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Preparation and Characterization of Curcumin-Silver Nanoparticle and Evaluation of the Effect of Poly Ethylene Glycol and Temperature

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ABSTRACT
In this research, the silver nanoparticle (AgNP) was rapidly prepared by simple solution method within 1 hour at 25 and 80 °C in the present and the absent polyethylene glycol (PEG). The curcumin-silver nanoparticle was synthesized from silver nitrate as precursor and sodium bore hydrate as a reduction in two conditions included water solvent and polyethylene glycol in water solvent at 25 °C as solution method and 80 °C as thermal method. The agar diffusion method was used for determination of the antibacterial activity of the samples against *Escherichia coli* (*E. coli*). The antibacterial properties against *E.coli* were observed because of the presence of AgNP. Based on the results, the curcumin loading and release was affected by temperature and PEG. The curcumin-AgNP nanoparticle can have a good potential for antibacterial activity and loading and release of the drug.

Keywords: *Antibacterial Activity, Curcumin, Poly Ethylene Glycol, Silver Nanoparticle, Temperature*

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INTRODUCTION

In the recent century, the world economy is leading by producing knowledge and ideas. In the last decade, the attention has been expanded to application of nanomaterial in different field because of unique properties that resulted in small size and high surface area (1-4). The nanotechnology can revolutionize the food industry with all its innovations (5-6). Recently, there are many signs of progress in the use of nanotechnology in the food industry in different parts such as processing, packaging and storage of food processing (7-10). Biotechnology and bioengineering are expanded in the quality assurance of foods (11-12). The nano-carriers can protect bioactive compounds such as flavoring, coloring, preservative agents (13-14). Curcumin is a well-known bioactive component as food application with yellow color from rhizomes of the Curcuma longa plant. This main polyphenolic nutraceutical compound of Turmeric has a long history of dietary applications for enhancing taste and color and medicinal use with antioxidant and anticancer properties (15-17). For decreasing of poor water solubility, curcumin can be conjugate with metal NPs like gold (18-19) or silver (20-22) and hydrophilic polymers like poly ethylene glycol (23).

Silver has a long history as products with hygienic effects for thousands of years. Silver was added to the drinking water for space men using

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NASA as bacterial growth inhibitor (24-25). The chemical methods are more widely used among different methods for preparation of silver metal nanoparticles (26-28). Recently, silver nanoparticle was reported by green synthesis using banana powder as a reducing and stabilizing agent (29). Synthesis of silver nanoparticle was reported in poly vinyl pyridine (PVP) (30-31). PEG can be used for synthesis of the silver nanoparticle as a capping agent for lipid drugs to enhance their water solubility and used to improve release property (32). The antibacterial effect was expanded as one of the important applications of nanomaterial (29, 33). Loo and coworkers were investigated antibacterial activity for silver nanoparticles and curcumin nanoparticles AgNPs and curcumin nanoparticles (Cur-NPs) against both Gram-negative (*Pseudomonas aeruginosa*) and Gram-positive (*Staphylococcus aureus*) microorganisms (34). Ravindra and coworkers were investigated antibacterial activity for curcumin loaded poly(AM-co-AMPS) hydrogel-silver nanocomposites against *Escherichia coli* (35). Jaiswal and coworkers have investigated antibacterial activity investigated for curcumin-silver nanoparticles with size 25-35 nm against both Gram-positive and Gram-negative bacteria by minimum inhibitory concentration (MIC = 5 mg/L) (36).

The objective of this study was to develop the production of curcumin-silver nanoparticle by chemical method and evaluation of the effect of polyethylene glycol and temperature. The curcumin-silver nanoparticle was synthesized at room temperature (as solution method) and 80 °C (as thermal method) in two solvents of water and poly ethylene glycol. PEG can be used for synthesis of silver nanoparticle as a capping agent for curcumin as lipid materials to enhance their water solubility and used to improve release property. The zone inhibition was examined against Escherichia coli through diffusion method for antibacterial activity. To the best of the authors' knowledge, at the present time, there are no reports available in the literature on the synthesis of the curcumin-silver nanoparticle in present of PEG at two temperatures.

