# Green Synthesis Silver Nanoparticles using Quercus infectoria Gall

*Oka Shinta Sekar* Kirana, *Fatimah Nurus* Shobah, *Zulfa Syaifana* Muslih, *Ade Irma* Rozafia, *Wahyu Prasetyo* Utomo, *and Djoko* Hartanto*

Institut Teknologi Sepuluh Nopember, Chemistry Department, 60111 Surabaya, Indonesia

**Abstract**. In this study, green synthesis of silver nanoparticles (AgNPs) was conducted using Quercus infectoria Gall (QIG) extract with AgNO3/QIG extract volume ratios of 1:1, 4:1, and 8:1. The synthesis successfully resulted in AgNPs, indicated by a color change to orange- brown and analyzed using UV-Vis spectrophotometer, yielding wavelengths in the range of 425 nm to 440 nm. Subsequently, each AgNP was analyzed using a particle size analyzer, resulting in particle diameter sizes of 5.48 nm, 79.88 nm, and 108 nm, respectively, and their stability was analyzed using a zeta sizer, yielding zeta potentials of -52.18 mV, -48.01 mV, and -24.86 mV.

## 1 Introduction

Silver nanoparticles (AgNPs) are commonly synthesized using chemicals, such as sodium citrate [1], sodium borohydride [2]. These chemicals serve as reducing agents for silver ions [2]. However, the use of these chemicals has drawbacks, namely toxicity [3], and the synthesis process requires high pressure and temperature [4, 5]. Therefore, an alternative method for AgNP formation can be achieved through green synthesis using plant extracts as reducing agents for silver ions [6]. Green synthesis using plant extracts is considered advantageous compared to the aforementioned chemicals, as it is environmentally friendly, sustainable, simple, non-toxic, efficient, and does not require high energy [7]. Plant extracts can act as reducing agents for silver ions due to their content of phenolic compounds capable of binding with metal ions [8]. AgNPs synthesized via green synthesis using plant extracts can also be applied in various fields and exhibit performance comparable to nanoparticles synthesized using hazardous chemicals [9].

Research has been conducted on the successful AgNPs synthesized via green synthesis using plant extracts, including durian peel extract [10], sugarcane leaf extract [11], *D. erecta* fruit extract [12], *T. chebula* fruit extract [13], and soapberry pericarp extract [14]. In the process of AgNP formation using plant extracts, certain compounds play a crucial role as reducing agents for silver ions, namely phenolics [8]. Phenolics are compounds rich in hydroxyl groups capable of binding with silver ions and stabilizing AgNPs [15]. One plant rich in phenolic compounds is *Quercus infectoria* Gall (QIG), primarily containing tannic acid, gallic acid, and ellagic acid [16, 17]. Hence, a problem arises regarding the influence of the $AgNO_3$/QIG extract volume ratio on the characteristics of AgNPs. In this study, the performance of AgNPs synthesized via green synthesis using QIG is influenced by the ratio of silver nitrate precursor volume to QIG extract volume. This ratio affects the size and stability of the resulting AgNPs [12].

* Corresponding author: djokohar@its.ac.id

## 2 Materials and Methods

The material used here are silver nitrate ($AgNO_3$, *p.a.* Merck), *Quercus infectoria* gall, distilled water Milli-Q.

Silver solution is made from silver nitrate precursor. Silver nitrate is weighed and then dissolved using distilled water.

QIG is ground using a chopper and then dried in an oven at 60°C for 24 hours. The dried QIG is then weighed, added with distilled water, and stirred at 60°C for 1 hour.

AgNPs are synthesized via green synthesis by mixing silver nitrate solution with QIG extract with a concentration of 1:1 at volume ratios of 1:1, 4:1, 8:1. The silver solution is stirred at 50°C, then QIG extract is added, and stirring is continued at 50°C for 1 hour. After 1 hour, AgNPs are analyzed using UV-Vis spectrophotometer, particle size analyzer, and zeta sizer.

Analysis of AgNPs synthesized via green synthesis with QIG extract is performed using a Thermo Scientific Genesys 10S UV-Vis spectrophotometer. The analysis of AgNP size and stability is performed using the Malvern Panalytical particle size analyzer-zeta sizer.

