PREPARATION OF NANOPARTICLES FROM ACRYLATED PALM OIL MICROEMULSION USING RADIATION TECHNIQUE

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ABSTRACT

The use of microemulsion in the development of nanoparticle based on acrylated palm oil product is demonstrated. Acr ylated palm oil microemulsions were prepared using ionic surfactant. Combination methods of emulsion polymerization and radiation crosslinking were applied to the microemulsion system for synthesizing nanoparticle. The ionizing radiat ion technique was introduced to generate a crosslinking reaction in the development of nanoparticle. The nanoparticle was evaluated in terms of particle diameter, surface charge, pH and conductance. Their image was captured using Tra nsmission electron microscopy (TEM). Results show that the size, charge and shape of the particles are influenced by c oncentration of surfactants, monomer concentration, radiation dose and time of storage. The study showed a promising method to produced nanoparticle. This nano-sized product has the potential to be utilized as controlled-drug-release-c arrier.

ABSTRAK

Kajian ke atas pembangunan produk nanopartikel menggunakan sistem mickroemulsi berasaskan minyak sawit berakril at telah dijalankan. Sistem mikroemulsi minyak sawit berakrilat telah dihasilkan daripada surfaktan ionik. Gabungan teknik pempolimeran emulsi dan taut-silang melalui sinaran telah diaplikasikan ke atas sistem mikroemulsi untuk mensi ntesis partikel nano. Teknik sinaran mengion digunakan untuk tindak balas taut-silang dalam pembangunan partikel n ano. Pencirian partikel nano telah dilakukan dari segi diameter partikel, cas permukaan, pH dan konduktans. Imej pa rtikel telah digambarkan menggunakan kaedah mikroskop transmisi elektron (TEM). Hasil kajian menunjukkan saiz, c as dan bentuk partikel nano adalah dipengaruhi oleh kepekatan surfaktan, kepekatan monomer, dos sinaran dan tempo h penyimpanan. Hasil kajian ini menunjukkan teknik penghasilan partikel bersaiz nano telah dibangunkan dan produk ini berpontesi untuk digunapakai sebagai agen pelepasan ubat terkawal.

Keywords: Palm oil, drug delivery system, microemulsion, nanoparticle, radiation crosslinking

INTRODUCTION

Various nanostructure polymers have been devised in drug delivery research. Over the past few decades and with the advances in nanoscience and nanotechnology, researchers showed interest in developing biodegradable nanoparticles as drug delivery devices. In this case, natural polymers such as vegetable oils (palm oil and soybean oil) are the potential materials and have been used to synthesis nanoparticles. The nanoparticles in the form of micellar solutions consisting of small particles of 10-400 nanometer (nm) diameters, called polymeric micelles showed great promise as potent vehicles for controlled drug delivery (Kaparissides et al., 2006).

Recently, a high pressure homegenation technique has been applied in the development of solid lipid nanoparticles based hydrogenation palm oil as carriers in pharmaceutical and cosmetic fields (Alhaj et al., 2008, 2009, 2010). In addition, solid lipid nanoparticle based hydrogenation soybean oil also has been developed as anticancer drug doxorubicin hydrochloride (Dox) carrier in treatment of multidrug-resistant human breast cancer cells (Wong et al., 2006).

Another method, known as emulsion polymerization, is well established in the manufacture of polymer nanoparticles via the polymer colloids formulation. They are two different types of colloids i.e. lyophobic colloid and association colloid. From the thermodynamic point of view, the lyophobic colloids are unstable and frequently form large aggregates where certain energy is require to be applied for their formation. Meanwhile, the association colloids which are known as micelle are more stable towards both dissociation and aggregation. Basically, surfactants are added to the emulsion to improve their stability by decreasing interfacial free energy and by providing a mechanical barrier to droplet coalescence and Ostwald ripening (Chidambaram and Burgess, 2000). In recent years, combination method of polymerization and cross-linking in emulsion has been introduced to synthesize microgels and nanogels (Ulanski et al., 2002; Rosiak et al., 2003; Ravi Kumar et al., 2004). Subsequently, in 1998, Ulanski and his co-workers have proposed a radiation induced intramolecular cross-linking as a tool for the synthesis of nanogel using a radiation technique (Ulanski et al., 1998). It has been shown that, radiation technique is suited for producing nanogels and microgels especially for biomedical applications because they are free of monomers, initiators and any other additives during the process reaction (Rosiak et al., 2003).