MATERIALS AND METHODS

Materials and instruments

Curcumin, silver nitrate ($AgNO_3$), polyethylene glycol (PEG) (6000 molecular weight) and sodium bore hydrate ($NaBH_4$) were purchased from Merk (Darmshtadt Germany).

Fourier transforms infrared spectra recorded using a Nicolet 380 Fourier transforms infrared spectroscopy (FTIR) spectrophotometer (Thermo electron corporation, USA). The X-ray diffraction (XRD) patterns of the products were collected utilizing Cu Kα X-ray radiation with a voltage of 40 kV and a current of 30 mA by X'pert pro diffractometer (EQUI NOX 3000 model, France). Scanning electron microscope (SEM) (S4160 model, HITACHI, Japan) was employed to observe the morphology and size. The thermo gravimetric analyses (TGA) were carried out at 700°C under nitrogen gas flow to assess the chemical composition (Mettler Toledo model, TGA-SF1, Swiss). The release of AgNP-curcumin and AgNP-curcumin in present of PEG was investigated at 37°C for curcumin as poor water solubility material. The antibacterial activities were evaluated by disk diffusion method against *Escherichia coli* bacteria, ATCC 1399, that procured from Islamic Azad University.

Preparation of samples

Silver nanoparticles were obtained by a simple chemical method using silver nitrate as precursor and sodium bore hydrate as a reducing agent. At first, solution A was perpetrated by dissolving silver nitrate solution (0.01 M) in distilled water that added sodium bore hydrate (0.02 M) drop by drop to this solution. The stoichiometric ratio of precursor is based on previous reports (37). During the process, solutions were mixed vigorously for 1 h in two conditions at 25 and 80 °C. Then the solution was centrifuged at 10,000 rpm for 10 min and the supernatant was discarded. The products were washed for three times using distilled water to remove the by-products and the excess precursor and dried in oven. At second, solution B was perpetrated by dissolving PEG (2% w) in solution A that mixed vigorously for 1 h in two conditions at 25 and 80 °C. The percent of PEG is based on previous reports (38). In typical experiment of curcumin-AgNP preparation, solutions were prepared in presence of curcumin (0.001 M) vigorously for 1 h in two conditions at 25 and 80 °C.

RESULT AND DISCUSSION

FTIR

The FTIR spectra for curcumin and curcumin-AgNP are shown in Fig. 1. The peaks at 460 and 540 cm^{-1} in curcumin were transferred to 511 and

582 cm^{-1} which related to CH groups of curcumin. The peak at 958 cm^{-1} was related to benzene ring which shifted to 1120 cm^{-1} because of interaction curcumin and AgNP. The peak at 1054 cm^{-1} was related to C-O-C and C-O. The peaks at 1153 and 1182 cm^{-1} were assigned to inner aromatic bonds of CCH. The weak peak at 1269 and 1271 cm^{-1} were related to C-H binding. The peaks around 1315 and 1462 cm^{-1} were related to enol bonds (C=O) which showed the crystal structure of curcumin and shifted to 1384 and 1456 cm^{-1} after interaction with AgNP. The peak at 1627 cm^{-1} was related to aromatic ring of C=C which shifted to 1643 cm^{-1} because of interaction curcumin and silver nanoparticle and signed crystalline structure of curcumin. The peaks at 1639 and 1635 cm^{-1} were related to C-C binding. The peaks at 2925 and 2921 cm^{-1} were related to CH_3 and OCH_3 binding between curcumin and silver nanoparticle. The peaks at 2960 and 2931 cm^{-1} were related to C-H group. The peak at 3504 cm^{-1} was related to phenol binding which shifted to 3515 cm^{-1} after interaction curcumin and silver nanoparticle. The peaks between 3400 and 3600 cm^{-1} were showed the O-H group. In present of

