Acta. Chim. Asiana., 2025, 8(1), 541-547
e-ISSN/p-ISSN 2550-0503/2550-049x
Available online at: www.aca.unram.ac.id

RESEARCH PAPER

Synthesis and characterization of ZnO nanoparticles using the duwet (*Syzygium cumini*) leaf extract as a bioreductor

Emmy Yuanita*[a], Ainni Rohmana[a], Maria Ulfa[a], Baiq Nila Sari Ningsih[a], Sudirman[a], Ni Komang Tri Dharmayani[a], Ima Arum Lestarini[b], Maulida Septiyana[a], Baiq Desy Ratnasari[c]

[a] Department of Chemistry, University of Mataram, Mataram, Indonesia
[b] Department of Medical, University of Mataram, Mataram, Indonesia
[c] Department of Chemistry and Biochemistry, University of North Carolina, Greensboro, USA
*Email: emmy_yuanita@unram.ac.id

DOI: 10.29303/aca.v8i1.175

Article info:

Received 19/10/2023

Revised 15/09/2024

Accepted 24/11/2024

Available online 30/05/2025

Abstract: Synthesis of ZnO nanoparticles was carried out using a green synthesis method that utilizes plants as bioreductors. Secondary metabolites contained in plants can act as bioreductors in the metal oxide reduction process and capping agents in the production of ZnO nanoparticles. In this study, the characterization of ZnO nanoparticles was carried out using duwet (Syzygium cumini) leaf extract. The Synthesis was carried out by varying the composition of zinc acetate dihydrate solution and duvet leaf extract in the 1:1, 1:2, 1:3, and 1:4 ratios, as well as pH 7, 8, 9, and 10. The resulting ZnO nanoparticles were then characterized using UV-Vis spectrophotometry to determine the optimal conditions, a Particle Size Analyzer (PSA) to determine the particle size and X-ray diffraction (XRD) to determine the purity of the resulting nanoparticles by looking at the 2θ peak formed. Optimal conditions for synthesizing ZnO nanoparticles were obtained with a maximum wavelength (λmax) of 369 nm at a ratio of 1:2 and pH 8. The particle size distribution analysis results from PSA showed an average size of 19.52 nm, with a Poly Dispersity Index (PDI) value of 0.2491. The results of the analysis using XRD showed that the synthesized nanoparticles showed typical peaks for ZnO with 2θ values of 31.7680º, 34.3699º, and 36.2281º, which indicated that the Synthesis of nanoparticles had successfully produced pure ZnO nanoparticles.

Keywords: ZnO nanoparticles, duwet leaf, bioreductor, zink acetate dihydrate

Citation: Yuanita, E., Rohmana, A., Ulfa, M., Ningsih, B. N. S., Sudirman, S., Dharmayani, N. K. T., Lestarini, I. A., & Ratnasari, B. D. Synthesis and characterization of ZnO nanoparticles using the duwet (Syzygium cumini) leaf extract as a bioreductor. *Acta Chimica Asiana*, 8(1), 541–547. https://doi.org/10.29303/aca.v8i1.175

INTRODUCTION

Technological advancement is closely linked to the global expansion of science and industry, which has increasingly directed attention to nanotechnology [1][2]. This field has emerged as a significant branch of science that considerably impacts various life aspects [3][4]. Nanoparticles have unique physical and chemical properties due to their high surface area and nanoscale size [5][6]. Nanoparticles have a high surface area and are sized in the nanometer range. Nanoparticles are materials with sizes ranging from 1 to 100 nanometers [7][8]. Products derived from the application of nanotechnology can be categorized as nanomaterials, such as nanocomposites, nanotubes, nanoparticles, etc [1]. One of the widely used nanoparticles is ZnO nanoparticles. ZnO nanoparticles have non-toxic properties, the synthesis process is easy, and the costs used are relatively cheap, so they are widely preferred [9][10][11][12].