## 3 Result and Discussion

AgNPs are synthesized by mixing silver precursor which is silver nitrate solution with QIG extract at volume ratios of 1:1, 4:1, 8:1. In this study, AgNPs are synthesized using QIG extract because it contains phenolic compounds [18] rich in hydroxyl functional groups [19] that act as reducing agents for silver ions [20]. Reduction of silver ions can occur because hydroxyl functional groups undergo oxidation to form quinone functional groups, producing free electrons [21]. These free electrons then reduce silver ions [22]. After silver ions are reduced, the process of AgNP formation occurs [23]. Silver nitrate solution is colorless, and QIG extract is also colorless. However, when they are mixed, a color change occurs in the solution to orange-brown. This color change, as observed, is consistent with previous research findings [24-27]. This color change indicates the formation of AgNPs [28]. The color changes for each volume ratio of $AgNO_3$/QIG extract are shown in Figure 1.


**Fig. 1.** Colors of Solution (a) QIG Extract, (b) AgNO3, Ratio of AgNO3/QIG Extract (c) 1:1, (d) 4:1, (e) 8:1.

From the four variations of the $AgNO_3$/QIG extract ratio, it has been observed that AgNPs are successfully formed through the color change in the solution. Furthermore, to confirm the successful formation of nanoparticles, analysis is conducted using a UV-Vis spectrophotometer. The wavelength results of AgNPs for each ratio are analyzed at 1 hour synthesis time as shown in Figure 3.2. From the UV-Vis spectrophotometer results, it can be observed that as the ratio of $AgNO_3$/QIG extract increases, new peaks become more apparent at wavelengths in the range of 425 nm to 440 nm. This is also consistent with the reported wavelengths of AgNPs earlier [29-32].

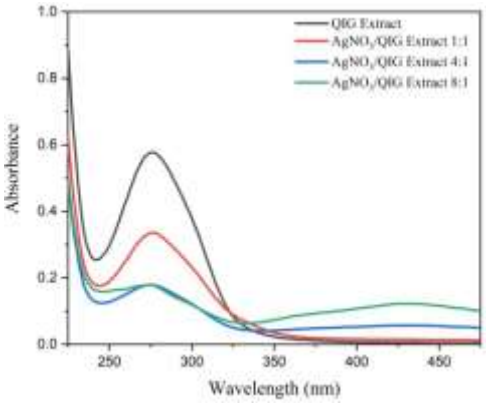


**Fig. 2.** UV-Vis Spectra of AgNP.

From the UV-Vis spectra results, it can be observed that AgNPs have been successfully formed at all ratios. Next, the formed AgNPs are analyzed for their size using a particle size analyzer and their stability using a zeta sizer. The size and stability of AgNPs for each $AgNO_3$/QIG extract ratio are displayed in Figure 3 and Table 1. Based on Figure 3, it can be observed that as the volume ratio of $AgNO_3$/QIG extract increases, the diameter size of the resulting AgNPs also increases. This can occur because the ratio of metal ions is greater than the QIG extract [33, 34], where the QIG extract not only functions as a reducing agent but also as a stabilizing agent that prevents agglomeration [35, 36]. The ability of the QIG extract as a stabilizing agent for AgNPs can also be observed from the results of the zeta potential. Based on Table 1, it can be seen that the 1:1 ratio has the highest zeta potential value. Zeta potential values greater than 30 mV indicate that the nanoparticles produced tend to have difficulty in agglomeration [37], while negative values indicate their charge [38]. From the three zeta potential results, it can be concluded that AgNPs synthesized using QIG extract have been successfully formed and possess good stability. The 8:1 ratio has the lowest zeta potential value, which can occur because the ratio of metal ions is greater than the QIG extract, making the AgNPs tend to be unstable due to the limited amount of QIG extract acting as a stabilizing agent. However, at the 8:1 ratio, its stability is still relatively good as its zeta potential value is not too far from 30 mV.