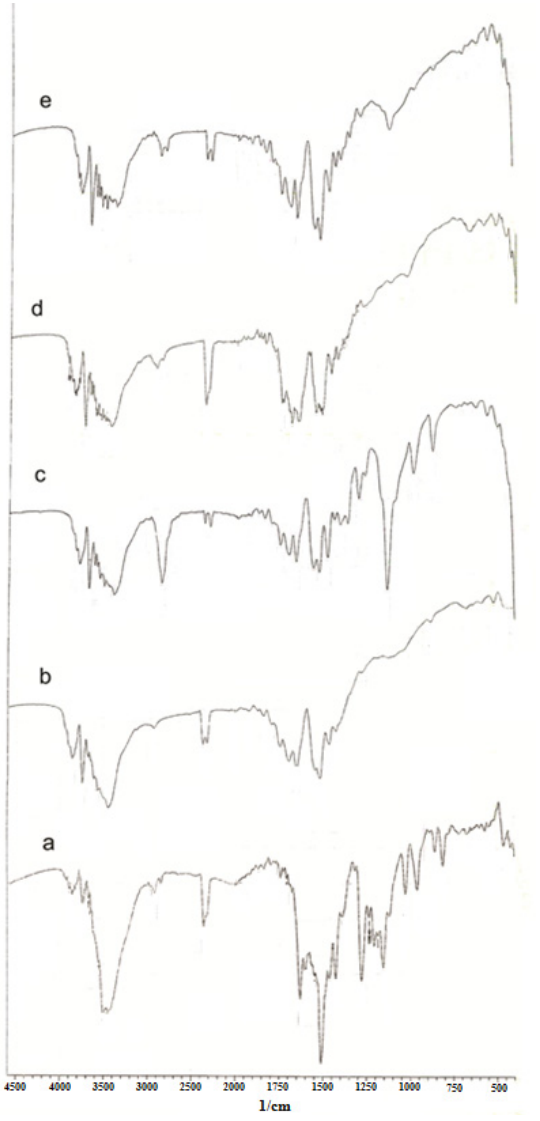

Fig. 1: FTIR (a) Curcumin (b) AgNP (c) AgNP in present of PEG (d) AgNP-curcumin (e) AgNP-curcumin in present of PEG.

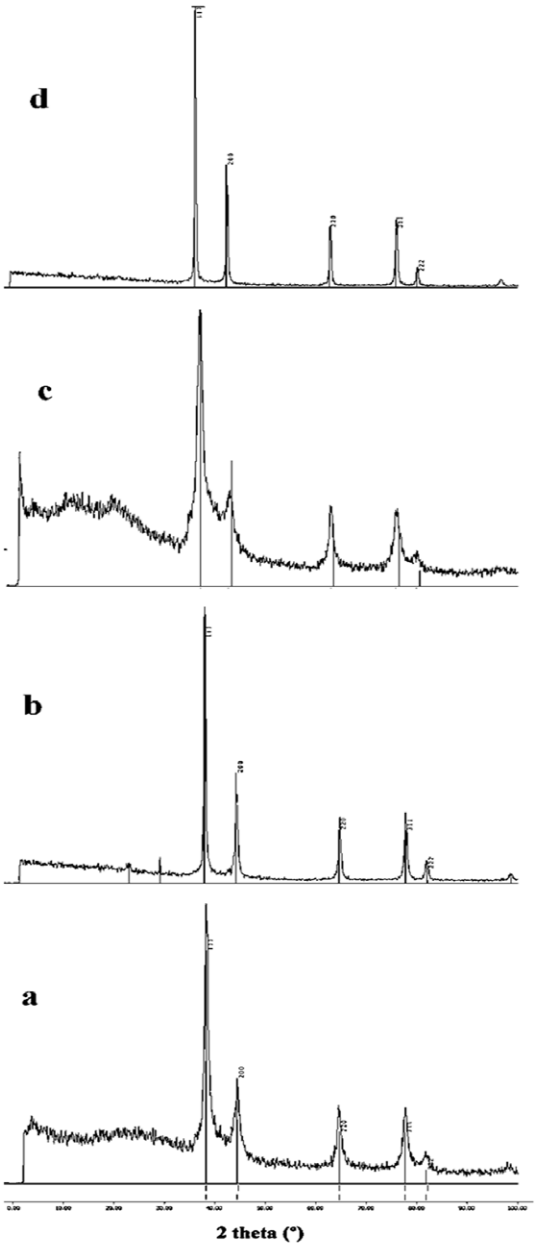

Fig. 2: XRD (a) AgNP (b) AgNP in present of PEG, (c) AgNP-curcumin (d) AgNP-curcumin in present of PEG.

