Jurnal Pijar MIPA
https://jurnalfkip.unram.ac.id/index.php/JPM

ISSN 1907-1744 (Print)
ISSN 2460-1500 (Online)

Green Synthesis Gold Nanoparticles using Bioreductant Red Shoot Leaf Extract (*Syzygium myrtifolium* Walp.) and Activity as Antioxidant

Neni Isna Farihah, Titik Taufikurohmah*

Departement of Chemistry, Faculty of Mathematic and Natural Science, Universitas Negeri Surabaya, Surabaya, Indonesia
*E-mail: titiktaufikurohmah@unesa.ac.id

Received: June 23, 2024. Accepted: July 16, 2024. Published: July 30, 2024

Abstract: Gold nanoparticles (AuNPs) are small-sized materials important in various commercial and industrial applications. Several methods have been developed to synthesise AuNPs. This study was conducted by synthesizing AuNPs using $HAuCl_4$ as a precursor and red shoot leaf extract as a bioreductor. The concentrations of AuNPs used were 20, 10, 5, and 2.5 ppm. Characterization of gold nanoparticles at a concentration of 20 ppm was carried out using a UV-Vis spectrophotometer to measure the maximum wavelength and Transmission Electron Microscopy (TEM) to determine particle size. Antioxidant activity at 20, 10, 5, and 2.5 ppm was determined by measuring free radical capture activity using the *1,1-diphenyl-2-picrylhydrazyl* (DPPH) method. The results showed that gold nanoparticles had a maximum wavelength of 530 nm with a ruby red color and an average particle size of 14.907 nm. The synthesized AuNPs showed high antioxidant activity: 99.6% (20 ppm), 98.9% (10 ppm), 96.7% (5 ppm), and 91.0% (2.5 ppm), indicating that higher concentrations of AuNPs resulted in more significant free radical scavenging. This study successfully synthesized gold nanoparticles using red shoot leaf extract as an environmentally friendly bioreduction. The resulting nanoparticles have a nanometer particle size with very high antioxidant activity, especially at a concentration of 20 ppm. The method used in this study offers a more environmentally friendly alternative for synthesizing gold nanoparticles, which previously often used hazardous chemicals. The use of red shoot leaf extract as a bioreductor has not been widely reported in the literature, thus providing a new contribution to green nanotechnology. Further research is recommended to explore the potential applications of gold nanoparticles synthesized by this method in medical and other industrial fields. In addition, additional studies are needed to optimize the synthesis conditions and more in-depth characterization of the stability and toxicity of gold nanoparticles in practical applications.

Keywords: Antioxidant Activity; Green Synthesis; Gold Nanoparticles; Red Shoot Leaf Extract.

Introduction

Nanotechnology has revolutionized various industrial applications and has seen exponential growth over the past five decades [1]. This field, encompassing the design, development, and implementation of components sized between 1-100 nm [2], holds significant promise across numerous sectors such as environmental science, agriculture, food technology, biotechnology, biomedicine, and pharmaceuticals [3]. Among the various metallic nanoparticles, gold nanoparticles (AuNPs) have garnered substantial attention due to their ease of synthesis [4] and multifaceted benefits in medical applications, including the treatment of diabetes mellitus, cancer, cardiovascular diseases, tuberculosis, and the mitigation of antibiotic resistance [5]. Moreover, AuNPs exhibit robust and enduring antioxidant properties, making them effective agents against free radicals and Reactive Oxygen Species (ROS), which are implicated in various degenerative diseases [6].

Degenerative diseases caused by oxidative stress and free radicals pose a major global health challenge, with projected increases in mortality rates, as the World Health Organization (WHO) indicates that deaths caused by degenerative diseases will continue to increase. Overall, it is estimated that 52 million people will die each year by 2030, an increase of 14 million people from 38 million people this year. More than two-thirds (70%) of the world's population will die from degenerative diseases. According to the 2018 Riskesdas data, the rate of degenerative diseases in Indonesia reached 65.7%. Overcoming this health problem requires the development of effective antioxidant therapy [6].

Gold nanoparticles are usually synthesized through chemical reactions. Two methods can be used for this: top-down, known as the physical approach, and bottom-up, known as the chemical approach [7]. Although effective, these methods often involve high costs, labour-intensive processes, and potential environmental and biological hazards [8]. In recent years, green synthesis has emerged as a sustainable alternative, utilizing biological entities such as plants for environmentally friendly production of nanoparticles [9].

