ISSN: 1410-8917
Jurnal Kimia Sains & Aplikasi
e-ISSN: 2597-9914

Jurnal Kimia Sains dan Aplikasi 27 (5) (2024): 243-249

Jurnal Kimia Sains dan Aplikasi
Journal of Scientific and Applied Chemistry

Journal homepage: http://ejournal.undip.ac.id/index.php/ksa

Synthesis and Characterization of Silver Nanoparticles Using Bioreductant Andong Leaf Extract (*Cordyline fruticosa* (L) A. Chev.)

Mayang Sulistiorini [1], Gusrizal Gusrizal [1,*], Ajuk Sapar [1]

[1] Department of Chemistry, Faculty of Mathematics and Natural Sciences, Tanjungpura University, Pontianak 78124, Indonesia

* Corresponding author: gusrizal@chemistry.untan.ac.id

https://doi.org/10.14710/jksa.27.5.243-249

Article Info

Article history:

Received: 26th September 2023
Revised: 03rd April 2024
Accepted: 26th April 2024
Online: 31st May 2024

Keywords:
Silver Nanoparticles; Bioreductant; *Cordyline fruticosa* (L) A. Chev.

Abstract

Silver nanoparticles are known to play a crucial role in various fields, prompting researchers to undertake synthesis and modification to obtain nanoscale particles. Silver nanoparticles were synthesized using a green synthesis-based chemical method with an extract from *Cordyline fruticosa* (L.) A. Chev. This study aims to determine the optimum conditions, including pH parameters, reaction time, and concentration, and assess the silver nanoparticles' stability and characteristics. The research findings revealed that the optimal conditions for synthesizing silver nanoparticles were an extract pH of 11, a reaction time of 60 minutes, a $AgNO_3$ concentration of 1.5 x 10^{-4} M, and an extract concentration of 0.008%. Characterization showed that silver nanoparticles were spherical, ranging from 5 to 20 nm and had an average hydrodynamic size distribution of 100.8 nm. In conclusion, leaf extract of *Cordyline fruticosa* (L.) A. Chev. can be utilized as a bioreductant and stabilizing agent, as indicated by stability test results, which showed considerable stability over a storage period of three months.

1. Introduction

Research on nanoparticles is rapidly advancing due to their significant role in various fields such as industry [1], medicine [2], cosmetics [3], biotechnology [4], catalysis [5], and the environment [6, 7]. This has prompted many researchers to synthesize and modify nanoparticles to obtain nano-sized particles, particularly in synthesizing silver nanoparticles that are less than 100 nm. Silver nanoparticle synthesis can be performed using the chemical method (bottom-up) and the physical method (top-down). Using bioreductant in chemical synthesis often involves toxic and hazardous reducing agents like $NaBH_4$ [8], while physical synthesis requires high energy consumption. With technological advancements, research has been conducted using chemical methods with more environmentally friendly bioreductant, known as green synthesis, which involves various biological organisms such as bacteria, algae, fungi, and various plant extracts [9]. Compounds found in plant extracts, such as flavonoids, alkaloids, terpenoids, triterpenoids, phenols, tannins, saponins, steroids, ascorbic acid, carbohydrates, proteins, and vitamins, can function as bioreductants and stabilizing agents [10].

The *Cordyline fruticosa* (L.) A. Chev. plant has been reported to contain various secondary metabolites in its leaves, such as saponins, polyphenols, steroids, triterpenoids, amino acids, and alkaloids, with tannins being the most dominant compounds [11]. Khandel *et al.* [12] reported that secondary metabolites like flavonoids and phenolics, which contain hydroxyl groups in their structures, contribute to antioxidant activity. Furthermore, phenolic compounds are considered effective hydrogen donors, making them potential reducing agents in the synthesis of silver nanoparticles. Rusnaenah *et al.* [13] successfully synthesized silver nanoparticles using extracts from *Terminalia catappa* leaves, which contain several secondary metabolites, including phenolics (tannins) and explained that the -OH functional groups are responsible for reducing Ag^+ to Ag^0.

Previous studies have not reported on the synthesis of silver nanoparticles using *Cordyline fruticosa* (L.) A. Chev. leaves. Therefore, this research aims to synthesize

silver nanoparticles utilizing the bioreductant extract derived from *Cordyline fruticosa* (L.) A. Chev. leaves. The objectives include determining the optimal conditions for pH variations, reaction time, silver concentration, and the concentration of *Cordyline fruticosa* (L.) A. Chev. leaves extract, as well as assessing the stability and characteristics of the resulting silver nanoparticles.

2. Experimental

2.1. Tools and Materials

The materials used in this research were *Cordyline fruticosa* (L) A. Chev. leaves, methanol (CH_3OH), sodium hydroxide (NaOH), and silver nitrate ($AgNO_3$). The tools used were pH meter (Hanna microprocessor-211), rotary evaporator (RE100-PRO), UV-Vis spectrophotometer (UV-1280 Shimadzu), FTIR (IR Prestige-21 Shimadzu), PSA (Microtrac Nanotrac Wave II), TEM (1400-Jeol Jem), and centrifuge (TOMY MX307).