Methods that can be used to synthesize ZnO nanoparticles are physical and chemical [13][14]. However, these methods consume a lot of energy, time, and cost and are not environmentally friendly [15][16]. Therefore, a more environmentally friendly green synthesis method is a better alternative for synthesizing ZnO nanoparticles [17][18]. The green synthesis method requires a bioreductor to Synthesize ZnO nanoparticles. Bioreductors used can be bacteria, algae and plants. In this study, the bioreductor used is a plant [19].

Plant extracts can reduce metal ions as stabilizers [20][21]. It is due to the content of secondary metabolite compounds such as alkaloids, flavonoids, proteins, terpenoids, tannins and phenolics [20][21][22]. Duwet leaves are one of the plants that contain this content. Duwet leaves contain alkaloid, flavonoid, tannin and saponin compounds that can help reduce Zn2+ ions in forming ZnO nanoparticles [23].

There is no research report on synthesizing nanoparticles using duwet leaf extract, especially ZnO nanoparticles. Therefore, this study will synthesize ZnO nanoparticles using duwet leaf extract (Syzygium cumini) as a bioreductor and stabilizing agent. In addition, ZnO nanoparticles will also be characterized using a UV-Vis Spectrophotometer instrument to determine the maximum absorption wavelength of nanoparticles and a Particle Size Analyzer (PSA) to determine the size distribution of particles.

RESEARCH METHODS

This research is experimental. This research was conducted at the Organic Chemistry Laboratory of the State University of Surabaya. The tools used in this research include UV-Vis (Shimadzu UV-1800), FTIR spectrophotometer (PerkinElmer), PSA (Biobase), XRD (PANalytical), analytical balance (Adventurer Ohaus), magnetic stirrer (Thermo scientietic), Erlenmeyer, beaker, measuring cup, volume pipette, dropper pipette, test tube, stirring rod, and spatula. At the same time, the materials used in this study include duwet leaf powder, zinc acetate dihydrate ($Zn(CH_3COOH)_2.2H_2O$), aquabides, sodium hydroxide (NaOH), and Whatman filter paper No. 1.

Research Procedures

Extraction of Duwet Leaf

A total of 10 g of powder was dissolved in 100 mL of deionized water and heated at 60℃ for 30 minutes. The extract was filtered using the Whatmann No. 1 filter [24][25].

Photochemical Screening

Phytochemical screening is the initial stage of identifying the content of a compound in the plant to be tested. *Alkaloid content test*. Duwet leaf extract of as much as 2 mL was put into a test tube, and then 1 mL of chloroform ($CHCl_3$) and 1 mL of ammonia (NH_3) were added. The mixture was shaken and allowed to form 2 layers. The top layer was divided into 3 tubes, and then each added 2N H_2SO_4 solution. Furthermore, in tube 1, Mayer reagent was added; in tube 2, Wagner reagent was added; and in tube 3, Dragendorf reagent was added. The presence of white precipitate indicates the presence of alkaloid compounds in the addition of Mayer reagent, Wagner reagent is indicated by brownish colour and Dragendorf reagent is indicated by orange-red colour [26].

Flavonoid content test. A 1 mL of duwet leaf extract was mixed with 0.1 g of Mg powder and 2 drops of concentrated HCl and shaken. The formation of an orange colour in the layer indicates the presence of flavonoid compounds [27].

Phenolic content test. A sample of 1 mL was put into a test tube and then added with 5% $FeCl_3$ solution. A total of 3 drops. Positive results of the phenolic test show green, blue, purple or red colour [26].

Tannin content test. A 1 mL of duwet leaf extract is added with 1% $FeCl_3$. Positive samples for the tannin test will produce a blue-black colour [28].

Saponin content test. A 1 mL sample of duwet leaf extract was put into a test tube, 10 mL of hot water was added, and then the mixture was shaken vigorously until foam appeared. The formation of a stable froth for approximately 10 minutes indicates the presence of saponin compounds [29].