Red shoot (*Syzygium myrtifolium* Walp.) was identified as a promising bioreductant for the green synthesis of gold nanoparticles. The plant is rich in secondary metabolites, including triterpenoids, steroids, saponins, flavonoids, phenolics, and anthocyanins, which facilitate the reduction of Au^+ ions to Au^0 and also act as capping agents to stabilize the nanoparticles [10]. Although red shoots are new in nanoparticle synthesis, previous studies have demonstrated the potential of plants containing similar secondary metabolites [11].

This research explores the green synthesis of gold nanoparticles using red shoot extract using an infusion method for extraction, which is economical, simple and

How to Cite:
Farihah, N. I., & Taufikurohmah, T. (2024). Green Synthesis Gold Nanoparticles using Bioreductant Red Shoot Leaf Extract (Syzygium myrtifolium Walp.) and Activity as Antioxidant. *Jurnal Pijar Mipa*, *19*(4), 746–752. https://doi.org/10.29303/jpm.v19i4.7171

minimizes thermal degradation of the active compound [12]. The synthesized nanoparticles will be characterized using UV-Vis spectroscopy and Transmission Electron Microscopy (TEM) to determine their optical properties and size distribution. Additionally, the antioxidant activity of the nanoparticles will be assessed through their interactions with the synthetic free radical DPPH, providing insight into their potential efficacy as therapeutic antioxidants. This research aims to increase the usefulness of red shoots in nanoparticle synthesis and contribute valuable information regarding their antioxidant properties.

Research Methods

Materials

The materials used in this research were the leaves of the red shoot plant (*Syzygium myrtifolium* Walp.), aquadest, 1000 ppm $HAuCl_4$ stock solution, filter paper, 96% ethanol solution, and *1,1-diphenyl-2-picrylhydryl* (DPPH) powder.

Extraction of red shoot leaves

Extraction of red shoot leaves was carried out using the infusion method [13]. The red shoot leaves that have been prepared are ground using a blender/copper and put into a 250 mL Erlenmeyer flask with 100 mL of distilled water added (the ratio of sample: distilled water is 3:4). The extraction process was carried out by heating an Erlenmeyer flask containing red shoot leaves using a water bath for 15 minutes, stirring occasionally [14], [15]. Filter using filter paper separates the filtrate and residue to obtain the red shoot leaf extract filtrate. The extraction process for red shoot leaves is shown in Figure 1a.

Synthesis of Gold Nanoparticles with Red Shoot Leaf Extract as a bioreductant

The 1000 ppm $HAuCl_4$ solution was measured in 2 mL and put into a 100 mL volumetric flask. Distilled water as a colorless solution was added to the mark and shaken until homogeneous. The homogenized solution was put into a 250 mL beaker, and 2 mL of red shoot leaf extract was added. Homogenize with a magnetic stirrer at a speed of 300 rpm until the color changes to ruby red [16]. The synthesis of gold nanoparticles is shown in Figure 1b.

Characterization

Gold nanoparticles (20 ppm) were characterized using a UV-Vis spectrophotometer in the range of 200-800 nm to see the maximum wavelength [17], and Transmission Electron Microscopy (TEM) to determine the size of the gold nanoparticles [18].

Antioxidant Activity Test of Gold Nanomaterials Using DPPH

The antioxidant activity test was carried out using a UV-Vis spectrophotometer. The gold nanoparticle solution (20 ppm) was diluted to 10, 5, and 2.5 ppm. Each sample (2 mL) was mixed with 2 mL of 0.003% DPPH solution [19], homogenized, and left for 30 minutes in the dark [20]. Absorbance was measured at λ max DPPH to calculate the percent scavenging of free radicals [21].

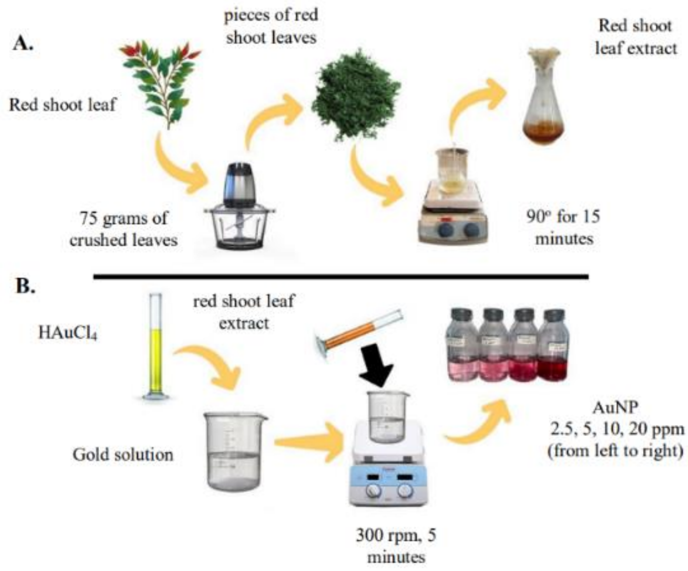

Figure 1. (a) Extraction of red shoot leaf, (b) Synthesis of AuNP using red shoot leaf extract

