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Research Article

Synthesis of Gold Nanoparticles Dispersed in Palm Oil Using Laser Ablation Technique

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Gold nanoparticles have more applications in biology, medicine, and industry. In this study, gold nanoparticles were synthesized in pure palm oil using laser ablation technique. Gold nanoparticles were fabricated in different temperature, and the effect of the temperature on the particle size was investigated. Consequently, the tail of the carbonyl band of fatty acids was capped gold nanoparticles, and spherically shaped gold nanoparticles with size range of 8.92 to 19.73 nm were formed in palm oil. The temperature caused the agglomeration of nanoparticles while the particle size increased with an increase in the temperature.

1. Introduction

The application of gold nanoparticles (Au-NPs) in drug delivery, microelectronics, environments, photonics, electronics [1], photodynamic therapy [2], therapeutic agent delivery [3], biosensors, sensors [4], medical diagnoses [5], and catalysis have been considered by many researchers. Gold nanoparticles have particular chemical and physical properties related to shape, size [6, 7], and surrounding medium of NPs [6, 8]. Numerous factors influence the shape and size of nanoparticles and one of each significant factor is temperature [9].

There was a strong interaction between electrical field of light and gold nanoparticles [10] while the surface plasmon absorption occurred in visible range [11]. The coherent excitation of free electrons causes the surface plasmon band in colloidal Au-NPs [12]. When the light beam interacts with Au-NPs, the response of Au-NPs strongly depends on particle size and concentration of Au-NPs in the liquid [13]. Many methods were presented to prepare Au-NPs including chemical methods [14, 15], microwave method [16], and sonochemical method [17]. Au-NPs were prepared in dimethyl sulfoxide, acetonitrile, tetrahydrofuran [18, 19], and nonorganic liquid [19] using laser ablation.

The main problem in the fabrication of Au-NPs is collapsing and agglomeration of Au-NPs in liquid due to thermodynamic principals. This challenge can be harnessed by improving the surrounding medium which prevents Au-NPs agglomeration through charge and steric stabilization. Hence, many researchers have made efforts to improve the stabilizers [20, 21] in order to counter the agglomeration of NPs in aqueous solution.

Recently, some fatty acids or vegetable oils were used as stabilizers [22, 23]. Fatty acids have amphiphilic molecules and they have a polar carboxylic group, which can cap Au-NPs. Consequently, nonpolar long carbon chains can prevent Au-NPs agglomeration through steric repulsion.

Past research has reported the preparation of Au-NPs in vegetable oils as stabilizing agents [24]. The best commercial vegetable oil traded in the world market is palm oil which contains palmitic 44.3%, stearic 4.6%, myristic 1%, oleic 38.7%, and linoleic 10.5% (Figure 1). It is cheaper and very stable for oxidation than canola, soybean, and rapeseed oil [25]. Palm oil contains the presence of long hydrocarbon chains and polar ester bond which makes it a good choice for stabilizing NPs (Figure 1).

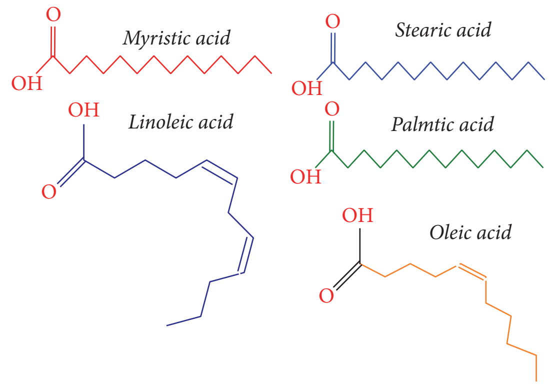

Figure 1: The chemical structure of fatty acids in palm oil contains stearic acid, palmitic acid, myristic acid, oleic acid, and linoleic acid.