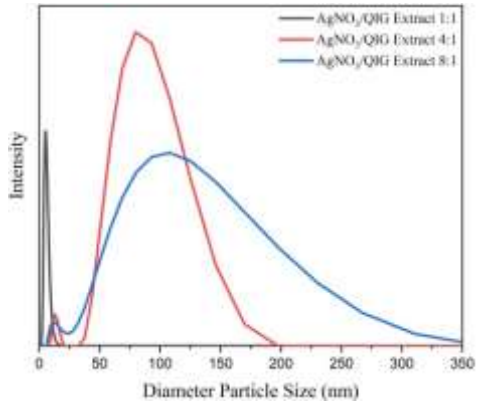


**Fig. 3.** Particle Size of AgNP.

**Table 1.** Stability of AgNP.

| $AgNO_3$/QIG Extract | Zeta Potential Value (mV) |
|---|---|
| 1:1 | -52.18 |
| 4:1 | -48.01 |
| 8:1 | -24.86 |

## 4 Conclusion

Green synthesis of AgNPs using QIG extract has been successfully achieved at volume ratios of $AgNO_3$/QIG extract 1:1, 4:1, 8:1. The formation of AgNPs is indicated by the orange-brown colored solution, which is then analyzed using a UV-Vis spectrophotometer, revealing peaks at wavelengths in the range of 425 nm to 440 nm. Each AgNP is analyzed for its size using a particle size analyzer and its stability using a zeta sizer. From the UV-Vis spectra results, it is determined that the most optimal ratio is 8:1.

## References

1. N. Blommaerts, H. Vanrompay, S. Nuti, S. Lenaerts, S. Bals, and S. W. Verbruggen, Small, **15(42)**, e1902791 (2019), doi: 10.1002/smll.201902791.
2. O. Pryshchepa, P. Pomastowski, and B. Buszewski, Adv Colloid Interface Sci, **284**, 102246 (2020), doi: 10.1016/j.cis.2020.102246.
3. N. Sahiner, Molecules, **26(9)**, 2429 (2021), doi: 10.3390/molecules26092429.
4. J. A. Kumar et al., Journal of Cleaner Production, **324**, 129198 (2021), doi: 10.1016/j.jclepro.2021.129198.
5. P. Vaid, P. Raizada, A. K. Saini, and R. V. Saini, Sustainable Chemistry and Pharmacy, **16**, 100247 (2020)
6. A. Wasilewska, U. Klekotka, M. Zambrzycka, G. Zambrowski, I. Święcicka, and B. Kalska-Szostko, Food Chemistry, **400**, 133960 (2023), doi: 10.1016/j.foodchem.2022.133960.
7. G. M. Nair, T. Sajini, and B. Mathew, Talanta Open, **5**, 100080 (2022), doi: 10.1016/j.talo.2021.100080.
8. N. A. I. M. Ishak, S. K. Kamarudin, and S. N. Timmiati, Mater. Res. Express, **6(11)**, 112004 (2019), doi: 10.1088/2053-1591/ab4458.
9. H.P. Borase et al., Appl Biochem Biotechnol, **173 (1)**, 1–29 (2014), doi: 10.1007/s12010-014-0831-4.
10. E. Alzahrani, Journal of Chemistry, **2020**, e4712130 (2020), doi: 10.1155/2020/4712130.
11. N. Srikhao, P. Kasemsiri, N. Lorwanishpaisarn, and M. Okhawilai, Res Chem Intermed, **47(3)**, 1269– 1283, (2021), doi: 10.1007/s11164-020-04354-x.
12. M. Ismail, M. I. Khan, K. Akhtar, M. A. Khan, A. M. Asiri, and S. B. Khan, Physica E: Low- dimensional Systems and Nanostructures, **103**, 367–376, (2018), doi: 10.1016/j.physe.2018.06.015.
13. T. N. J. I. Edison, R. Atchudan, and Y. R. Lee, J Clust Sci, **27(2)**, 683–690, (2016), doi: 10.1007/s10876-016-0972-4.
14. K. Dayanidhi, P. Vadivel, and S. E. Noorjahan, (2023) doi: 10.21203/rs.3.rs-3268563/v1.
15. Y. Feng, P. Li, and J. Wei, Coordination Chemistry Reviews, **468**, 214649 (2022), doi: 10.1016/j.ccr.2022.214649.
16. A. Elham, M. Arken, G. Kalimanjan, A. Arkin, and M. Iminjan, Journal of Ethnopharmacology, **273**, 113592 (2021) doi: 10.1016/j.jep.2020.113592.
17. M. Mahboubi, Clin Phytosci, **6(1)**, 44, (2020) doi: 10.1186/s40816-020-00194-9.
18. A. Elham, M. Arken, G. Kalimanjan, A. Arkin, and M. Iminjan, J Ethnopharmacol, **273**, 113592 (2021) doi: 10.1016/j.jep.2020.113592.
19. J. Chen, J. Yang, L. Ma, J. Li, N. Shahzad, and C. K. Kim, Sci Rep, **10(1)**, 2611 (2020) doi: 10.1038/s41598- 020-59451-z.
20. A. A. Bhutto, Ş. Kalay, S. T. H. Sherazi, and M. Culha, Talanta, **189**, 174–181 (2018) doi: 10.1016/j.talanta.2018.06.080.