In this present work a microemulsion polymerization method via ionizing radiation technique will be used for formation of nanoparticles based on acrylated palm oil. The main focus of this study was to develop radiation polymerization procedure and to determine the effects of concentration of surfactant and polymer, radiation dose and the storage time on the size of nanoparticles.

MATERIALS AND METHODS

Materials

The acrylated palm oil (APO) used in this study was synthesized in the laboratory of Radiation Processing Technology Division (BTS), Malaysian Nuclear Agency. Sodium dodecyl sulfate (SDS) (Aldrich Chemical Company) as surfactant and is used as received without further purification. Distilled and deionized water were used through out of this study.

Preparation of microemulsion

The micellar system was prepared based on oil in water (O/W) and was created using a ternary phase and solubilization diagrams. The solubilization of these three basic components, i.e., oil (APO), water and surfactant were deeply observed to determine the emulsion/microemulsion regions as illustrated in Figure 1. Different concentrations of APO, i.e. approximately at 1.8% (noted as *a*) and 0.18% (noted as *b*), with different concentration of the surfactant (above and below SDS cmc region) in an aqueous solution were prepared. These samples were used for size and stability measurements.

Particle sizing

The samples were filtered using a disposable polytetrafluoroethylene (PTFE) Teflon filter for removing of suspended materials or impurity. The sizes of the micelles were determined by photon cross correlation spectroscopy (PCCS) using a dynamic light scattering (DLS) (Nanophox, Sympatec) at a wavelength of 632 nm.

Particle size stability

The storage time was arranged from day 1, 7, 14, 30, to day 60. The size of the micelles was determined using a dynamic light scattering (Nanophox, Sympatec).

Zeta Potential

The same samples were used for the determination of zeta potential using a zeta potential analyzer (ZetaPlus, BrookHaven) by means of an electrophoresis mechanism. The pH and conductance of the samples were also recorded.

Radiation synthesis of nanoparticles

Subsequently, the micelles which are in the form of microemulsions were irradiated at different doses using a gamma radiation at 1, 5, 10, 15 and 25 kilogray (kGy). After irradiation, the irradiated micelles were subjected to sizes determination.

Transmission Electron Microscopy (TEM)

Transmission electron microscopy was performed using a Zeiss microscope (Jeol, Japan), 120 kiloelectron volt (keV), with 30000 times of magnification for the measurement of particle sizes of the micelles in dried form.

RESULTS AND DISCUSSIONS

Microemulsion

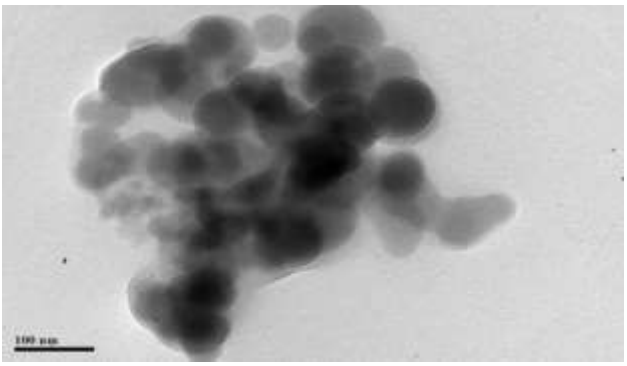
1(a) Emulsion systems 1(b) Microemulsion systems

Figure 1: Solubilization images of the (Water/SDS/APO) systems

Two main properties of APO in water system, (Water/SDS/APO) have been found. First property is known as emulsion, as shown in Fig.1a. Emulsion can be described as unstable solution and has been visualized as two layer phases. In this system, unstable molecules undergo coalescent forms creaming layer (upper phase) and turbid layer (bottom phase). Meanwhile, another property is more isotropic, homogeneous and semi transparent, as shown in Fig.1b. This system is known as microemulsion. Their appearance can be determined at the solution that has less amount of polymer content. These microemulsions were then used for further analysis.