Results and Discussion

Extraction of red shoot leaves

Red shoot leaves are extracted using the infusion method. Rich in active compounds such as triterpenoids, steroids, saponins, flavonoids, and phenolics [22]. This method was chosen because it is faster and reduces the risk of damage to active compounds due to excessive heating [23]. In addition, the infusion method is more cost-effective and easy to apply to complex plant parts such as leaves and bark [12].

The extraction process includes cleaning fresh red shoot leaves, grinding, and mixing with distilled water as a polar solvent [24]. This mixture was heated at 90°C for 15 minutes to ensure efficient extraction without damaging the active compounds [25]. After heating, the mixture is filtered to separate the filtrate and residue to obtain red shoot leaf extract, which is then used as a bioreduction agent to synthesise AuNPs.

Synthesis of gold nanoparticles

This research synthesized gold nanoparticles using a bottom-up synthesis method that utilized 1000 ppm $HAuCl_4$ stock solution, red shoot leaf extract, and distilled water [5]. The $HAuCl_4$ solution is produced from 1 gram of gold dissolved in aqua regia and diluted to a 1000 ppm solution. Gold dissolution is done by heating to evaporate the gas from the by-product [12]. Red shoot leaf extract rich in flavonoid compounds is used as a reducing agent, converting gold ions (Au^{3+}) into gold nanoparticles (Au^0) [22]. This process is explained in detail in Figure 2a, showing the oxidation-reduction reaction of Au^{3+} ions with flavonoid compounds in red shoot leaf extract. The synthesis process was carried out at room temperature because the secondary metabolite compounds in red shoot leaves are active at this temperature, encouraging the formation of gold nanoparticles.

The reaction mechanism for forming gold nanoparticles using flavonoid compounds is also explained through reduction, oxidation, and disproportionation reactions, which trigger the formation of nanometer-sized gold nanoparticles [26]. The growth process of gold nanoparticles consists of three phases: activation, growth, and termination. The activation phase involves the reduction of gold ions to Au^0, while the growth phase allows small nanoparticles to combine into larger particles spontaneously. The termination phase produces gold nanoparticles with the desired size and structure. This is illustrated in Figure 2b due to the synthesis of gold nanoparticles with a concentration of 20 ppm [26].

Overall, the gold nanoparticle synthesis process using red shoot leaf extract as a reducing agent clearly shows gold nanoparticles' reaction mechanism and growth and potential applications in various scientific fields such as biomedicine and catalysis.

