COMPARISON OF SELENIUM NANOPARTICLES PRODUCED BY ELECTRON BEAM, GAMMA IRRADIATION AND THEIR STABILITY

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TÓM TẮT

SO SÁNH HẠT NANO SELEN CHẾ TẠO BẰNG BỨC XẠ CHÙM TIA ĐIỆN TỬ VÀ BỨC XẠ GAMMA VÀ ĐỘ ỔN ĐỊNH CỦA CHÚNG

Trong công trình này, các hạt nano selen (SeNPs) được tạo ra bằng cách chiếu xạ sử dụng máy gia tốc chùm tia điện tử và nguồn gamma Co-60. Các đặc trưng của hạt SeNPs thu được được xác định bằng cách đo UV-Vis, DLS để xác định phân bố hạt theo kích thước và đo điện thế zeta. DLS cũng được đo ở các thời gian bảo quản khác nhau (1 – 6 tháng) theo nhiệt độ bảo quản (4 °C và 27 °C). Kết quả thu được chỉ ra rằng các hạt SeNPs được tổng hợp bằng chùm tia điện tử và chiếu xạ gamma có cùng phạm vi phân bố hạt theo kích thước. Độ ổn định của hệ hạt SeNPs tạo thành trong pha lỏng bảo quản ở nhiệt độ mát (4 °C) tốt hơn ở nhiệt độ phòng (27 °C).

***Từ khóa**: hạt nano selen, chùm tia điện tử, bức xạ, gôm Arabic, độ ổn định.*

1. INTRODUCTION

Selenium is a critically nutritional element for human body and selenium nanoparticles are preferred form of selenium due to their low toxicity [1, 2]. Various methods have been applied for the selenium nanoparticle produciton [3-5]. Irradiation technology for production of selenium nanoparticles is considered the method with many outstanding advantages including the absence of toxic reducing agent, the easiness to adjust the particle size and size distribution, the

high purity of obtained product as well as the capability of producing large volumes at competitive price [6-7].

While gamma irradiation is as a well-known method to produce nanoparticles with gradually reduced intensity, non-controllable and non-switchable performance, the electron beam irradiation has a lower penetration depth but possesses much higher energy with constant emission intensity and high dose rate, and especially switchable, giving the ability to fully automate the process and making the product quality uniform [7].

It is necessary to compare the two methods of irradiation, so that one can choose a suitable method to scale up the process for mass production of selenium nanoparticles and a better method for the product storage.

2. MATERIALS AND METHODS

2.1. Materials

Selenium dioxide (SeO_2) was supplied by Merck, Germany. Gum Arabic from the acacia tree (GA) was purchased from Sigma-Aldrich as dry powder. Double distilled water was used throughout the study. All chemicals were used as purchased without further purification.

2.2. Synthesis of selenium nanoparticles using electron beam irradiation method.

The synthesis was as described in previous study [7]. In a typical experiment, a Se^{4+} solution (prepared by dissolving SeO_2 in water) is first mixed with gum arabic water solution. Then, water was added to form a 1.25 mM solution Se^{4+}/ 1% GA. The mixture is stirred well and then transferred to a plastic container with a lid so that the solution thickness is 2.5 cm. The irradiation process was performed on an electron beam accelerator UERL-10-15S2, 10 MeV, 1.5 mA (dose rate of 5 kGy.s $^{-1}$) for a dose of 10 kGy.

2.3. Synthesis of selenium nanoparticles using gamma Co-60 rays

For the synthesis of SeNPs coated with GA (SeNPs/GA) by gamma irradiation, 1.25 mM solution Se^{4+}/ 1% GA was irradiated using a Gamma irradiator SVST-Co60/B at a dose of 10 kGy with dose rate of 1.3 kGy.h^{-1}.

2.4. Characterization of obtained nanoparticles.

Absorption spectra of Se^{4+}/1% GA and obtained SeNPs solutions were recorded using UV-Vis spectrophotometer UV-2401PC (Shimadzu, Japan). Zeta-potential and size distribution of the synthesized SeNPs were determined by Dynamic Light Scattering (DLS) using a Zetasizer Nano ZS instrument (Malvern).

2.5. Stability of gum arabic-coated SeNPs.

SeNPs/GA in solution prepared by electron beam irradation are stored under different conditions including ambient temperature (27°C) and cool temperature (4°C).

The change in the hydrodynamic diameter of nanoparticles during storage (upto 6 months) is performed by DLS measurements using Zetasizer Nano ZS, Malvern to investigate the stability of SeNPs/GA.

3. RESULTS AND DISCUSSION

3.1. Synthesis of gum arabic coated selenium nanoparticles by electron beam and gamma Co-60 irradiation.

The formation of SeNPs/GA synthesized by either gamma Co-60 or electron beam irradiation was depicted by the color change of the reaction solution. Particularly, the solution color evolved from colorless to orange in both cases as displayed in the insets of Figure 1 a and 1b. In addition, UV-Vis spectra of obtained SeNPs/GA showed only the absorption peak of Se^{4+} ions at the wavelength of around 279 nm. There were no characteristic absorption peaks of nano selenium indicating that the obtained SeNPs/GA using these irradiation sources are in the size range of less than 100 nm. These observations were also reported in previous researches [8, 9].