Steroid content test. A sample of 1 mL was put into a test tube and mixed with 3 mL of 70% ethanol, then added 2 mL of concentrated H_2SO_4 and 2 mL of anhydrous acetic acid. Positive steroid results are characterized by the formation of a green or blue colour [30].

Synthesis of ZnO Nanoparticle

Biosynthesis of ZnO nanoparticles was carried out by varying the volume ratio of 0.1 M zinc acetate dihydrate solution and duwet leaf extract. Variations were made with a ratio of 1:1, 1:2, 1:3, 1:4 with leaf extract made fixed and zinc acetate dihydrate solution made variations with a total volume of 60 mL. Furthermore, the mixture of duwet leaf extract and zinc acetate dihydrate solution was stirred for 30 minutes at 1000 rpm at 60ºC. The synthesis results were analyzed using a UV-Vis spectrophotometer at a wavelength of 200 - 800 nm to determine the maximum absorption of ZnO nanoparticles. The most optimal synthesis results were pH optimized from pH 7, 8, 9, and 10 with the addition of 0.1 M NaOH and stirred continuously for 1 hour to form colloidal ZnO nanoparticles. The optimization results were analyzed using a UV-Vis spectrophotometer at 200 - 800 nm wavelength to determine the most optimum pH.

The Synthesis results that have an optimum pH are centrifuged at room temperature, around 25 ℃, at a speed of 1000 rpm. After forming a precipitate, the precipitate was washed with distilled water and then dried at 80 ℃ for 3 hours in an oven to remove the water content. The solution was crystallized using a furnace at 400 ℃ for 4 hours to dry [22][31].

Characterization of ZnO Nanoparticle

Spectrophotometer UV-VIS

A 3 mL solution of ZnO nanoparticles was put into a cuvette and then measured at a wavelength of 200-600 nm using a UV-Vis Spectrophotometer (Shimadzu UV-1800) [32].

Particle Size Analyzer

ZnO nanoparticle solution of as much as 3 mL was put into the cuvette. Then, the cuvette is inserted into the PSA tool (Biobase) and shot with visible light so that diffraction occurs. The reading results with PSA are then displayed as a graph [32][33].

X-Ray Diffraction

Crystal phase analysis was performed with an X-ray diffractometer (Shimadzu XRD-6000) equipped with a Cu radiation source using a Ni filter and set at 40 kV/30 mA. All XRD data were collected under the same experimental conditions, within an angle range of 20° ≤ 2θ ≤ 80° [34].

RESULTS AND DISCUSSION

Extraction of Duwet Leaf Extract

Extraction was carried out using duwet leaf powder and deionized water solvent. The purpose of using fine powder is to increase the sample's surface area so that the solvent is easier to attract the chemical compounds contained in the sample more optimally. The solvent used in this extraction is aquabides. Aquabides are used because aquabides are polar, so they can attract secondary metabolite compounds in duvet leaves, which are also polar. The extraction results were then filtered using Whatman filter paper no. 1 to obtain the filtrate.

Phytochemical Screening

Phytochemical screening of the duwet leaf extract is a fundamental step in identifying its bioactive compounds. The results of this study's phytochemical screening of the duwet leaf extract indicate a positive presence of alkaloids, flavonoids, saponins, phenolics, and tannins [35]. The results of the phytochemical screening of the duwet leaf extract can be seen in Table 1.

Table 1. Phytochemical Screening of Duwet Leaf Extract

Test	Observation	Results
Alkaloids	Orange precipitate with Dragendorff reagent, white precipitated with Mayer reagent, brown precipitated with Wagner reagent	Positive
Flavonoids	Formed an orange colour	Positive
Phenolics	Formed a dark blue colour	Positive
Saponins	Formed a stable foam	Positive
Steroids	Formed a pale yellow colour	Negative
Tannins	Formed a blackish-blue colour	Positive

Synthesis of ZnO Nanoparticle

The Synthesis of ZnO nanoparticles was conducted using hydrated acetate precursor and duwet leaf extract at volume ratios of 1:1, 1:2, 1:3, and 1:4. The most optimum result can be determined using a UV-Vis spectrophotometer. Subsequently, the pH was optimized at 7, 8, 9, and 10 to identify the most optimal pH using the UV-Vis spectrophotometer.