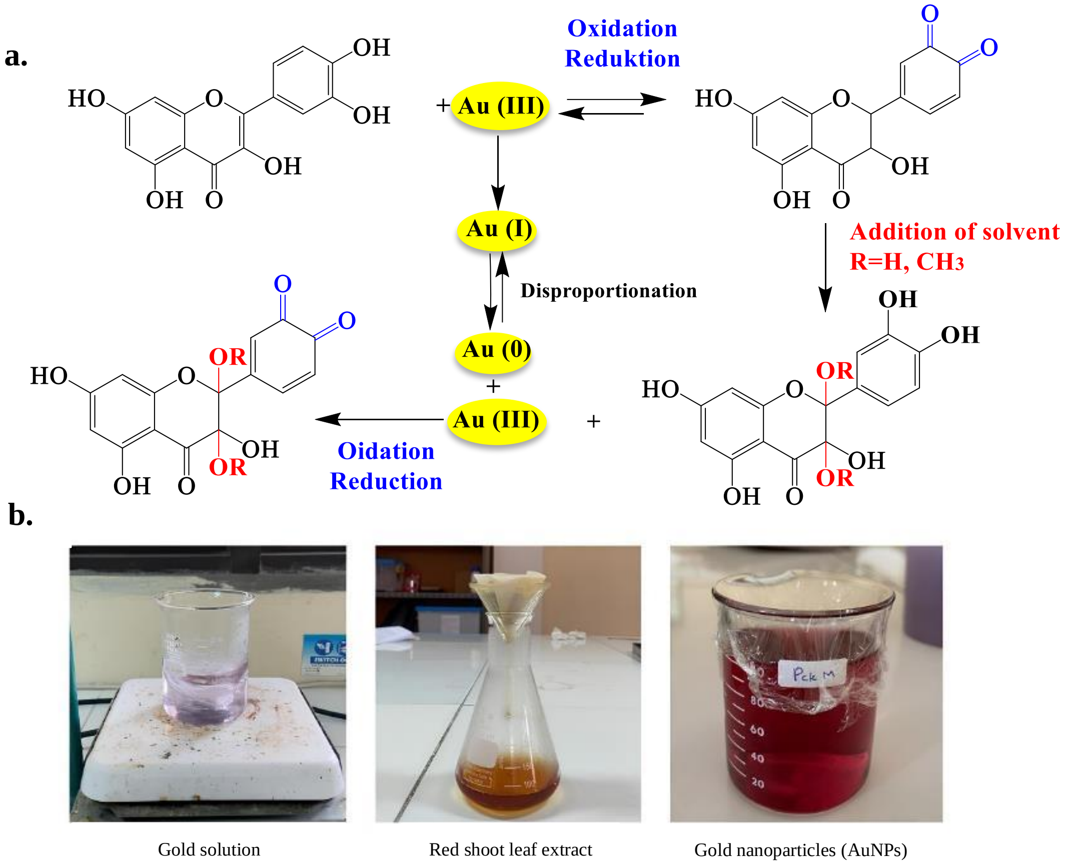

Figure 2. (a) The reaction mechanism for the formation of gold nanoparticles uses flavonoid compounds (b) Gold solution, Red shoot leaf extract, Gold nanoparticles

Characterization of Nanoparticles

The results of the characterization of gold nanoparticles at a concentration of 20 ppm using a Shimadzu 1800 UV-Vis Spectrophotometer show a maximum absorption wavelength at 530 nm with an absorbance of 0.244, as seen in Figure 3. The change in wavelength from 309 nm (the initial wavelength of $HAuCl_4$) to 530 nm indicates the formation of gold nanoparticles, which is an indicator of successful synthesis [27]. Other research by [28], [17] also supports this finding by showing a similar wavelength shift in the 500-600 nm range when the formation of gold nanoparticles occurs.

Apart from the shift in wavelength, the color change from pale yellow to ruby red is also an indicator of successful synthesis [29]. The increasingly intense color at higher concentrations indicates an increase in the density of gold nanoparticles, which can be explained by approaches based on cluster diameter and cluster concentration or density [30]. This can be seen in Figure 4, which illustrates the effect of cluster density on colloid color, where the color density is more caused by the concentration or cluster density at a concentration of 20 ppm.

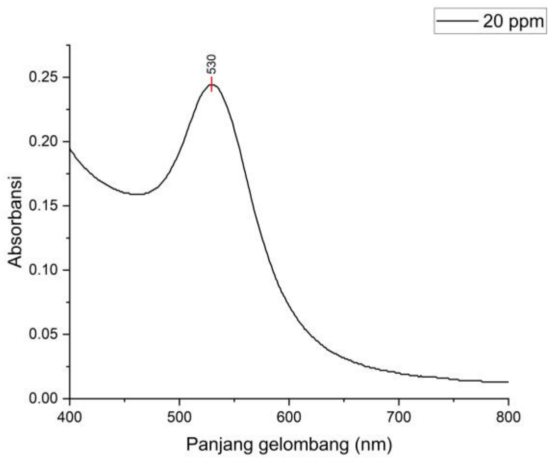

Figure 3. Gold nanoparticle absorption graph

Apart from the shift in wavelength, the color change from pale yellow to ruby red indicates successful synthesis [29]. The increasingly intense color at higher concentrations indicates an increase in the density of gold nanoparticles, which can be explained by approaches based on cluster diameter and cluster concentration or density [30]. This can be seen in Figure 4, which illustrates the effect of cluster density on colloid colour, where the colour density is more caused by the concentration or cluster density at a concentration of 20 ppm.

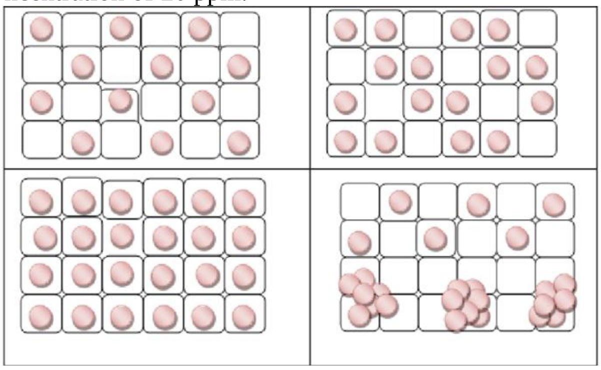

Figure 4. Illustration of the effect of cluster density on colloid color [31]

Characterization using TEM (Transmission Electron Microscopy) on a gold nanoparticle sample with a concentration of 20 ppm (Figure 5) shows that the smallest particle size is 5.89 nm, and the largest is 19,319 nm, with an average particle size of 14,907 nm. The particle size distribution was also analyzed via Origin Lab software, showing particle size variations between 8-22 nm, as shown in Figure 6.