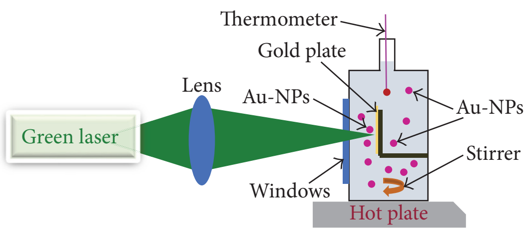

Figure 2: Laser ablation setup for fabrication of Au-NPs in palm oil contains a Nd:YAG laser, a lens, a gold plate, a hotplate, a thermometer, and a stirrer.

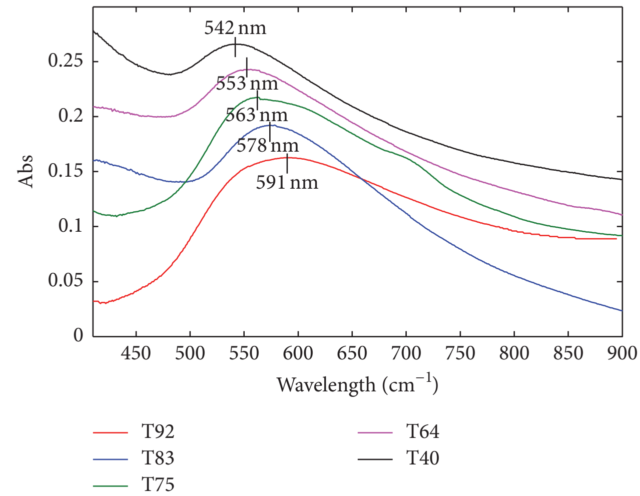

Figure 3: UV-visible results show the intensity peak having a red shift with increasing the temperature.

In this research, Au-NPs were synthesized in pure palm oil using laser ablation method in different temperature. The capping of the nanoparticles, particle size, and particle shape were investigated using Fourier transfer infrared spectroscopy, UV-visible spectroscopy, and transmission electron microscopy to test the stabilizing ability of palm oil.

2. Methods

2.1. Laser Ablation Synthesis of Gold Nanoparticle. In this experiment, a gold plate (Aldrich, high impurity 99.99%) was immersed in 10 mL of pure palm oil. A laser beam of 532 nm wavelength with duration of 10 ns and 1200 mJ ablated the gold plate in different temperature for 10 mins with 30 Hz repetition rate. Figure 2 shows the laser ablation setup which contains a Q-switched Nd:YAG laser, a solution container, a gold plate, a lens ($f = 30$ cm), a hot plate with stirrer, and a thermometer. The solution was heated using the hot plate, and the temperature of the solution was measured using the thermometer.

Gold nanoparticles formed in pure palm oil during laser ablation of the gold plate with ablation time of 20 minutes. The experiment was continued in different temperatures as 40°C, 64°C, 75°C, 83°C, and 92°C. In order to make sure that gold nanoparticles were dispersed evenly in palm oil, the solution was stirred during the ablation of the gold plate, and the solution container was moved horizontally to obtain the fresh surface area.

The UV-visible spectrum, morphology, size, and concentration of the prepared samples were obtained using the UV-visible double-beam spectrophotometer (Shimadzu), transmission electron microscopy (TEM, Hitachi H-7100, Hitachi, Chula Vista, CA), Fourier transform infrared spectroscopy (FT-IR), and atomic absorption spectroscopy (AAS, S series), respectively.

3. Results and Discussion

Figure 3 shows the UV-visible spectrum of palm oil with gold nanoparticles and the peaks appeared at 542 nm, 553 nm, 563 nm, 578, and 591 nm. These peaks arose from a localized surface plasmon resonance of Au-NPs. Hence, they confirmed that Au-NPs were formed inside palm oil. The ablation time was 20 minutes while the temperatures of palm oil during the ablation of the gold target were 40°C, 64°C, 75°C, 83°C, and 92°C. The peak intensity of UV-visible spectrum decreased with an increase in the temperature, and the red shift is observed in the UV-visible spectrum. In accordance with Mie theory, the red shift authenticates the increase in particle size. Consequently, the particle size increases with an increase in the temperature.