21. C. Gangwar, B. Yaseen, I. Kumar, N. K. Singh, and R. M. Naik, ACS Omega, **6(34)**, 22344–22356 (2021) doi: 10.1021/acsomega.1c03100.
22. Y.-S. Liu, Y.-C. Chang, and H.-H. Chen, Journal of Food and Drug Analysis, **26(2)**, 649–656 (2018) doi: 10.1016/j.jfda.2017.07.005.
23. Z. A. Ratan et al., Cancers, **12(4)**, 4 (2020) doi: 10.3390/cancers12040855.
24. N. Gautam et al., Proc. Natl. Acad. Sci., India, Sect. B Biol. Sci., **90(2)**, 439–446 (2020), doi: 10.1007/s40011-019-01115-8.
25. M. Ansari et al., Sci Rep, **13(1)**, 18048 (2023), doi: 10.1038/s41598-023-45038-x.
26. K. Chand et al., Arabian Journal of Chemistry, **13(11),** 8248–8261 (2020) doi: 10.1016/j.arabjc.2020.01.009.
27. D. Das, M. S. Haydar, and P. Mandal, J Inorg Organomet Polym, **31(4),** 1527–1548 (2021) doi: 10.1007/s10904-020-01794-1.
28. V. Soni et al., Environmental Research, **202**, 111622 (2021) doi: 10.1016/j.envres.2021.111622.
29. M. R. Shaik et al., Sustainability, **10(4)**, 4 (2018) doi: 10.3390/su10040913.
30. S. Jain and M. S. Mehata, Sci Rep, **7(1)**, 15867 (2017) doi: 10.1038/s41598-017-15724-8.
31. P. Roy, B. Das, A. Mohanty, and S. Mohapatra, Appl Nanosci, **7(8)**, 843–850 (2017) doi: 10.1007/s13204-017-0621-8.
32. F. Ali et al., ChemistrySelect, **8(43),** e202301889 (2023) doi: 10.1002/slct.202301889.
33. K. D. Dejen et al., Materials Technology, **38(1)**, 2164647 (2023) doi: 10.1080/10667857.2022.2164647.
34. I. Rehman et al., Nanomaterials, **13(8)**, 8 (2023) doi: 10.3390/nano13081343.
35. S. Pedroso-Santana and N. Fleitas-Salazar, Particle & Particle Systems Characterization, **40(2)**, 2200146 (2023) doi: 10.1002/ppsc.202200146.
36. H. Wan, S. Habib, H. Liu, and S. Mahmud, Results in Surfaces and Interfaces, **14**, 100194 (2024) doi: 10.1016/j.rsurfi.2024.100194.
37. A. Serrano-Lotina, R. Portela, P. Baeza, V. Alcolea-Rodriguez, M. Villarroel, and P. Ávila, Catalysis Today, **423**, 113862 (2023) doi: 10.1016/j.cattod.2022.08.004.
38. P. Liu, B. Li, D. Yang, C. Zhang, and P. Ming, Journal of Power Sources, **556**, 232427 (2023) doi: 10.1016/j.jpowsour.2022.232427.