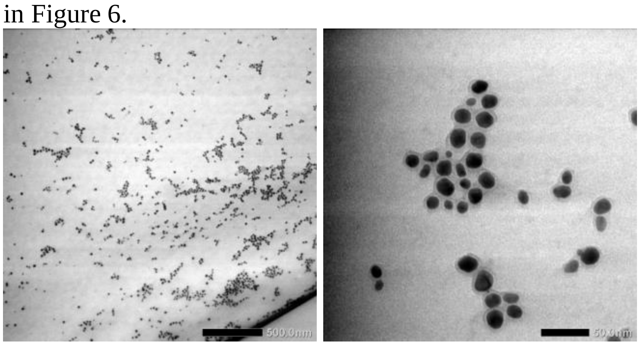

Figure 5. Characterization of 20 ppm gold nanoparticles using TEM (a) magnification 10000 (b) magnification 80000

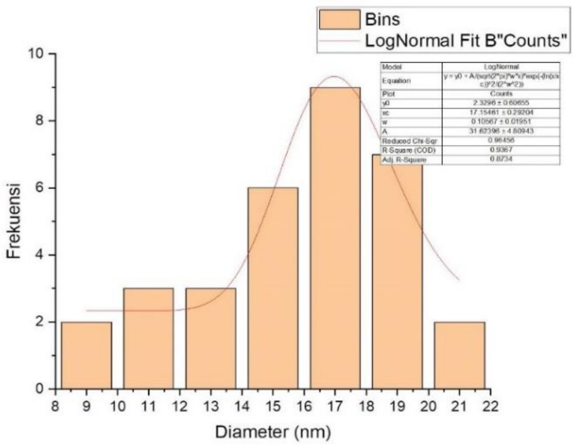

Figure 6. The results at 80,000 magnification were characterized using Image J software

Thus, characterization using a UV-Vis Spectrophotometer and TEM provides comprehensive information about the physical and optical properties of the synthesized gold nanoparticles at a concentration of 20 ppm.

Antioxidant Activity

In testing antioxidant activity, gold nanoparticles were diluted with distilled water to 20 ppm in a 100 mL volumetric flask, resulting in gold nanoparticle concentrations of 10, 5, and 2.5 ppm, as shown in Figure 7. This concentration variation is used to determine the Optimal antioxidant activity of gold nanoparticles synthesized using red shoot leaf extract bioreduction.

Figure 7. The results of the synthesis of gold nanoparticles at a concentration of 2.5; 5; 10; and 20 ppm

The synthesis results with concentrations of 20, 10, 5, and 2.5 ppm were tested for antioxidant activity using the *1,1-diphenyl-2-picryhydrazyl* (DPPH) reduction method. DPPH is an artificial free radical used to test the effectiveness of antioxidant compounds [32]. The principle of reducing free radicals is that when antioxidants interact with free radicals, the color of the solution will change from dark purple to bright yellow [33]. The results of measuring the absorbance of samples at a DPPH wavelength of 517 nm are used to calculate the percent reduction of free radicals.

The test was carried out by preparing 2 mL of sample and 2 mL of DPPH solution, then placing it in a test tube covered with aluminium foil in a 1:1 ratio. The solution mixture was shaken until homogeneous and incubated for 30 minutes for interaction between DPPH and gold nanoparticles. The absorbance measurement results show the percent reduction of DPPH by gold nanoparticles, as recorded in Table 1.

Further analysis showed that the highest antioxidant activity was at a concentration of 20 ppm with a reduction percentage of 99.1%. This shows that red shoot leaf extract has the potential to be a gold nanoparticle bioreductant with high antioxidant activity. The relationship between sample concentration and percent attenuation shows a consistent increase, where the higher the concentration, the higher the percent attenuation of DPPH [24]. Things that can influence the percent attenuation value as a benchmark for determining the level of strength of antioxidant activity include measuring the test material, solubility of the test material, pipetting the sample and DPPH for incubation. The better the researcher's way of conducting this research, the better the R_2 value obtained from each linear regression, namely the line relationship between sample concentration and % inhibition, where a good R_2 value is an R_2 value that is almost 1. This shows a correlation between sample concentration and % inhibition [34].