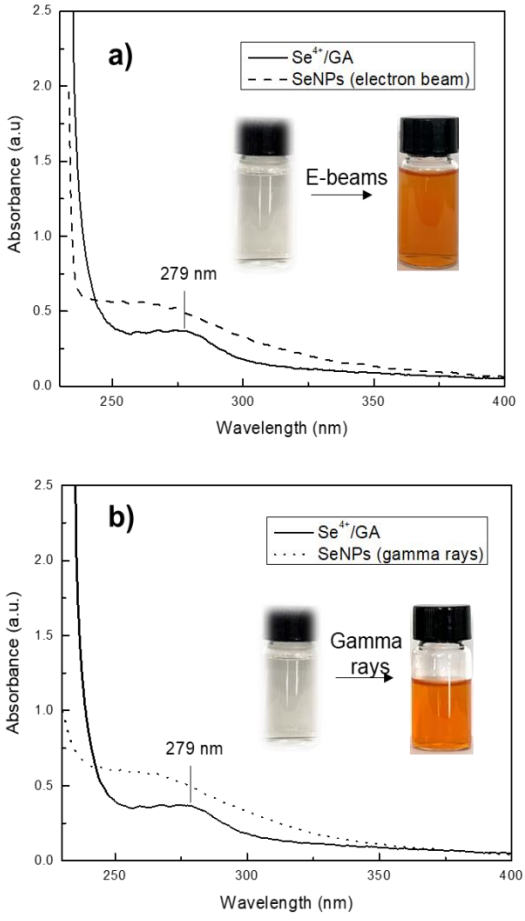

Figure 1. *UV-Vis spectra of Se^{4+}/GA (before irradiation) and SeNPs/GA (after irradiation) solutions. a) by electron beam, b) by gamma rays. The inset is the photographs of corresponding solutions.*

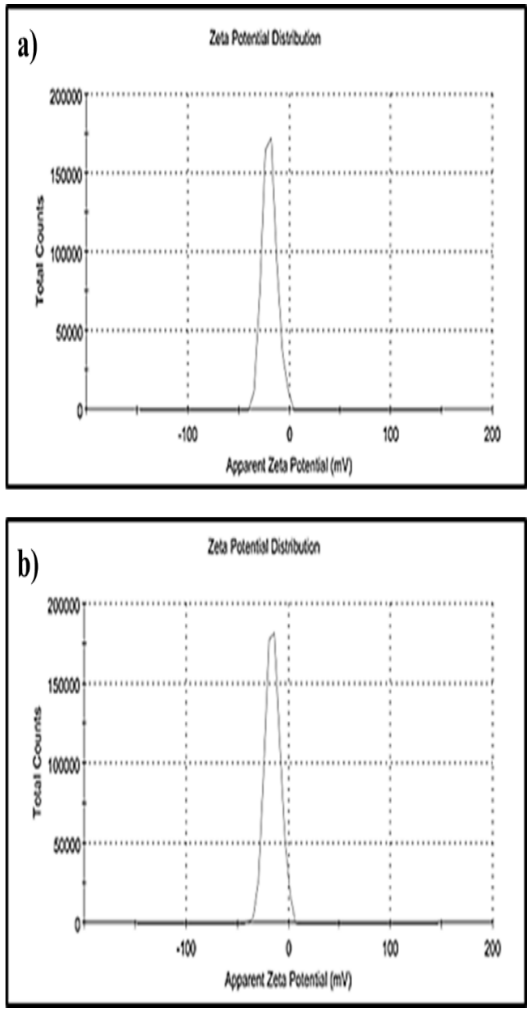

Figure 2. *Zeta potential of SeNPs/GA synthesized by electron beam (a) and Co-60 gamma irradiations (b)*

3.2. Zeta potential of the SeNPs/GA produced by electron beam and gamma Co-60 irradiation

Zeta potential results showed that the SeNPs/GA prepared by gamma Co-60 and electron beam irradiation were negatively charged with equivalent zeta potential values of -15.4 and -19.5 mV, respectively (Figure 2). This implies that the SeNPs could be efficiently stabilized not only by steric repulsion due to the presence of biopolymers, i.e. gum arabic, but also by the electrostatic interaction. Furthermore, the zeta-potential values are in the range of -30 mV and -10 mV indicating that the SeNPs are moderate anionic [10].