PEG, the peak at 3504 cm^{-1} in curcumin curve is shifted to 3564 cm^{-1} and the peak at 2921 cm^{-1} was related to C-H (CH_3, OCH_3) that shifted to 2920 cm^{-1}. The pure curcumin and curcumin-Ag NPs peaks are according to Kundu and Nithiyanantham studies (39).

XRD

The XRD pattern of the sample was measured in 2θ range 0-120° with 1.54°A wavelength that used to identify the crystalline structure of silver nanoparticles and their changes after addition of PEG and curcumin solution. It has been found that four strong peaks at 38.2°, 44.3°, 64.5°, 77.5° and 83.2° attributed to (111), (200), (220), and (311) crystal planes of AgNP respectively. Based on the result, the crystalline structure of silver nanoparticle was maintained in AgNP in present of PEG, AgNP-curcumin, and AgNP-curcumin in present of PEG. The XRD pattern of samples remained the same in present of temperature and PEG.

SEM microscopy

The size and the morphology of nanostructures were investigated using SEM images. SEM was shown nanoparticles with different size via changes of synthesis condition. AgNP and AgNP-curcumin were spherical shape with the same size that measured average diameter of 100 nm and 120 nm at 25 and 80°C respectively. Considering the results, increase of temperature caused to increase of nanoparticle size at the same time because of increase of irreversible collision.

In the present of PEG, AgNP and AgNP-curcumin were spherical shape with same size that measured average diameter of 90 nm and 100 nm at 25 and 80 °C respectively. Based on the result, increase of temperature and present of PEG caused to increase and decrease of nanoparticle size respectively. In fact, PEG has prevented growth of nanoparticle and acted as a capping agent. The present of temperature and PEG were caused by the increase and decrease of AgNP size respectively.

The increase in the size of nanoparticle was observed due to increase temperature and present of PEG. The selection of optimum condition was related to curcumin loading and release percentage.

TGA

Thermo gravimetric analysis has been recorded by heating under a nitrogen atmosphere in the temperature range from 25 to 80 °C at a constant rate of 20 °C/min. TGA is commonly used to determine of materials by decreasing of a known mass of sample that exhibits either mass loss due to decomposition, oxidation, or loss of volatiles such as moisture. Thermal degradation temperature curcumin is between 350-400°C, therefore the