The concentrations of Au-NPs measured using atomic absorption spectroscopy for the sample at temperatures of 40°C, 64°C, 75°C, 83°C, and 92°C were 21.3, 13.4, 10.8, 9.1, and 8.6 mg/L, respectively. The volume fraction of each sample was obtained using the following equation [26, 27]:

$$V = \frac{V_p}{V_p + V_L}, \quad (1)$$

where V_L and V_p are the volume of palm oil and the volume of Au-NPs (m/ρ, where ρ and m are the mass density of gold and the mass of the particles dispersed in palm oil, resp.). Hence,

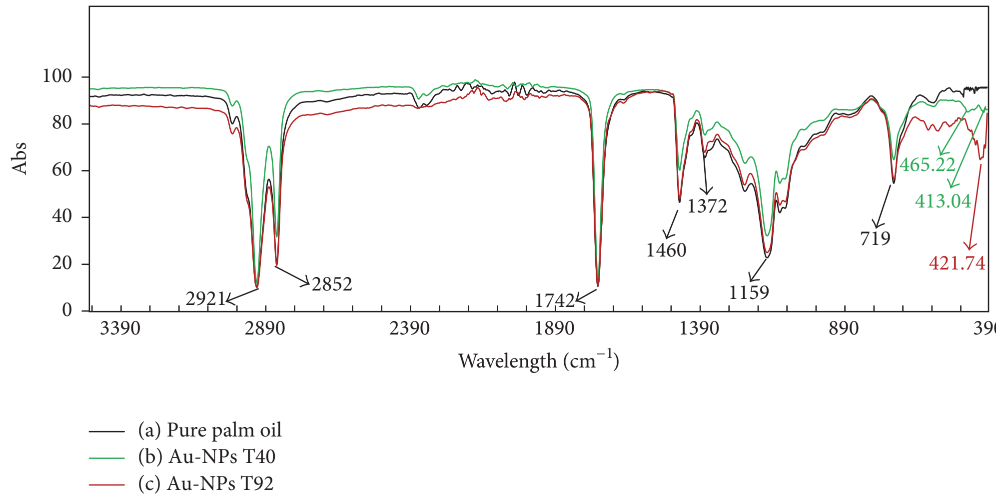

Figure 4: FT-IR results related to pure palm oil and palm oil with Au-NPs in 40°C and 90°C.

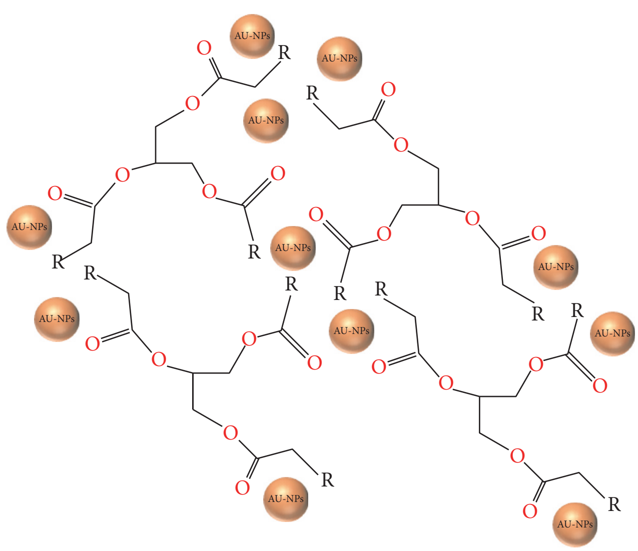

Figure 5: Au-NPs capped with fatty acids in palm oil.

(2) was derived from modification and a simplification of (1) as follows:

$$V = \frac{C_{\text{Particle}}}{C_{\text{Particle}} + \rho}, \quad (2)$$

where C_{Particle} are the concentrations of Au-NPs obtained from the AAS. The volume fraction of Au-NPs was obtained in the range of 0.1104×10^{-5} to 0.0446×10^{-5} which decreased with an increase in the temperature of the sample (see Table 1).