2.2. *Cordyline fruticosa* (L) A. Chev. Leaf Extraction

Fresh leaves were initially cleaned and subsequently dried by exposure to air without direct sunlight. Once dried, the leaves were finely cut into small pieces and then ground using a blender before being sieved through a 40-mesh sieve. The resulting leaf powder was carefully stored in a clean container, shielded from light exposure. Subsequently, 350 grams of the powdered material underwent maceration in CH_3OH solvent for 3×24 hours. Following maceration, the resultant extract was concentrated using a rotary evaporator until a thick consistency was achieved.

2.3. Synthesis of Silver Nanoparticles

The synthesis of silver nanoparticles was conducted by varying several parameters, including pH, reaction time, silver concentration, and extract concentration.

2.3.1. Determination of Optimum pH of *Cordyline fruticosa* (L) A. Chev. Leaf Extract

In each test tube, 5 mL of leaf extract solution with a concentration of 0.01% was combined with NaOH solution until the pH reached variations of 10, 11, and 12, respectively. Subsequently, 5 mL of $AgNO_3$ solution with a concentration of 1×10^{-4} M was added to each test tube. The mixture was then heated at boiling water temperature for 60 minutes. After heating, the solution was cooled using cold water and measured using UV-Vis spectrophotometer at a wavelength ranging from 300 to 700 nm. The optimal pH obtained from these measurements was utilized for the subsequent parameters.

2.3.2. Determination of Optimum Reaction Time

In each test tube, 5 mL of leaf extract solution with a concentration of 0.01% was combined with NaOH solution until reaching a pH of 11. Subsequently, 5 mL of $AgNO_3$ solution with a concentration of 1×10^{-4} M was added to each test tube. The mixtures were then heated to the boiling water temperature for 15, 30, 45, 60, 90, and 120 minutes. After that, the solutions were cooled using cold water and measured using UV-Vis spectrophotometer at a wavelength ranging from 300 to 700 nm. The optimal reaction time, as determined from these measurements, was utilized for the subsequent parameters.

2.3.3. Determination of Optimum Concentration of $AgNO_3$

A leaf extract solution with a concentration of 0.01% was added to 5 mL of NaOH solution in each test tube until the pH reached 11. Then, 5 mL of $AgNO_3$ solution was added at varying concentrations of 0.5×10^{-4} M, 1×10^{-4} M, 1.5×10^{-4} M, 2×10^{-4} M, and 3×10^{-4} M. The mixtures were then heated to the boiling water temperature for 60 minutes. After heating, the solutions were cooled using cold water and measured using UV-Vis spectrophotometer at wavelengths ranging from 300 to 700 nm. The optimal concentration of $AgNO_3$ determined from these measurements was used for the subsequent parameters.

2.3.4. Determination of Optimum Concentration of Leaf Extract

Leaf extract solutions with varying concentrations of 0.002, 0.004, 0.006, 0.008, and 0.01% were prepared, with 5 mL of each solution added to separate test tubes. NaOH solution was then added to each test tube until the pH reached 11. Subsequently, 5 mL of $AgNO_3$ solution with a concentration of 1.5×10^{-4} M was added to each test tube. The mixtures were then heated to boiling water temperature for 60 minutes. After heating, the solutions were cooled using cold water and measured using UV-Vis spectrophotometer at wavelengths ranging from 300 to 700 nm. The optimal leaf extract concentration determined from these measurements was used for further research.

2.4. Stability Test

Silver nanoparticles were re-synthesized using the optimal conditions determined previously: a 0.008% leaf extract solution was adjusted to pH 11 with NaOH, followed by the addition of a 1.5×10^{-4} M $AgNO_3$ solution. The mixture was then heated to boiling water temperature for 60 minutes. After heating, the solution was cooled and stored in a closed bottle. Absorptions were measured using a UV-Vis spectrophotometer at wavelengths ranging from 300 to 700 nm at various intervals: every 1 day, 2 days, 3 days, 1 week, 2 weeks, 3 weeks, 1 month, 2 months, and 3 months of storage.

2.5. Characterization of Silver Nanoparticles

The solution for characterization was synthesized using the optimal conditions determined in the previous tests, specifically: an extract pH of 11, a reaction time of 60 minutes, an $AgNO_3$ solution concentration of 1.5×10^{-4} M, and an extract solution concentration of 0.008%, with a 1:1 ratio of extract solution to $AgNO_3$ solution. The resulting colloidal silver nanoparticle solution was then characterized using FTIR, PSA, and TEM.