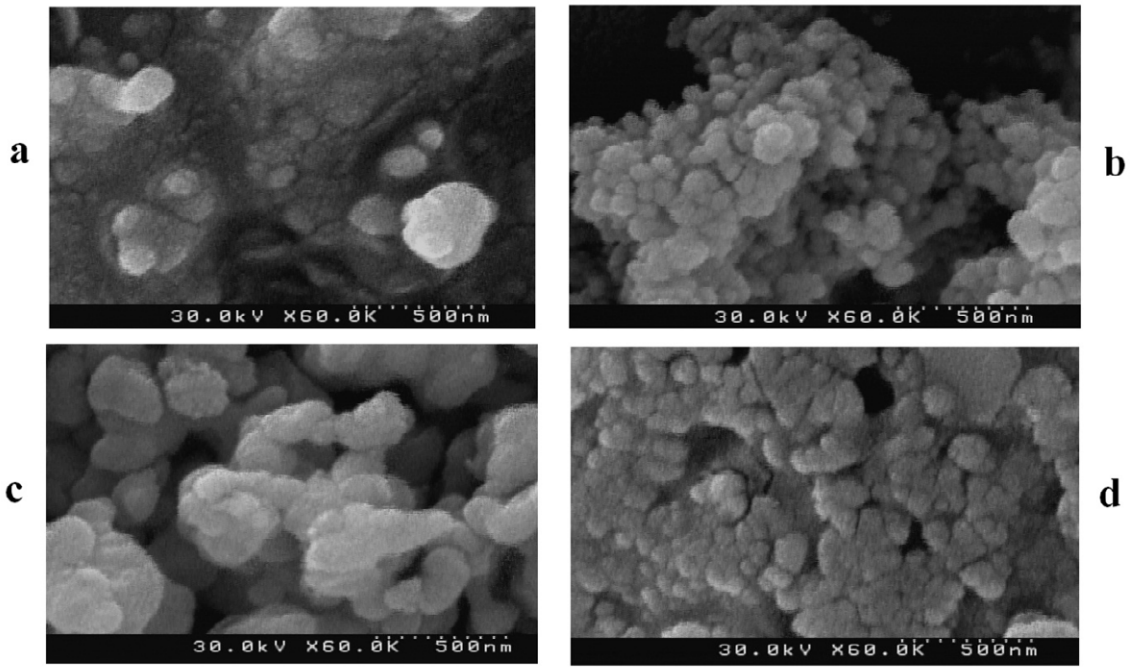

Fig. 3. SEM (a) AgNP at 25 °C, (b) AgNP-curcumin at 25 °C, (c) AgNP at 80 °C, and (d) AgNP-curcumin at 80 °C.

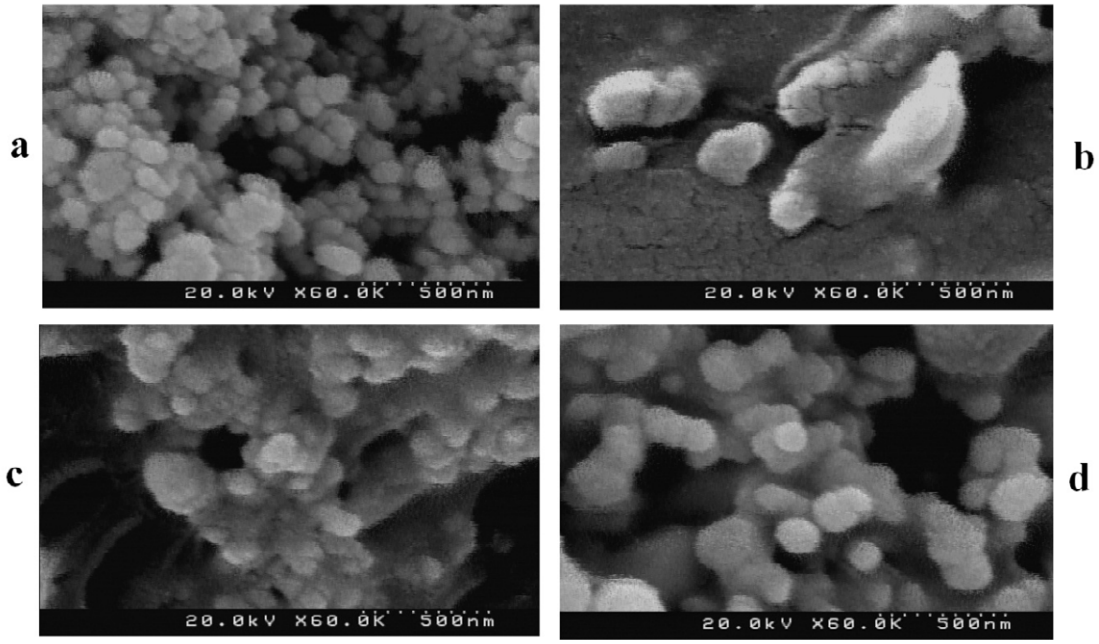

Fig. 4. SEM in present PEG (a) AgNP at 25 °C, (b) AgNP at 80 °C, (c) AgNP-curcumin at 25 °C, and (d) AgNP-curcumin at 80 °C.