Characterization of ZnO Nanoparticle

Spectrophotometer UV-Vis

The results of the volume comparison optimization using the UV-Vis spectrophotometer are shown in Figures 1 and 2.

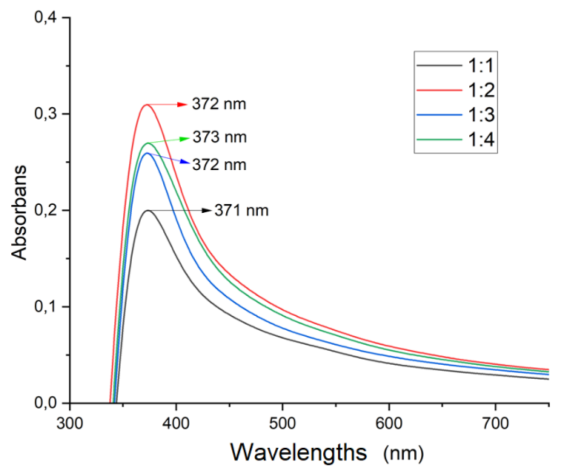

Figure 1. UV-Vis spectrum of synthesized ZnO nanoparticles

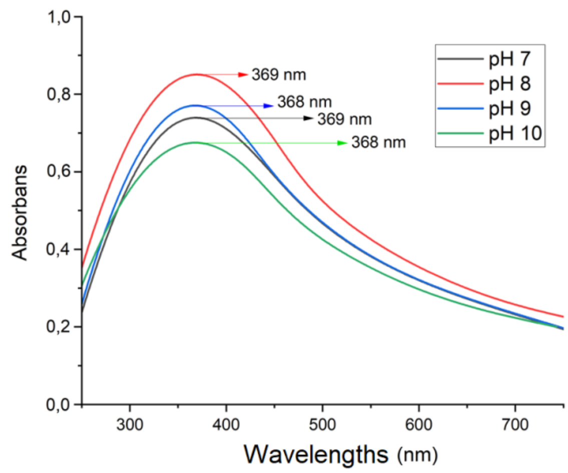

Figure 2. UV-Vis spectrum of synthesized ZnO nanoparticles

It can be seen in the figure that the most optimal ratio is 1:2, with an absorbance of 2.43 (Table 2).

Table 2. Results of UV-VIS spectrum with volume variation

Ratio	Wavelength (nm)	Absorbance
1:1	371	0.20
1:2	372	0.31
1:3	372	0.26
1:4	373	0.27

Next, this optimal ratio (1:2) will be varied at pH levels 7, 8, 9, and 10, resulting in data as shown in Figure 2. The most optimum pH optimization is 8, with an absorbance of 1.90, as shown in Table 3.

Table 3. Results of UV-Vis Spectrum with pH Variation

pH	Wavelength (nm)	Absorbance
7	369	0.73
8	369	0.85
9	368	0.77
10	368	0.67

Particle Size Analyzer (PSA)

Based on measurements using a Particle Size Analyzer (PSA) for ZnO nanoparticles from duwet leaf extract (*Syzygium cumini*), the average particle diameter was found to be 19.52 nm, which falls within the nanoparticle size range of 1-100 nm, thus confirming that the synthesized ZnO nanoparticles meet the nanoparticle size criteria. The PSA measurements yielded a polydispersity index (PDI) of 0.2491. A PDI value approaching zero indicates that the particle distribution is increasingly uniform [36].