Based on Figure 8, the linear equation y = 3.8231x + 88.947 is obtained with an R_2 regression of 0.8206, so the average IC_{50} value obtained is 0.0000699 µg/mL, which indicates it has very strong antioxidant activity. The IC_{50} value indicates antioxidant power that inhibits free radicals by 50%. The results of the antioxidant activity test show that gold nanoparticles synthesized using red shoot leaf extract have high antioxidant activity, showing potential as an effective gold nanoparticle bioreductant.

Table 1. Data on the percent reduction of DPPH radicals by gold nanoparticles

Gold nanoparticle concentration (ppm)	DPPH Absorbance	Absorbance of gold nanoparticles + DPPH (A)	The absorbance of gold nanoparticles (B)	A-B	% Inhibition
2,5		0.083	0.046	0.037	91.0%
5	0.409	0.099	0.086	0.013	96.7%
10		0.137	0.132	0.005	98.9%
20		0.233	0.229	0.004	99.1%

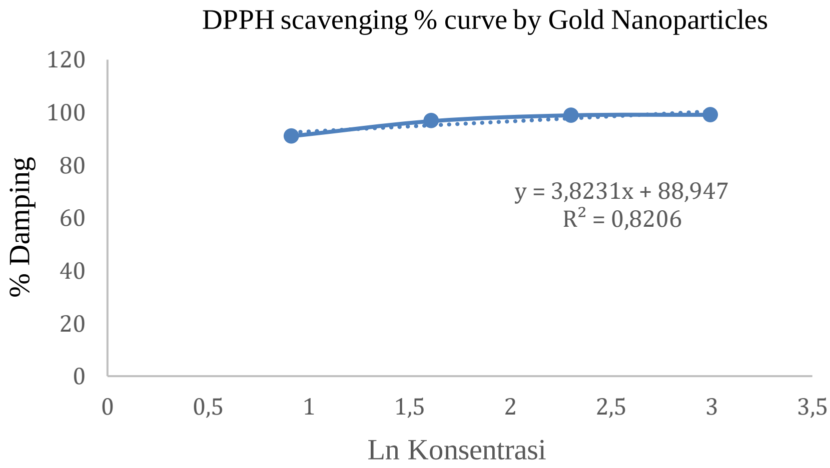

Figure 8. Percent DPPH reduction curve by gold nanoparticles

Conclusion

The results of green synthesis of gold nanoparticles using a bioreductant from red shoot leaf extract (*Syzygium myrtifolium* Walp.) are ruby red, with a maximum wavelength of 535 nm and an average particle size of 14,907 nm. The results of the antioxidant activity test show that gold nanoparticles synthesized using the bioreduction extract of red shoot leaves (*Syzygium myrtifolium* Walp.) have high antioxidant activity, as seen from the results of the percent reduction, namely 99.1% (20 ppm), 98.9% (10 ppm), 96.7 % (5 ppm), and 91.0 (2.5 ppm) this shows that the relationship between the sample concentration and the percent scavenging of free radicals increases from low concentration to high concentration, where the higher the concentration, the higher the percent scavenging of free radicals.

Acknowledgements

First of all, thank you to the Universitas Negeri Surabaya, especially the chemistry department and faculty of mathematics and natural sciences, which has provided the opportunity and support in carrying out this research, and I would like to thank the gold nanoparticle team who have provided moral support and motivation during this research.

References

[1] Afolalu, S. A., Kayode, J. F., Monye, S. I., Lawal, S. L., & Ikumapayi, O. M. (2023). An overview of nanotechnology and its potential risk. In *E3S Web of Conferences* (Vol. 391, p. 01080). EDP Sciences.

[2] Bharadwaj, K. K., Rabha, B., Pati, S., Sarkar, T., Choudhury, B. K., Barman, A., ... & Mohd Noor, N. H. (2021). Green synthesis of gold nanoparticles using plant extracts as beneficial prospect for cancer theranostics. *Molecules*, *26*(21), 6389.

[3] Altammar, K. A. (2023). A review on nanoparticles: characteristics, synthesis, applications, and challenges. *Frontiers in microbiology*, *14*, 1155622.

[4] Erlangga, T. M. S., Nandiyanto, A. B. D., & Fiandini, M. Analisis Tekno-Ekonomi pada Produksi Nanopartikel Emas (AuNP) dengan Metode Biosintesis menggunakan Sargassum horneri pada Skala Industri. *Jurnal Teknik Industri*, *1*(2), 103-110.