Figure 4 shows the FT-IR spectrum analysis of pure palm oil and palm oil/Au-NPs. The spectra wavelength ranges from 400 cm^{-1} to 3400 cm^{-1}, and they show a chemical structure of palm oil and palm oil/Au-NPs. Since the effect of temperature has been investigated for the preparation of Au-NPs, the FT-IR results related to nanofluid which was formed in 40°C (Au-NPs T40) and 92°C (Au-NPs T92) were presented.

Table 1: The pertinent parameters of palm oil/Au-NPs nanofluid.

Gold-NPs	Temperature (°C)	Concentration (mg/L)	Particle size (nm)	Volume fraction ($\times 10^{-5}$)
Au-NPs T40	40	21.3	8.92	0.1104
Au-NPs T64	64	13.4	9.80	0.0694
Au-NPs T75	75	10.8	12.87	0.0560
Au-NPs T83	83	9.1	15.07	0.0472
Au-NPs T92	92	8.6	19.73	0.0446

Figure 4(a) shows the FT-IR spectrum of pure palm oil where the peaks at 2921, 2852, and 1742 cm^{-1} correspond with the =C-H stretching vibration, CH_2 asymmetric and symmetric bending, and -C=C stretching ester carbonyl function group of triglycerides, respectively.

In addition, the peaks of 1460, 1372, 1159, and 719 cm^{-1} are related to the CH_2 bending, -C-O stretching vibration, and -CH_2 bending (cis -CH=CH- bending) [28, 29]. Figures 4(b) and 4(c) depict the FT-IR spectrum of samples after the ablation of the gold target in palm oil. The peaks at 2921, 1742, 1460, 1372, 1159, and 719 cm^{-1} are related to pure palm oil and the peaks in 413.04, 421.74, and 465.22 cm^{-1} are related to Au-NPs [28, 30] that formed inside palm oil using laser ablation of the gold plate. The peaks at 2921, 1742, 1460, 1372, 1159, and 719 cm^{-1} remain stable during synthesis of Au-NPs in palm oil while other peaks related to formation of another component such as graphitic compound did not appear. Therefore, there was no mutation of the molecular structure and functional groups of palm oil during laser ablation of the gold plate.

As a result, palm oil components can be used as capping agents for Au-NPs. Figure 5 shows the model of capping the nanoparticles. The tail of the carbonyl band capped Au-NPs through the electron transfer from the carboxylic group to Au-NPs thereby causing an impediment of the motion of the molecules inside the particular area with a decrease in