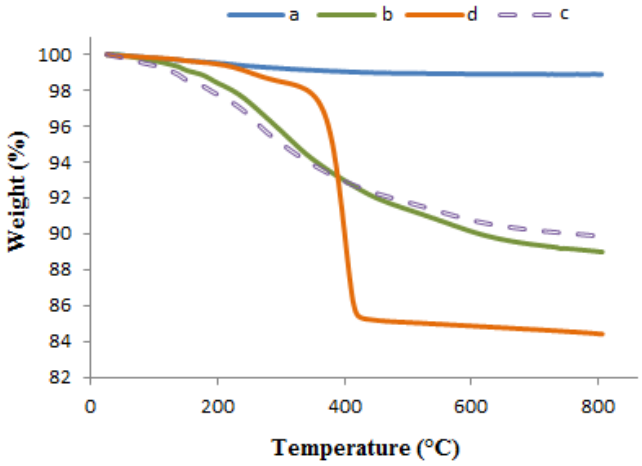

Fig. 5. TGA (a) AgNP-curcumin at 25 °C, (b) AgNP-curcumin at 80 °C, (c) AgNP-curcumin in present PEG at 25 °C, and (d) AgNP-curcumin in present PEG at 80 °C.

loading percentage reaches. Based on the TGA result, the curcumin loading was about 14% for AgNP in present of PEG at 80 °C and about 9% for AgNP in present of PEG at 25 °C and AgNP at 80 °C. The least curcumin loading was about 1% for AgNP at 25 °C. The curcumin loading percentage increased in present of temperature and PEG.

Release study

Based on the result of curcumin release, the burst release was observed in the early hours consists of simple diffusion of weakly bonded molecules. Also, the present of PEG caused to the increase of curcumin release. Based on the results, curcumin release of AgNP shows that samples are as following: in present of PEG at 80 °C > AgNP in present of PEG at 25 °C > AgNP at 80 °C > AgNP at 25 °C. The curcumin release percentage increased in present of temperature and PEG.

Antibacterial activity

In this study,the minimum inhibitory

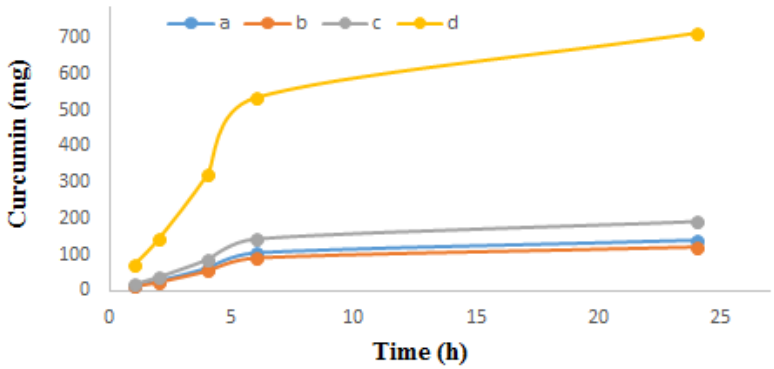

Fig. 6. Release study of curcumin from synthetized AgNP (a) at 25 °C, (b), at 80 °C (c), in present PEG at 25 °C and (d) in present PEG at 80 °C.

concentration (MIC) was investigated for determination antibacterial activity of samples against *E.coli*. Based on the result, the MIC was 0.0005 M for all samples and present of curcumin and PEG didn't effect on the antibacterial activity. Considering this result, the size of all particles was on a nanometer scale about 90 to 120 nm and didn't effect on the antibacterial activity. The good antibacterial activity was observed for AgNP-curcumin against *Escherichia coli* which is in line with the studies of other researchers for another microorganisms and compositions (34-36).

CONCLUSION

A simple method was used for the preparation of AgNP, AgNP in present of PEG, AgNP-curcumin, and AgNP-curcumin in present of PEG at 25 and 80 °C that combined reduction of $AgNO_3$ by $NaBH_4$. The AgNP at nano-carrier is a good candidate to the active component of poor water solubility for food application. The presence of AgNP caused to antibacterial properties against *E.coli*. The XRD pattern of samples remained the same in present of PEG and at 80 °C. Respectively the present of temperature and PEG were caused by the increase and decrease of nanoparticle size in the other words AgNP had smaller size at 25 °C with PEG. The loading and release percentage of curcumin increased in present of PEG at 80 °C.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this manuscript.

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