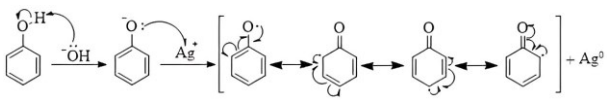

Figure 1. Ag^+ reduction reaction

Table 1. Profile of surface plasmon resonance of silver nanoparticles synthesis during storage

Storage time	λ_{max} (nm)	Peak intensity (Absorbance)	FWHM (nm)
After synthesis	414	0.971	98
1 day	414	0.966	98
2 days	414	0.953	99
3 days	414	0.992	105
1 week	414	0.905	97
2 weeks	415	0.876	98
3 weeks	413	0.816	98
1 month	414	0.907	100
2 months	414	0.828	102
3 months	414	0.827	104

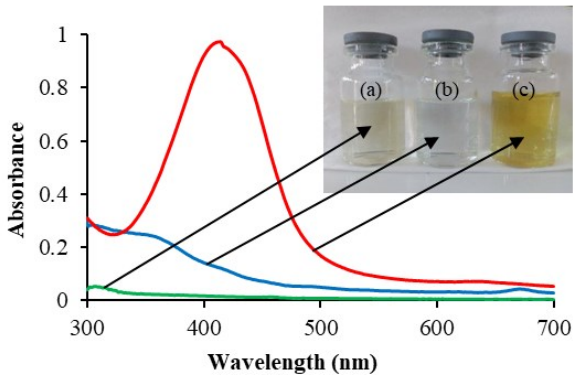

Figure 2. UV-Vis spectra of (a) extract, (b) $AgNO_3$, and (c) colloidal silver nanoparticle

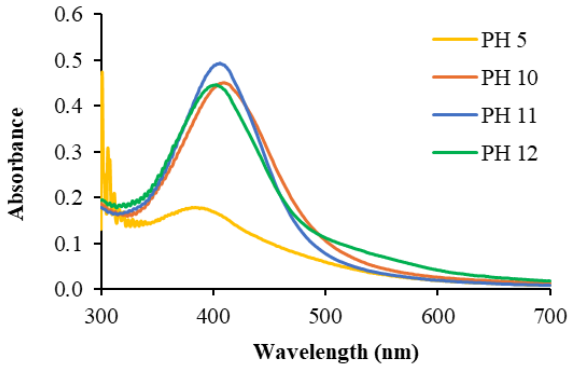

Figure 3. Surface plasmon resonance spectra of silver nanoparticles with pH variations

FTIR was performed to analyze the functional groups in synthesized silver nanoparticles. Solid samples for FTIR analysis were prepared by centrifuging the colloidal silver nanoparticles at 15,000 rpm for 20 minutes and then drying the resulting solid at 40°C in an oven.

PSA was used to determine the size distribution of the silver nanoparticle colloids. Samples for PSA analysis were prepared in 10 mL volumes and sent to the characterization instrument operator. The results included particle size distribution data and polydispersity index values.

TEM was employed to determine the morphology and size of the silver nanoparticles. Samples for TEM analysis were also prepared in 10 mL and sent to the characterization instrument operator. The results were provided as TEM images, which were further analyzed using ImageJ software to measure the nanoparticle sizes.

3. Results and Discussion

3.1. Synthesis of Silver Nanoparticles

Silver nanoparticles are synthesized by reducing Ag^+ from $AgNO_3$ to Ag^0 using leaf extract as a bioreductant. The secondary metabolites contained in the leaves have antioxidant properties due to the presence of -OH functional groups, which are easily oxidized. Typically, - OH are acidic; when NaOH is added as a base, proton release occurs due to deprotonation, forming phenoxide anions that have three pairs of free electrons. These anions are used to reduce metal ions, thus forming Ag^0 [14].

Figure 2 displays the spectra results, indicating that the $AgNO_3$ solution shows an absorption peak at a wavelength of 305 nm. In contrast, the synthesized silver nanoparticles exhibit a peak at a wavelength of 414 nm. The surface plasmon resonance spectrum within the wavelength range of 400-450 nm confirms that all Ag^+ ions have been reduced to Ag^0. Similar research by Bagur *et al.* [15] demonstrated that the $AgNO_3$ solution produces a peak spectrum with a λ_{max} below 350 nm, whereas the synthesized silver nanoparticles show a peak at a wavelength of 425 nm. This surface plasmon resonance spectrum in the 400-450 nm range corroborates the complete reduction of Ag^+ to Ag^0.

3.1.1. pH Optimization

This study compared the utilization of pH without adding a base (pH 5) to basic pH conditions (pH 10, 11, and 12). Analysis revealed that the solution at pH 5 exhibited a wavelength of 385 nm, suggesting the absence of silver nanoparticle formation (Figure 3). Conversely, solutions at pH 10, 11, and 12 displayed a wavelength of 410 nm, indicating the presence of silver nanoparticles. Notably, silver nanoparticle formation occurred exclusively under basic pH conditions, as the protons from hydroxyl groups underwent deprotonation, forming a negative charge that facilitated the binding of these groups to metal cations [16].

These findings align with prior research conducted by Moldovan *et al.* [17], which concluded that basic pH supports silver nanoparticle formation, while acidic conditions lead to aggregation and generating larger

particles. The absorbance of the three pH variations was examined to ascertain the optimum pH. Results demonstrated that at pH 11, the absorbance was notably higher, indicating a greater production of nanoparticles compared to pH 10 and 12. Consequently, subsequent synthesis endeavors were conducted at pH 11, which was identified as the optimal pH condition.