Transmission electron microscopy

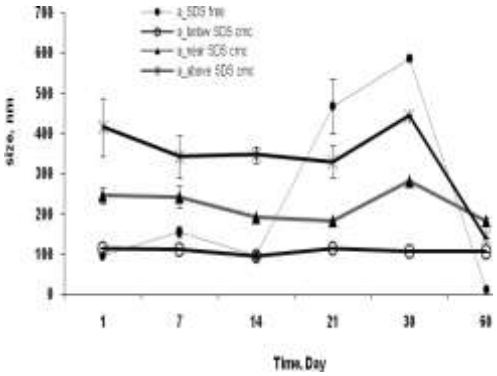
The TEM images of nanoparticles were shown in Fig.2. The shape of sample of the (Water/SDS/APO) system was spherical and particle size is less than 130 nm (Fig.2).



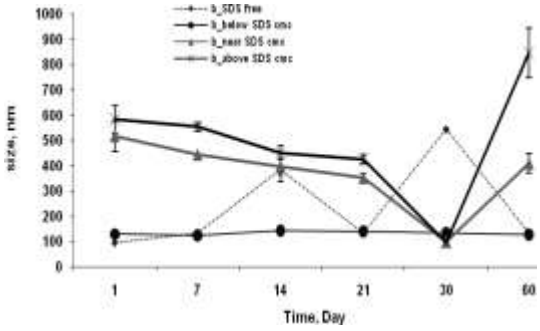
(Water/SDS/APO)

Figure 2: TEM images of nanoparticle

Particle size and size stability



3(a)



3(b)

Figure 3: Microemulsion of SDS/Acrylated palm oil

Figures 3 showed varieties size of micro/nanoparticles. Size of the particle is influenced by the formulation. Parameters such as monomer (APO) concentration, surfactant (SDS) concentration and the storage time plays important role in this study. Size of the particle increases when the surfactant concentration is above the surfactant's critical micelles concentration (cmc), *see* Fig. 3a and Fig.3b. An ionic based microemulsion with higher APO content shows that the size of the particle is almost unchanged with the storage time until 3 weeks (Fig.3a). Then, the particle sizes slightly increases after a month and decrease at two months (Fig.3a) due to instability. Meanwhile, an ionic based microemulsion with less APO content shows that the size of the particle is slightly decrease during the storage time (Fig.3b). The size of particles for ionic based microemulsions with higher APO content along the storage time is in the range of 110 nm to 420 nm and for ionic microemulsions with less APO content is in the range of 100 nm to 600 nm. For surfactant free particle, the size is in the regions of 100-600 nm.

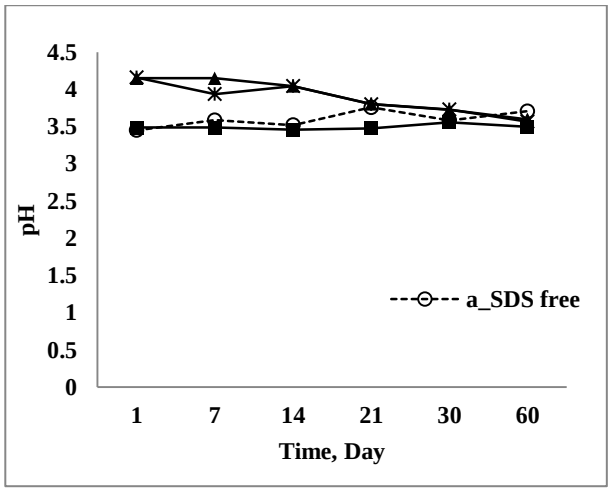
Effect of monomer and surfactant concentrations and type of surfactant on the particle size

Figure 3a and Figure 3b showed that monomer and polymer concentration affects the end products size. Figure 3a showed that systems with higher APO content resulted in smaller sizes particle and vice versa the result for the formulation with less APO content (Fig.3b). When more APO is added, the droplet size decreases is due to the solubility between the APO in solvent. Results showed that APO has good solubility in ionic/SDS surfactant. Add more APO may affect increased saturated polymer/surfactant aggregation and thus presence intramolecular interaction between particles. Other factors which influence the product sizes are concentration of surfactants used. If less APO added in systems with high SDS content, systems may resulted more free-APO micelle are formed. Furthermore, particle sizes are grown above the surfactants cmc, in both medium (see Fig.3a and Fig.3b). Meanwhile, below SDS cmc or at low SDS content systems the stability of the particle is good where sizes of particles are unchanged until 2 months. Surfactant molecules also help to protect the APO from intermolecular reaction and maintain their sizes in aqueous solution. For surfactant free particle, the particle could only maintain their size for less than a week. The size decreasing is due to the flocculation of the particles in system. It showed us that surfactant molecules play major role to control the stability of the particles.