[5] Sari, D. N., & Taufikurohmah, T. (2019). Pengaruh Penambahan Nanogold Terhadap Aktivitas Antioksidan Ekstrak Gambir (Uncaria gambir Roxb.) Effect Of Nanogold Addition Toward Antioxidant Activity Of Extract Gambir (Uncaria gambir Roxb.). *UNESA Journal of Chemistry*, *8*(1).

[6] Ibroham, M. H., Jamilatun, S., & Kumalasari, I. D. (2022, October). A Review: Potensi tumbuhan-tumbuhan di Indonesia sebagai antioksidan alami. In *Prosiding Seminar Nasional Penelitian LPPM UMJ* (Vol. 1, No. 1).

[7] Lestari, G. A. D., Cahyadi, K. D., & Suprihatin, I. E. (2021). Characterization of Gold Nanoparticles

From Clove Flower Water Extract and Its Antioxidant Activity. *Indonesian Journal of Materials Science*, *22*(2), 487817.

[8] P. Rico, R. Piedras, P. Rico, R. Piedras, P. Rico, and R. Piedras, *Fabrication of Nanomaterials by Pulsed Laser Synthesis How to Cite this Chapter : Habiba K , Makarov VI , Weiner BR , Morell G . Fabrication of Nanomaterials by Pulsed*, no. September. 2014.

[9] Shah, M., Fawcett, D., Sharma, S., Tripathy, S. K., & Poinern, G. E. J. (2015). Green synthesis of metallic nanoparticles via biological entities. *Materials*, *8*(11), 7278-7308.

[10] Syafriana, V., & Wiranti, Y. (2022). Potensi Daun Tanaman Pucuk Merah (Syzygium myrtifolium Walp.) sebagai Agen Antibakteri Terhadap Streptococcus mutans. *Farmasains*, *9*(2), 65-75..

[11] Indonesia, J. A. K. (2020). INDONESIA CHIMICA ACTA. *Jurnal Akta Kimia Indonesia*, *13*, 16-22.

[12] Risfianty, D. K., & Indrawati, I. (2020). Perbedaan Kadar Tanin Pada Infusa Daun Asam Jawa (Tamarindus indica L.) dengan Metoda Spektrofotometer UV-VIS. *Lombok Journal Of Science*, *2*(3), 1-7.

[13] Wenas, D. M., Meilani, P. A., & Herdini, H. (2022). Uji Antioksidan Infusa Daun berwarna Merah dan Hijau dari Pucuk Merah (Syzygium Myrtifolium Walp.) dengan Metode DPPH. *JUSTE (Journal of Science and Technology)*, *3*(1), 11-23.

[14] Noval, N., Melviani, M., Rohama, R., Vita, S. W., & Dilla, K. N. (2023, January). P Pelatihan Pembuatan Sediaan Infusa Beserta Evaluasinya dari Bahan Alam. In *Prosiding Seminar Nasional Masyarakat Tangguh* (Vol. 2, No. 1, pp. 261-267).

[15] Purnamasari, E., Susilowati, H., & Tandelilin, R. T. (2022). Uji Pengaruh Infusa Daun Beluntas (Pluchea indica L.) Konsentrasi 10%, 20% dan 40% Terhadap Jumlah Koloni Bakteri Plak Gigi In Vitro. In *Prosiding Seminar Nasional Unimus* (Vol. 5).

[16] Fazrin, E. I., Naviardianti, A. I., Wyantuti, S., Gaffar, S., & Hartati, Y. W. (2020). Sintesis dan karakterisasi nanopartikel emas (AuNP) serta konjugasi AuNP dengan DNA dalam aplikasi biosensor elektrokimia. *PENDIPA Journal of Science Education*, *4*(2), 21-39.

[17] Yasser, M., & Widiyanti, S. E. (2019). Pengaruh Waktu Terhadap Kestabilan Nanopartikel Emas yang Disintesis Menggunakan Ekstrak Air Daun Jati (Tectona Grandis) Termodifikasi Mercaptopropionic. *Makassar: INTEK Jurnal Penelitian*, *6*(1), 43-45.

[18] Asadi Asadabad, M., & Jafari Eskandari, M. (2015). Transmission electron microscopy as best technique for characterization in nanotechnology. *Synthesis and Reactivity in Inorganic, Metal-Organic, and Nano-Metal Chemistry*, *45*(3), 323-326.

[19] Anton, N., Yudistira, A., & Siampa, J. P. (2021). Uji Aktivitas Antioksidan Dari Ekstrak Etanol Spons Ianthella basta Dari Desa Tumbak Kecamatan Pusomaen Kabupaten Minahasa Tenggara. *Pharmacon*, *10*(1), 713-719.