3.1.2. Reaction Time Optimization

The experiment aimed to ascertain the ideal duration necessary for producing silver nanoparticles in optimal quantities. Various heating durations, ranging from 15 to 120 minutes, were tested. Analysis depicted in Figure 4 revealed a direct relationship between the heating duration and the absorbance intensity, signifying the progressive reduction of silver ions leading to the formation of silver nanoparticles. The synthesis of silver nanoparticles exhibited an ascending trend, with absorbance values increasing from 0.481 at 15 minutes to 0.659 at 60 minutes. Subsequently, absorbance declined to 0.636 at 90 minutes and further decreased to 0.606 at 120 minutes.

Notably, heating for 60 minutes resulted in the highest absorbance intensity, indicating the optimal formation of silver nanoparticles. This observation aligns with prior research conducted by Dada *et al.* [18], which demonstrated that all Ag^+ ions had been successfully reduced to Ag^0, completing the silver colloid nucleation process and yielding small, stable particle sizes under optimal conditions. Hence, the optimal duration for synthesizing silver nanoparticles is determined to be 60 minutes.

3.1.3. Silver Concentration Optimization

Variations in silver concentration were conducted to confirm the ability of the extract used to reduce silver ions in line with increasing silver concentration. As the $AgNO_3$ concentration increased, the yellow color in the silver nanoparticle colloid intensified, indicating a proportional increase in nanoparticle formation. This validates that the extract can effectively reduce silver ions in tandem with increasing silver concentration up to a concentration of 3×10^{-4} M.

Figure 5 shows the spectrum of silver nanoparticles with wavelengths ranging from 405 to 415 nm. The concentration of 1.5×10^{-4} M is considered the optimal silver concentration. At a concentration of 0.5×10^{-4} M, the measured wavelength is 403 nm with low absorbance intensity, attributable to the insufficient presence of Ag^+ ions and, thus, a limited number of nanoparticles formed. At concentrations of 1×10^{-4} M and 1.5×10^{-4} M, the measured wavelength is 410 nm, with a higher absorbance intensity observed at 1.5×10^{-4} M due to the increased nanoparticle formation compared to the 1×10^{-4} M concentration.

At silver concentrations of 2×10^{-4} M and 3×10^{-4} M, two measured wavelengths, namely 410 and 415 nm, were observed, accompanied by a broadening of the peak towards the redshift, indicative of larger nanoparticle sizes. This finding aligns with previous research by Gusrizal *et al.* [19], which demonstrated an increase in absorbance intensity with rising silver concentration and a consequent increase in silver nanoparticle size. Therefore, a silver concentration of 1.5×10^{-4} M was chosen for further synthesis.

3.1.4. Optimization of Extract Concentration

From the spectrum analysis, it is evident that there is a correlation between absorbance and extract concentration, reaching a peak at 0.008%. This signifies an optimal reduction of available Ag^+ ions and the subsequent formation of numerous silver nanoparticles. However, there is a decline in absorbance beyond this concentration, likely due to the depletion of silver ions available for reduction.

Octavianus *et al.* [20] conducted similar research, exploring variations in wild almond leaf extract concentrations, with the optimal concentration determined to be 0.008%. Consistent with these findings, the surface plasmon resonance spectrum data in Figure 6 reveal the highest absorbance at an extract concentration of 0.008%, indicating optimal nanoparticle formation compared to other concentrations. Therefore, it is decided to employ an extract concentration of 0.008% for further synthesis.

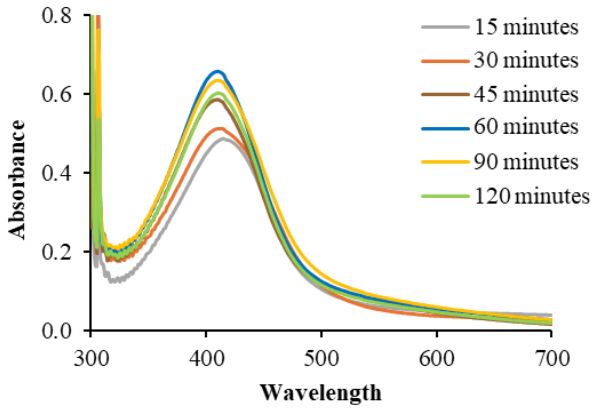

Figure 4. Surface plasmon resonance spectra of silver nanoparticles with varying reaction times

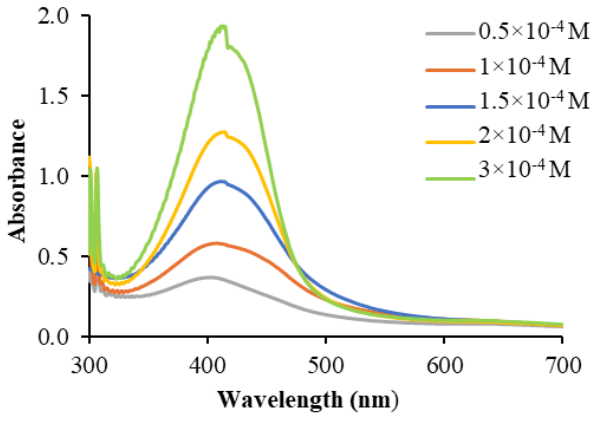

Figure 5. Surface plasmon resonance spectra of silver nanoparticles with varying concentrations of $AgNO_3$