3.3. DLS of the SeNPs/GA produced by electron beam and gamma Co-60 irradiation

Size distributions of SeNPs/GA produced by electron beam and gamma Co-60 irradiation measured by DLS were presented in Figure 3. It was found that the hydrodynamic diameters of SeNPs synthesized by electron beam and gamma Co-60 irradiation were 281 nm and 293.3 nm, respectively. Similar to zeta-potential results, there was no considerable difference between the average size (hydrodynamic diameter) and size distribution of the SeNPs/GA obtained from two irradation sources.

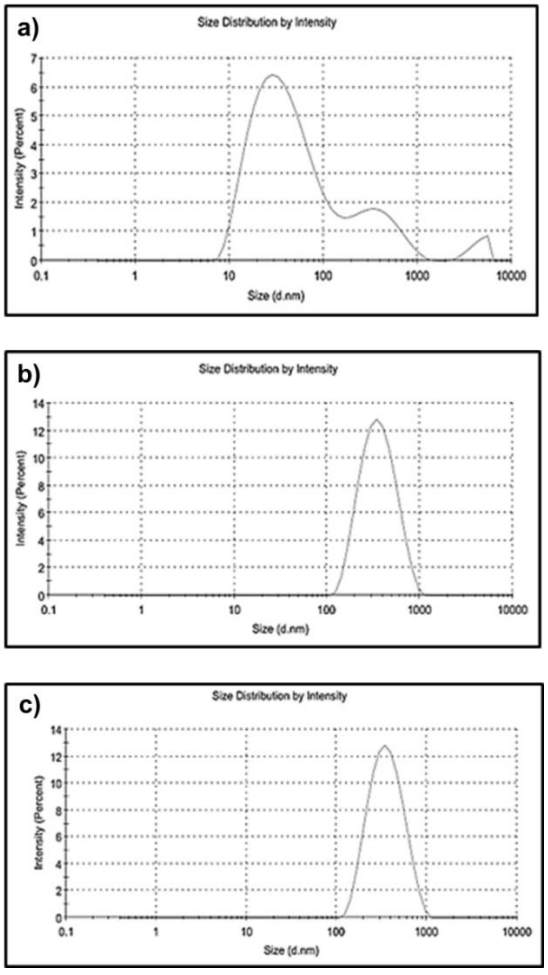

Figure 3*. DLS of SeNPs/GA synthesized by electron beam and gamma Co-60 irradiations a) H_2SeO_3 solution without irradiation b) SeNPs/GA synthesized by electron beam c) SeNPs/GA synthesized by gamma Co-60 rays*

3.4. Size distribution of SeNPs/GA synthesized by electron beam at different storage time

The stability of SeNPs/GA synthesized by electron beam during storage was also investigated via DLS measurement. In particular, DLS size distribution of the SeNPs/GA was recorded at various storage time including 2, 4 and 6 months at different storage conditions (4 $^{\circ}$C and room temperature).

It can be seen from Figure 4 that there were only one peak in the size distribution graphs of the samples over time at different temperature of storage. This implies that there was no agglomerations in the NPs solution. In another word, the SeNPs/GA solution was stable up to 6 months of storage.

Besides, it was found that the average hydrodynamic diameter of SeNPs/GA when being stored at room temperature increased more than the corresponding one of cool temperature (4 $^{\circ}$C). Therefore, cool condition is more favorable to preserve the NPs compared with ambient condition.

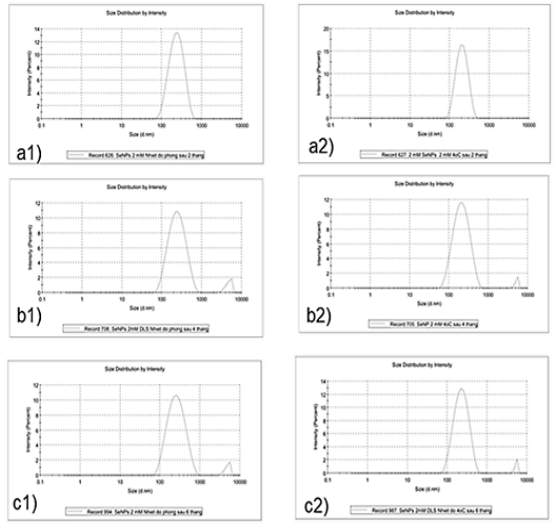

Figure 4*. DLS SeNPs/GA at different storage time. a1, b1, c1: SeNPs/GA stored at room temperature (27 $^{\circ}$C) after 2, 4, 6 months, a2, b2, c2: SeNPs/GA stored at cool temperature (4 $^{\circ}$C) after 2, 4, 6 months*

4. CONCLUSION

Selenium nanoparticles stabilized by 1% gum arabic have been successfully fabricated by irradiation using electron beam accelerator as well as by Co-60 gamma rays. The SeNPs/GA obtained when using both irradiation sources showed no significant difference in size distribution and zeta-potential. Low temperature (4 $^{\circ}$C) was found to be favourable for storing the SeNPs/GA colloidal solution. The results also indicated that SeNPs/GA solution could be stable up to 6 months without considerable agglomerations.

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