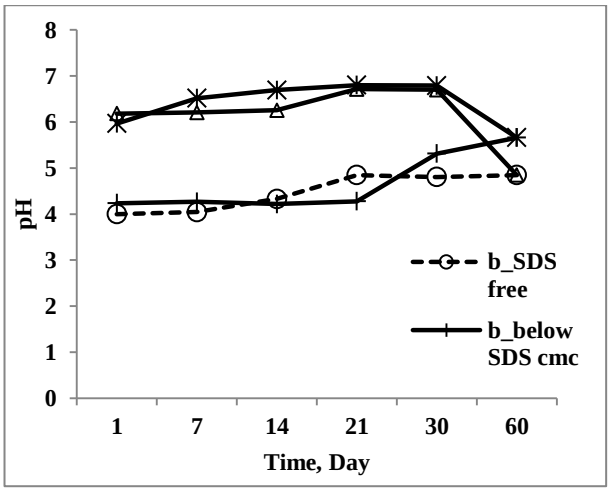
pH and Conductance Analysis

The pH of Water/SDS/APO is in the regions 3.5 -7.0. It gives an acidic solution to the systems. The resulted pH values are influenced by the surfactant and monomer concentrations. As shown in Fig.4, in Water/SDS/APO system, when it consits less polymer, pH value drops (less acidic), see curves *b*. Their pH regions 4.0-7.0. It is due to the less active electrostatic reaction between ions surfactant and oil droplet. But, when polymer concentration increasing, see curves *a*, the pH value rises (more acidic), due to the increasing of the surfactant ions nucleaction in outer shell of the oil droplets or particles. The particle size decreases as the pH rises. Their pH regions 3.4 - 4.2. Thus, the study conclude that ionic surfactant showed good association to microemulsion. Rising of pH in ionic based microemulsion at higher polymer content resulted in smaller size product. The results also agreed that the system needs high ratio molecules of an ionic surfactants to form a one molecule oil droplet/nanoparticle according to the pH risen. It means

that droping and rising of the pH is due to the electrostatic interactions of hydrogen ions within the surfactant moleculed which came to interact with oil droplets. Furthermore, growth of size of particles will give rise to their surface force. The study also agreed that due to the increase of conductances such as shown in Water/SDS/APO (Fig.5) systems, where, the size of particle increases as their conductance increases. Also *see* Fig. 5. A conductance of Water/SDS/APO systems are in the regions 150 -800 ***micro Siemens*** (μS). For less and high APO content systems, their conductance regions are 120-920 μS and 220-860 μS, respectively. For a surfactant free systems, their conductance and pH is in the regions 10-300 μS and 3.5-5.0, respectively.

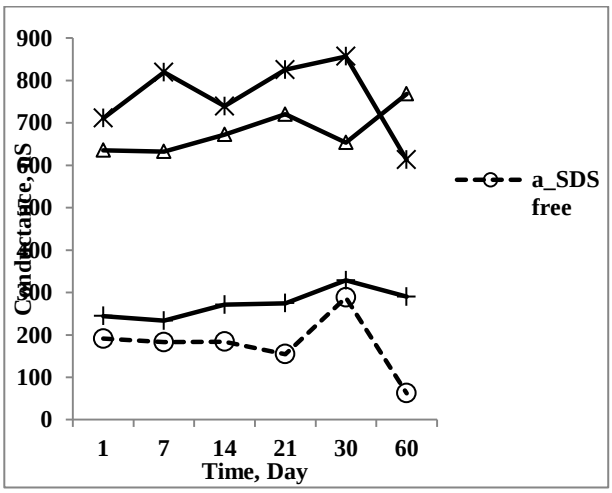


4(a)