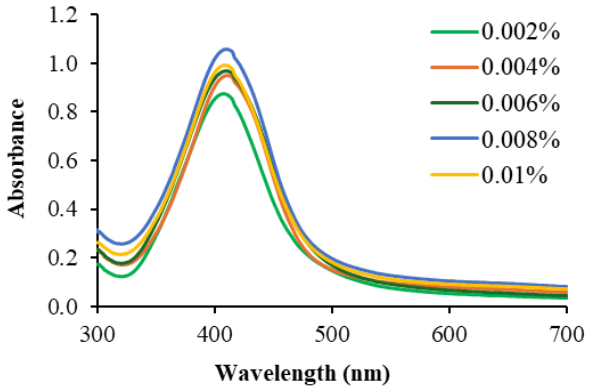

Figure 6. Surface plasmon resonance spectra of silver nanoparticles with varying concentrations of leaf extract

3.2. Stability Test

The stability test data depict the ability of silver nanoparticles to maintain their size against aggregation. The surface plasmon resonance spectrum generated is observed to determine changes in the spectrum's wavelength, absorbance intensity, and peak width [21].

Table 1 presents the surface plasmon resonance spectra over four months. After three months of storage, the silver nanoparticle colloids exhibited absorption peaks within the range of 413-415 nm, accompanied by a slight wavelength shift of approximately 1-2 nm towards longer wavelengths, commonly referred to as a bathochromic or red shift [22]. This shift remains within the typical range for nanoparticles, typically between 400-450 nm. Additionally, there was a 15% decrease in absorption intensity, suggesting a reduction in the number of silver nanoparticles present in the colloid due to nanoparticle precipitation. Furthermore, the FWHM value experienced a slight increase from 98 nm to 104 nm, indicating the stability of the silver nanoparticles.

Figure 7 demonstrates the stability of the synthesized silver nanoparticles, indicating their suitability for storage over three months. This suggests that the *Cordyline fruticosa* (L) A. Chev. leaf extract, employed as both a bioreductant and stabilizing agent, obviates the need for additional stabilizing agents [23]. This finding aligns with research by Rahayu *et al.* [24], who found that silver nanoparticles synthesized using Dayak onion bulb extract remained stable throughout 4 months of storage.

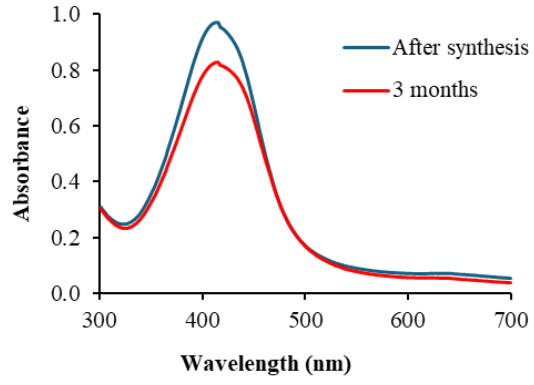

Figure 7. Surface plasmon resonance spectra of silver nanoparticles after three months of storage

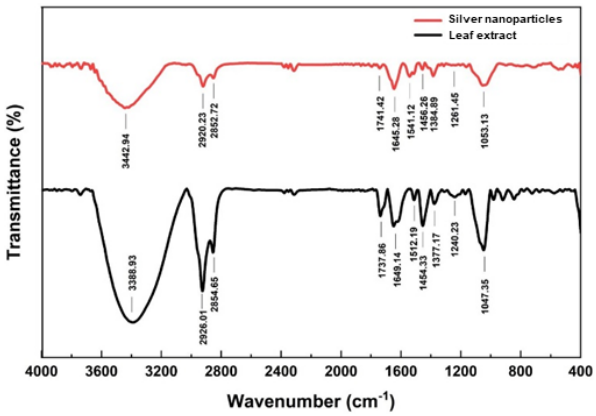

Figure 8. FTIR spectra of leaf extract and silver nanoparticles

3.3. Characterization of Silver Nanoparticles

FTIR characterization is employed to identify the functional groups present in leaf extracts and silver nanoparticles by analyzing the intensity of infrared light absorbed by the material. The FTIR spectra results of *Cordyline fruticosa* (L) A. Chev. leaf extract reveal several key absorption peaks. At the wavenumber 3388.93 cm^{-1}, there is a broad absorption peak indicative of -OH functional groups from alcohols and phenols. The absorption at 1727.86 cm^{-1} indicates the presence of the C=O carboxylate functional group.

Absorption peaks at 2926.01 cm^{-1} and 2854.65 cm^{-1} correspond to the -CH (aliphatic) functional groups. Aliphatic compounds are further supported by the presence of CH_2 and CH_3 groups at wavenumbers 1454.33 cm^{-1} and 1377.17 cm^{-1}, respectively, which show sharp absorption and weak intensity characteristic of aliphatic CH bending vibrations. Additionally, absorptions at 1649.14 cm^{-1} and 1512.19 cm^{-1} indicate stretching vibrations from the aromatic C=C functional group. A peak with moderate intensity at 1047.35 cm^{-1} suggests stretching vibrations from the CO functional group [25].