[20] Hasanah, N., Dahlia, A. A., & Handayani, V. (2023). Uji Aktivitas Antioksidan Ekstrak Daun Kedondong Laut (Nothopanax fructicosum (L.) Miq) Dengan Metode Peredaman Radikal Bebas DPPH. *Makassar Natural Product Journal (MNPJ)*, 10-17.

[21] Damanis, F. V., Wewengkang, D. S., & Antasionasti, I. (2020). Uji aktivitas antioksidan ekstrak etanol ascidian Herdmania Momus dengan metode DPPH (1, 1-difenil-2-pikrilhidrazil). *Pharmacon*, *9*(3), 464-469.

[22] Aini, H. N., & Chairul Saleh, E. (2015). Uji toksisitas dan aktivitas antibakteri ekstrak daun merah tanaman pucuk merah (Syzygium myrtifolium Walp.) terhadap bakteri Staphylococcus aureus dan Escherichia coli. *Jurnal Kimia*, *13*(1), 35-40.

[23] Wijaya, H., Novitasari, N., & Jubaidah, S. (2018). Perbandingan metode ekstraksi terhadap rendemen ekstrak daun rambai laut (Sonneratia caseolaris L. Engl). *Jurnal ilmiah manuntung*, *4*(1), 79-83.

[24] Poojar, B., Ommurugan, B., Adiga, S., Thomas, H., Sori, R. K., Poojar, B., ... & Gandigawad, P. (2017). Methodology used in the study. *Asian J Pharm Clin Res*, *7*(10), 1-5.

[25] Perwitasari, M., Awaliyah, S. N., Putri, I. K., Harahap, N. R. A., Anggarany, A. D., Anindita, R., ... & Nathalia, D. D. (2023). Potensi Antioksidan Infusa Bunga Telang (Clitoria ternatea), ROSELLA (Hibiscus sabdariffa) dan Daun Stevia (Stevia rebaudiana) sebagai Antidiabetes. *Jurnal Mitra Kesehatan*, *5*(2), 118-126.

[26] M. Inayah, Maming, and M. Zakir, "Sintesis Nanopartikel Emas Menggunakan Bioreduktor Dari Ekstrak Kulit Buah Manggis (Garcinia mangostana L.) Sebagai Indikator Kolorimetri Keberadaan Logam Zn 2+," *J. Ilm. Tek. Kim.*, vol. 4, no. 2, pp. 1–9, 2014.

[27] Lestari, G. A. D., & Cahyadi, K. D. (2022). Biosynthesis of Gold Nanoparticles Mediated by Andaliman Fruit Water Extract and Its Application as Antioxidants. *Jurnal Kimia Sains dan Aplikasi*, *25*(2), 56-62.

[28] Wilapangga, A., & Sari, L. P. (2018). Analisis fitokimia dan antioksidan metode DPPH ekstrak metanol daun salam (Eugenia polyantha). *Indonesian Journal of Biotechnology and Biodiversity*, *2*(1).

[29] Hammami, I., & Alabdallah, N. M. (2021). Gold nanoparticles: Synthesis properties and applications. *Journal of king Saud university-science*, *33*(7), 101560.

[30] Tamam, N. (2014). Penentuan Ukuran Cluster Nanopartikel Emas Menggunakan Matrikgliserin Dengan Instrumen Zetasizer Nanodetermination Of The Cluster Size Gold Nanoparticles Usesa Glycerol Matrix With Zetasizer Nano Instruments. *Unesa Journal of Chemistry*, *3*(2).

[31] Taufikurohmah, T., Sanjaya, I. G. M., Baktir, A., & Syahrani, A. (2014). TEM analysis of gold nanoparticles synthesisin glycerin: novel safety materials in cosmeticsto recovery mercury damage. *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, *5*(1), 397-407.

[32] Rahmi, H. (2017). Aktivitas antioksidan dari berbagai sumber buah-buahan di Indonesia. *Jurnal Agrotek Indonesia*, *2*(1).

[33] Aryanti, R., Perdana, F., & Syamsudin, R. A. M. R. (2021). Telaah Metode Pengujian Aktivitas Antioksidan pada Teh Hijau (Camellia sinensis (L.) Kuntze): Study of Antioxidan Activity Testing Methods of Green Tea (Camellia sinensis (L.) Kuntze). *Jurnal Surya Medika (JSM)*, *7*(1), 15-24.
[34] Kamal, S. E., & Aris, M. (2021). Aktivitas antioksidan ekstrak etanol 70% daun kelor (Moringa oleifera Lam.) Terhadap DPPH. *Jurnal Pro-Life*, *8*(2), 168-177.