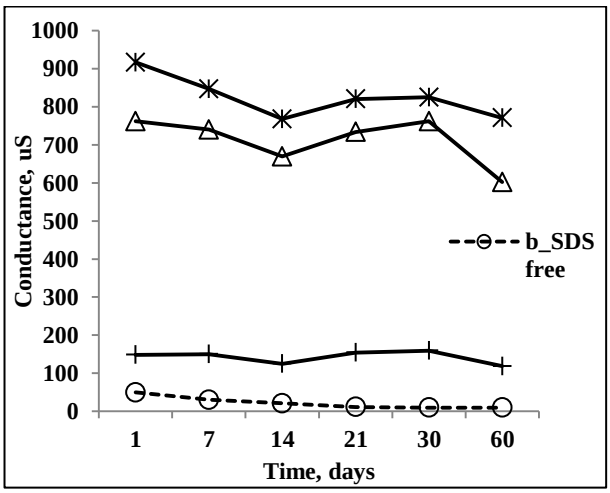


4(b)

Figure 4: pH for Water/SDS/APO microemulsion



5(a)



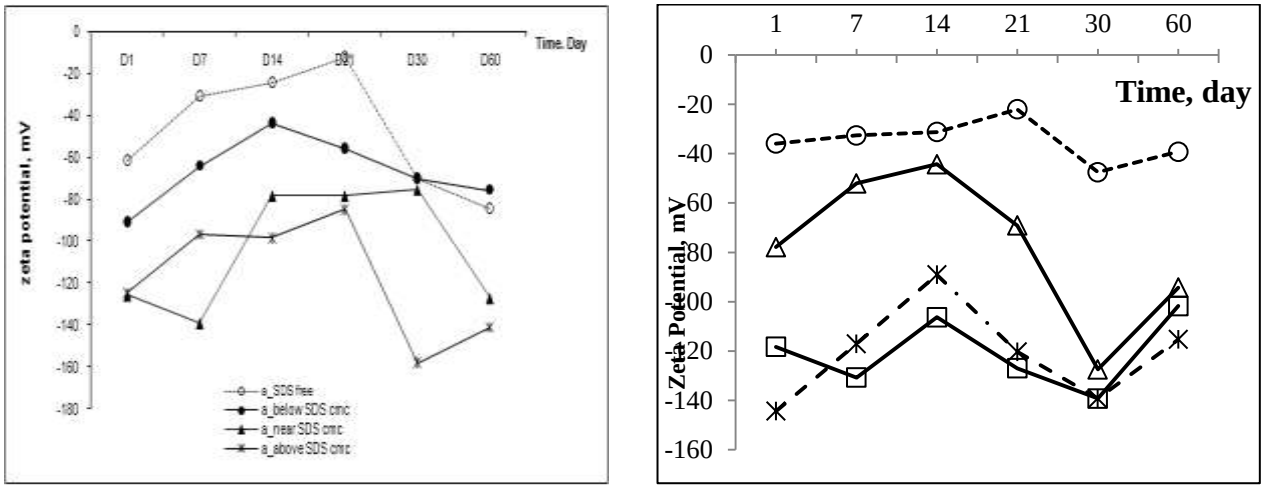
5(b)

Figure 5: Conductance for Water/SDS/APO microemulsion

Zeta Potential

The zeta potential value was fully depends on the type of the surfactant, as shown in Fig.6. The results of zeta potential measurements are related with penetration phenomenon of the surfactant head or their hydrophobic part in microemulsion. Ionic surfactant i.e. SDS gives a negatively charged particle surface (Fig.6). Furthermore, the degree of the zeta potential is depended on the concentration of the surfactant, as clearly shown in Fig.6. Increasing the surfactant volume in microemulsion decreases the zeta potential. Moreover, the zeta potential degree is affected by the volume of monomer presence in the microemulsions. We can assume that at higher water content, lower monomer and higher surfactant concentration in the system, the surfactant molecule is dominantly solubilized, contributing lower zeta potential degree, *see* curves noted as *b* in Fig. 6. In the oil/water systems with higher water content, lower monomer and higher surfactant concentration, the surfactant molecules are most likely solubilized in the water-continuous system.