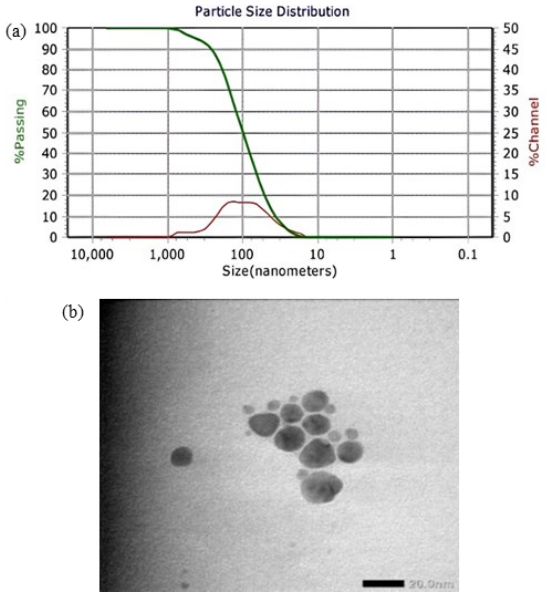

Figure 9. (a) particle size distribution of silver nanoparticles and (b) silver nanoparticles shape

The FTIR spectrum of silver nanoparticles, shown in Figure 8, reveals a decrease in the absorption intensity of several functional groups. These groups include the -OH group, with an absorption band at 3442.94 cm^{-1}, aliphatic CH groups at 2920.23 and 2852.72 cm^{-1}, the C=O group at 1741.42 cm^{-1}, aromatic C=C groups at 1645.28 and 1541.12 cm^{-1}, and the CO group at 1053.13 cm^{-1}. This decrease in absorption intensity suggests that these functional groups are involved in the reduction of Ag^{+} ions to Ag^{0}. FTIR spectra analysis of *Cordyline fruticosa* (L) A. Chev. leaf extract indicates the presence of flavonoid and phenolic compounds, which function as bioreductants. This finding implies forming a layer of organic compounds on the surface of the silver nanoparticles, acting as stabilizing agents to prevent aggregation [26].

Figure 9a shows the average size distribution of silver nanoparticles at 100.8 nm. The size distribution data indicate that the synthesized silver nanoparticles produce particles within the 1-100 nm nano-size range, with some particles exceeding 100 nm. Similar results were obtained in studies by Daniel *et al.* [27], using Epomea carnea, which produced silver nanoparticles ranging from 30-130 nm, and by Dua *et al.* [28], using Eupatorium adenophorum leaf extract, which produced nanoparticles with an average size of 117.75 nm, distributed from 30-400 nm. The presence of silver nanoparticles above 100 nm can be attributed to the amount of extract functioning as a capping agent on their surfaces [29].

Figure 9b illustrates several dispersed nanoparticles, forming small aggregates coated with a thin organic layer derived from plant extracts, which acts as a capping agent [30]. TEM characterization reveals silver nanoparticles varying in size from 5 nm to 20 nm with a spherical morphology. This finding is consistent with research by Raj *et al.* [31], which produced spherical silver nanoparticles with an average size of 18.12 nm. Therefore, it can be concluded that *Cordyline fruticosa* (L) A. Chev. leaf extract effectively functions as a stabilizing agent in synthesizing silver nanoparticles.

4. Conclusion

This research successfully synthesized silver nanoparticles using *Cordyline fruticosa* (L) A. Chev. leaf extract as a bioreductant. The synthesis was conducted under optimum conditions: a $AgNO_3$ concentration of 1.5×10^{-4} M, a leaf extract concentration of 0.008% at pH 11, and a heating time of 60 minutes. FTIR analysis confirmed that flavonoid and phenolic compounds in the leaf extract played a crucial role in the synthesis process. The resulting silver nanoparticles were spherical, ranging from 5 to 20 nm and an average hydrodynamic size of 100.8 nm. The nanoparticles demonstrated good stability, as the colloidal solution remained stable for three months. These findings indicate that *Cordyline fruticosa* (L) A. Chev. leaf extract is effective both as a reducing agent and a stabilizing agent in synthesizing silver nanoparticles.

References

[1] Cátia S. C. Santos, Barbara Gabriel, Marilys Blanchy, Olivia Menes, Denise García, Miren Blanco, Noemí Arconada, Victor Neto, Industrial Applications of Nanoparticles – A Prospective Overview, *Materials Today: Proceedings*, 2, 1, (2015), 456-465 https://doi.org/10.1016/j.matpr.2015.04.056

[2] Alessandro L. Urzedo, Marcelly C. Gonçalves, Mônica H. M. Nascimento, Christiane B. Lombello, Gerson Nakazato, Amedea B. Seabra, Multifunctional alginate nanoparticles containing nitric oxide donor and silver nanoparticles for biomedical applications, *Materials Science and Engineering: C*, 112, (2020), 110933 https://doi.org/10.1016/j.msec.2020.110933

[3] Payapo Irfa Apriliyanti, Muhammad Zakir, Nunuk Hariani Soekamto, Synthesis of Silver Nanoparticles Using Bioreductor of Ketapang Leaf Extract (*Terminalia catappa*) and Its Potential as Sunscreen, *Jurnal Akta Kimia Indonesia (Indonesia Chimica Acta)*, 10, 1, (2019), 1-19

