1}, carbonyl groups (C=O) at 1748.5 cm^{-1}, N-H bending vibrations at 1470 cm^{-1}, and C-H bending vibrations at 1172 cm^{-1}. The similar results were obtained by many researchers. There was observed the existence of functional groups such as C-OH, C-H and C=O at C-Dots [4-6]. The thermal process causes the intensity of the functional groups such as C-H, C=C, C=O increases with the increasing temperature. These was due to the increasing number of functional groups which suffered rearrangements caused by the thermal process [6]. In simple term, the result of analysis of functional groups from the FTIR device showed the cooking oils that have been through the thermal process above have strongly indicates that there is a C-Dots on the waste cooking oil. However, these results are other supporting analysis is required to identify C-Dots on the waste cooking oil. The changes of functional groups were observed cannot be directly used to identify the existence of C-Dots. The changes of functional groups only indicates the existence of rearrangements which is a stage of the process in the manufacture of C-Dots [4, 5].

Estimation of the band gap energy of waste oil as a result of thermal processes at different temperatures is performed to identify the presence of C-Dots. The band gap energy of C-Dots shown in Figure 3. Table 1 shows that the band gap energy on waste oil as a result of the thermal process for 1 h at a temperatures of 100^{o}C, 150^{o}C, 200^{o}C and 250^{o}C have the same value, which is about ~2.7 eV. The changes of band gap energy were observed on the waste oil by the thermal process at temperatures of 300^{o}C and 350^{o}C, i.e. ~ 2.0 eV. In this condition, the thermal process causes changes in the structure and the optical properties from the waste cooking oil. The changes of band gap energy is expected as a result of change in the structure in which closely related to change in the dimensions of particle C-Dots are formed. The thermal process with high-temperatures cause the carbon chains of the cooking oils were suffered rearrangements in an amount very much. The particle size of C-Dots was estimated get greater with the incresing temperature on the thermal process. It is assumed from the band gap energy that descend. This result corresponds with which is obtained by many researchers, that the greater of particle size, will causes the band gap energy is getting smaller [7].

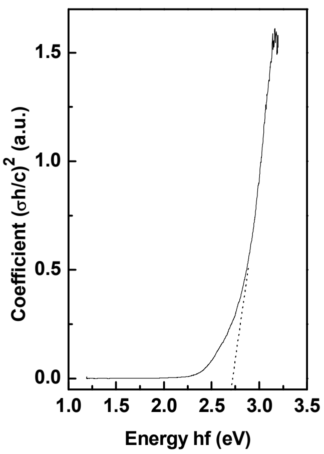

Figure 3. Absorption coefficient (σ) and the frequency (f) of light for cooking oil heated at 100^{o}C.

Table 1. Band gap energy of heated cooking oil for various temperatures

Temperature (^{o}C)	Band gap energy (eV)
100	2.75
150	2.70
200	2.73
250	2.73
300	2.00
350	2.00

The luminescence of C-Dots in waste cooking oil was simply observed with visible light which is produced when irradiated by UV light. The absorbed UV rays are able to excite electrons and produce visible light (yellow-greenish). Optical images of C-dots were illuminated under white (left; daylight lamp) and UV light (right; 365 nm), as shown in Figure 4. This phenomenon can occur because of the electron excited by UV light from molecules which have high energy to low energy. Electron which is excited in an unstable state and then the electron returns to the ground state by emitting energy at wavelengths of visible light [7].

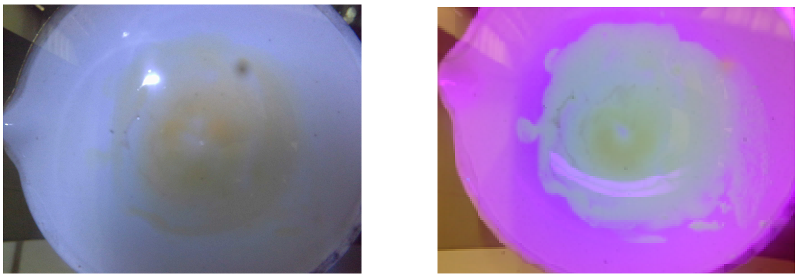

Figure 4. The optical images of C-dots were illuminated under white (left; daylight lamp) and UV light (right; 365 nm)

Conclusion

C-Dots were found on waste oil. C-Dots were formed as a result of the heating process that caused changes in the structure of the cooking oil. Luminescence was observed while C-Dots on waste cooking oil was irradiated by UV Light and the emissions were radiated in the visible light area which looks yellow-greenish color. In addition, increasing of temperatures in the thermal process causes a shift of the band gap energy of C-Dots.

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