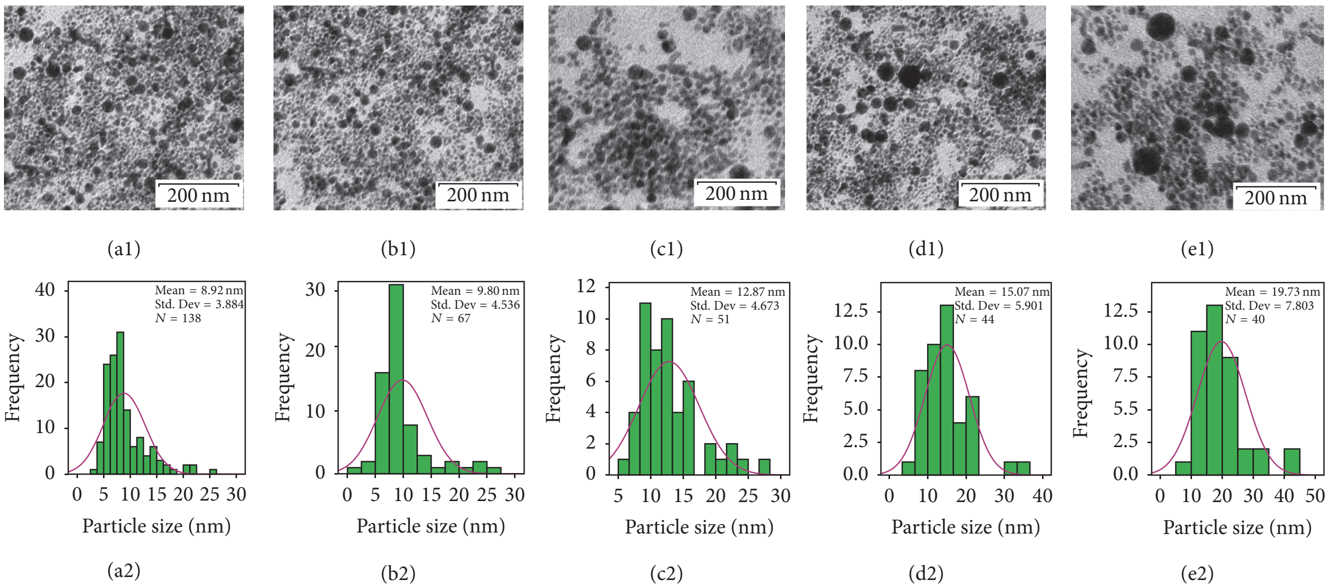

FIGURE 6: The TEM images demonstrate the Au-NPs formed in palm oil in spherical shape.

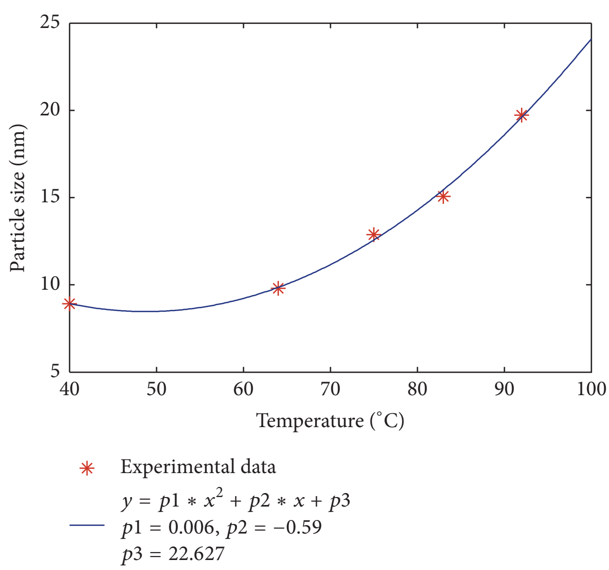

FIGURE 7: Variation of particle size with temperature.

entropy [28, 30]. This proves that a long hydrocarbon chain prevents the agglomeration of Au-NPs.

Figures 6(a1), 6(a2), 6(b1), 6(b2), 6(c1), 6(c2), 6(d1), 6(d2), 6(e1), and 6(e2) show the TEM images and their analysis. It was observed that Au-NPs formed in the spherical form. The particle size was achieved after analyzing the TEM image using the UTHSCSA image tool software program. As a result, the particle size was in the range of 8.92 to 19.73 nm. Figure 7 shows the variation of particle size according to the temperature. The pertinent parameters were sorted in Table 1.

Temperature of a sample is a significant parameter for formation of the nanoparticles during ablation of the gold target. The effect of the temperature appeared in the size of the nanoparticles, and the final size was achieved due to agglomeration of Au-NPs inside palm oil. At initial step, laser beam causes the phase transition and nucleation of Au-NPs near the target inside palm oil. Consequently, Au-NPs cluster was formed in spherical shape and small size, and Au-NPs were dispersed in palm oil. When the temperature of palm oil was increased, in accordance with Maxwell–Boltzmann kinetic energy [9, 31], the probability of agglomeration of Au-NPs cluster increased therefore causing an increase in particle size as the temperature increased.

4. Conclusions

Gold nanoparticles formed in palm oil in the spherical shape with particle size ranging from 8.92 to 19.73 nm. The heat had an effect on the particle size thereby causing an increase in the particle size as the temperature increased. The localized surface plasmon resonance peaks appeared in the green range of UV-visible spectrum. The tail of carbonyl band capped Au-NPs. Consequently, the laser ablation technique is a green and simple method for the synthesis of Au-NPs in the presence of fatty acids.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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