[4] Santosh Kumar, Indra Bhusan Basumatary, Hemanth P. K. Sudhani, Vivek K. Bajpai, Lei Chen, Shruti Shukla, Avik Mukherjee, Plant extract mediated silver nanoparticles and their applications as antimicrobials and in sustainable food packaging: A state-of-the-art review, *Trends in Food Science & Technology*, 112, (2021), 651-666 https://doi.org/10.1016/j.tifs.2021.04.031

[5] Leili Shaker Ardakani, A. Surendar, Lakshmi Thangavelu, Tanmay Mandal, Silver nanoparticles (Ag NPs) as catalyst in chemical reactions, *Synthetic Communications*, 51, 10, (2021), 1516-1536 https://doi.org/10.1080/00397911.2021.1894450

[6] Rythem Anand, Madhulika Bhagat, Silver nanoparticles (AgNPs): As nanopesticides and nanofertilizers, *MOJ Biology and Medicine*, 4, 1, (2019), 19-20 https://doi.org/10.15406/mojbm.2019.04.00107

[7] Cheah Liang Keat, Azila Aziz, Ahmad M. Eid, Nagib A. Elmarzugi, Biosynthesis of nanoparticles and silver nanoparticles, *Bioresources and Bioprocessing*, 2, (2015), 47 https://doi.org/10.1186/s40643-015-0076-2

[8] Dorlina Salasa, Henry Aritonang, Vanda Kamu, Sintesis Nanopartikel Perak (Ag) Dengan Reduktor Natrium Borohidrida ($NaBH_4$) Menggunakan Matriks Nata-De-Coco, *CHEMISTRY PROGRESS*, 9, 2, (2019), 34-40

[9] Rizwan Arif, Rahis Uddin, A review on recent developments in the biosynthesis of silver nanoparticles and its biomedical applications, *MEDICAL DEVICES & SENSORS*, 4, 1, (2021), e10158 https://doi.org/10.1002/mds3.10158

[10] Khwaja Salahuddin Siddiqi, Azamal Husen, Rifaqat A. K. Rao, A review on biosynthesis of silver nanoparticles and their biocidal properties, *Journal of Nanobiotechnology*, 16, (2018), 14 https://doi.org/10.1186/s12951-018-0334-5

[11] N. W. Bogoriani, A. A. B. Putra, S. Wahjuni, W. E. Heltyani, N. P. P. M. S. Dewi, V. Y. K. Sadin, The effect of Andong (*Cordyline terminalis*) leave, one of the traditional plants in Bali as antioxidant and antibacterial, *IOP Conference Series: Earth and Environmental Science*, 724, (2021), 012018 https://doi.org/10.1088/1755-1315/724/1/012018

[12] Pramila Khandel, Sushil Kumar Shahi, Deepak Kumar Soni, Ravi Kumar Yadaw, Leeladhar Kanwar, *Alpinia calcarata*: potential source for the fabrication of bioactive silver nanoparticles, *Nano Convergence*, 5, (2018), 37 https://doi.org/10.1186/s40580-018-0167-9

[13] Andi Rusnaenah, Muhammad Zakir, Prastawa Budi, Synthesis of Silver Nanoparticles Using Bioreductor of Ketapang Leaf Extract (*Terminalia catappa*), *Jurnal Akta Kimia Indonesia (Indonesia Chimica Acta)*, 10, 1, (2019), 35-43

[14] Fatiha Lisa, Dwyana Zaraswati, Johannes Eva, Silver Nanoparticles Synthesis from Dragon Fruit (*Hylocereus polyrhizus*) Peel Extract and Its Potential as Antiseptic Mouthwash, *Proceedings of the 2nd International Conference on Education and Technology (ICETECH 2021)*, 2022 https://doi.org/10.2991/assehr.k.220103.054

[15] Hemashekhar Bagur, Chandrappa Chinna Poojari, Govindappa Melappa, Rajesh Rangappa, N. Chandrasekhar, Prathap Somu, Biogenically Synthesized Silver Nanoparticles Using Endophyte Fungal Extract of *Ocimum tenuiflorum* and Evaluation of Biomedical Properties, *Journal of Cluster Science*, 31, 6, (2020), 1241-1255 https://doi.org/10.1007/s10876-019-01731-4

[16] Qurrataayun Siti, Rifai Yusnita, Rante Herlina, Sintesis Hijau Nanopartikel Perak (AgNP) Menggunakan Ekstrak Daun Serai (*Cymbopogon citratus*) Sebagai Bioreduktor, *Majalah Farmasi dan Farmakologi*, 26, 3, (2022), 124-128

[17] Bianca Moldovan, Vladislav Sincari, Maria Perde-Schrepler, Luminita David, Biosynthesis of Silver Nanoparticles Using *Ligustrum Ovalifolium* Fruits and Their Cytotoxic Effects, *Nanomaterials*, 8, 8, (2018), 627 https://doi.org/10.3390/nano8080627