The zeta potential for ionic based microemulsions with higher APO content along the storage time is in the range of -90 to -140 ***millivolt*** (mV) and for ionic microemulsions with less APO content is in the range of -70 to -140 mV. For surfactant free particle, the zeta potential is in the regions of -10 to - 90 mV.



6(a) 6(b)

Figure 6: Microemulsion of SDS/Acrylated palm oil

Irradiation effect

The microemulsion system with concentration of their surfactants near and above cmc was selected for irradiation. Correlation between the dose effect and the particle sizes is shown in Fig.7. After the micellar system was irradiated, the sizes of the particles decrease when the dose of irradiation increased to 1 kGy or higher, as shown in Fig. 7. A small dose of ionizing radiation is enough to influence the product sizes. The change of the particle size after the micro/nanoemulsion samples triggered to several irradiation doses proved that chains present in the system undergo intramolecular crosslinking reaction (Ulanski et al., 1998). In these circumstances, reactive species are formed along the polymer chains. At 1 kGy or higher, the crosslinking reaction leads to the formation of fine particles which means that polymer radicals present in the system fabricated into the network. For high APO content particles with SDS near cmc, noted as *a* graph, their sizes decrease from approximately 120 nm (at 1 kGy) to 80 nm (at 25 kGy), meanwhile particles with SDS above cmc, their sizes decreases from approximately 110 nm (at 1 kGy) to 100 nm (at 25 kGy). For less APO content particles with SDS near cmc, noted as *b* graph, their sizes decrease from approximately 480 nm (at 1kGy) to 100 nm (at 25 kGy), meanwhile particles with SDS above cmc, their sizes decreases from approximately 330 nm (at 1 kGy) to 250 nm (at 25 kGy).

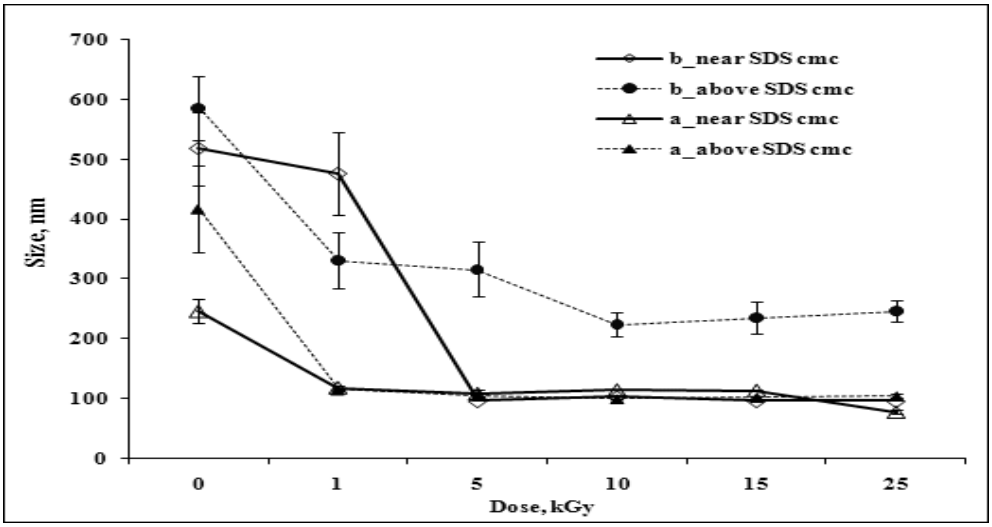


Figure 7: Dose effect on the particle diameter

CONCLUSIONS

Acrylated palm oil can be synthesized and developed into micro and nano sized particles using ionizing radiation technique in microemulsion system. The sized, charge and shape of the particles are influenced by several conditions i.e. the concentration of surfactants, monomer concentration, radiation dose and time of storage.

ACKNOWLEDGMENT

The authors sincerely acknowledge the Malaysian Nuclear Agency for supporting this project. The scholarship from Public Service Department (HLP) of the Government of Malaysia is greatly appreciated for sponsoring the MSc study. This work was also supported by the Ministry of Science, Technology and Innovation of the Government of Malaysia through the Ninth Malaysian Plan program (RMK-9). Authors also acknowledges to the staff of Technical University of Poland, i.e., Prof. Rosiak J.M. and Prof. Ulanski P. for their valuable assistant during the preliminary work of this project prior to MSc study at UPM.

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