[18] Adewumi O. Dada, Adejumoke A. Inyinbor, Ebiega I. Idu, Oluwasesan M. Bello, Abimbola P. Oluyori, Tabitha A. Adelani-Akande, Abiodun A. Okunola, Olarewaju Dada, Effect of operational parameters, characterization and antibacterial studies of green synthesis of silver nanoparticles using *Tithonia diversifolia*, *PeerJ*, 6, (2018), e5865 https://doi.org/10.7717/peerj.5865

[19] Gusrizal Gusrizal, Sri Juari Santosa, Eko Sri Kunarti, Bambang Rusdiarso, Dual function of *p*-hydroxybenzoic acid as reducing and capping agent in rapid and simple formation of stable silver nanoparticles, *International Journal of ChemTech Research*, 9, 9, (2016), 472-482

[20] Chris Octavianus, Imelda Hotmarisi Silalahi, Gusrizal Gusrizal, Synthesis of Silver Nanoparticles Using *Premna serratifolia* Linn. Leaf Extract as Reducing Agent and Their Antibacterial Activity, *Jurnal Farmasi Sains dan Komunitas*, 19, 1, (2022), 34-40 https://doi.org/10.24071/jpsc.003185

[21] Gusrizal Gusrizal, Sri Juari Santosa, Eko Sri Kunarti, Bambang Rusdiarso, Two highly stable silver nanoparticles: Surface plasmon resonance spectra study of silver nanoparticles capped with m-hydroxybenzoic acid and p-hydroxybenzoic acid, *Molekul*, 13, 1, (2018), 30-37 http://dx.doi.org/10.20884/1.jm.2018.13.1.424

[22] James W. Robinson, Eileen Skelly Frame, George M. Frame II, *Undergraduate Instrumental Analysis*, 7th ed., CRC Press, 2014,

[23] Gusrizal Gusrizal, Sri Juari Santosa, Eko Sri Kunarti, Bambang Rusdiarso, Synthesis of Silver Nanoparticles by Reduction of Silver Ion with m-Hydroxybenzoic Acid, *Asian Journal of Chemistry*, 29, 7, (2017), 1417-1422 https://doi.org/10.14233/ajchem.2017.20436

[24] Normaningsih Rahayu, Gusrizal Gusrizal, Nurlina Nurlina, Ekstrakk Umbi Bawang Dayak (*Eleutherine palmifolia* (L.) Merr.) Sebagai Pereduksi Ion Perak dalam Sintesis Nanopartikel Perak, *Indonesian Journal of Pure Applied Chemistry*, 3, 3, (2020), 17-24

[25] Endah Nurrohwinta Djuwarno, Hamsidar Hasan, Mahdalena Sy Pakaya, Faramita Hiola, Dewa Ayu Puspita, Isolasi dan Uji Aktivitas Antiinflamasi Ekstrak Daun Andong (*Cordyline fructicosa* (L) A. Chev), *Journal Syifa Sciences & Clinical Research*, 4, 3, (2022), 696-708

[26] Gowri Shankar K., Namrata Pradhan, Masilamani K., Albin T. Fleming, Silver Nanoparticles from *Trianthema portulacastrum*: Green Synthesis, Characterization, Antibacterial and Anticancer Properties, *Asian Journal of Pharmaceutical and Clinical Research*, 10, 3, (2017), 308-313 https://doi.org/10.22159/ajpcr.2017.v10i3.16216

[27] S. C. G. Kiruba Daniel, B. Nazeema Banu, M. Harshiny, K. Nehru, P. Sankar Ganesh, S. Kumaran, M. Sivakumar, *Ipomea carnea*-based silver nanoparticle synthesis for antibacterial activity against selected human pathogens, *Journal of Experimental Nanoscience*, 9, 2, (2014), 197-209 https://doi.org/10.1080/17458080.2011.654274

[28] Tarun Kumar Dua, Simran Giri, Gouranga Nandi, Ranabir Sahu, Tapan Kumar Shaw, Paramita Paul, Green synthesis of silver nanoparticles using *Eupatorium adenophorum* leaf extract: characterizations, antioxidant, antibacterial and photocatalytic activities, *Chemical Papers*, 77, (2023), 2947-2956 https://doi.org/10.1007/s11696-023-02676-9

[29] Annisaa Siti Zulaicha, Iwan Syahjoko Saputra, Indah Puspita Sari, M. Alvien Ghifari, Yoki Yulizar, Yogi Nopiandi Permana, Sudirman Sudirman, Green Synthesis Nanopartikel Perak (AgNPs) Menggunakan Bioreduktor Alami Ekstrak Daun Ilalang (*Imperata cylindrica* L), *RAFFLESIA JOURNAL OF NATURAL AND APPLIED SCIENCES*, 1, 1, (2021), 11-19 https://doi.org/10.33369/rjna.v1i1.15588

[30] Suvardhan Kanchi, Shakeel Ahmed, *Green Metal Nanoparticles: Synthesis, Characterization and their Applications*, Wiley, 2018, ^https://doi.org/10.1002/9781119418900

[31] Shani Raj, Suresh Chand Mali, Rohini Trivedi, Green synthesis and characterization of silver nanoparticles using *Enicostemma axillare* (Lam.) leaf extract, *Biochemical and Biophysical Research Communications*, 503, 4, (2018), 2814-2819 https://doi.org/10.1016/j.bbrc.2018.08.045