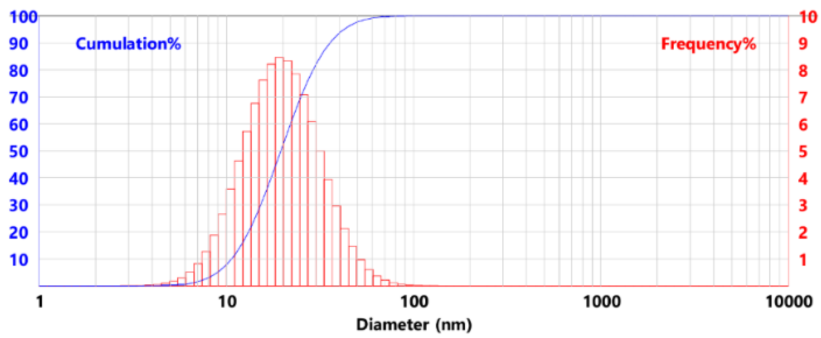

Figure 3. PSA of synthesized ZnO nanoparticles

X-ray diffraction (XRD)

Based on the results of XRD measurements (Figure 4), it was found that the X-ray diffraction results had diffraction peaks at 2θ angles of 31.7680º, 34.3699º, 36.2281º, 47.5745º, 56.5552º; 62.8643º; 68.0114º; 69.1933º.

The resulting diffraction pattern is by ICDD No. 00-005-0664. The synthesized nanoparticles showed the typical peak for ZnO at a 2θ value of 31.7680°, 34.3699 °, and 36.2281 °. Thus, it can be concluded that the Synthesis of ZnO nanoparticles was conducted successfully.

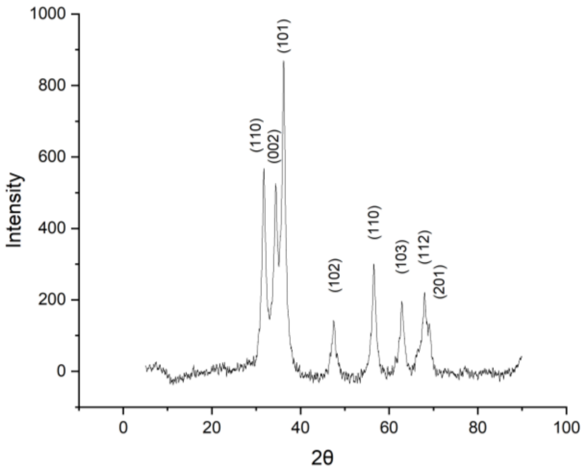

Figure 4. XRD of synthesized ZnO nanoparticles

CONCLUSION

This study synthesized ZnO nanoparticles using duwet leaf extract (*Syzygium cumini*). The compounds in the duwet leaf extract include alkaloids, flavonoids, tannins, saponins, and phenolics, which serve as reducing and capping agents in synthesizing ZnO nanoparticles. The Synthesis of ZnO nanoparticles under optimal conditions was achieved with a volume ratio of 1:2 at a wavelength of 373 nm and a pH of 8 (368 nm). Particle size analysis using PSA revealed an average size of the copper nanoparticles of 19.52 nm, with a PDI value of 0.2491 nm. The analysis results using XRD showed the typical peak for ZnO with 2θ values of 31,7680°, 34,3699 °, and 36,2281°

REFERENCES

[1] Rambaran T. & Schirhagl R. (2022). Nanotechnology from lab to industry - a look at current trends. *Royal Society of Chemistry*, 4, 3664-3675.
[2] Malik S., Muhammad K., and Waheed Y. (2023). Nanotechnology: a revolution in modern industry. *Molecules*, 28(661), 1-26.
[3] Elzein B. (2024). Nano revolution: "tiny tech, big impact: how nanotechnology is driving sdgs progress. *Heliyon*, 10(10), 1-26.
[4] Haleema X., Munir M. U., Phan D. N., and Khan M. Q. (2022). Recycling of nanomaterials by solvent evaporation and extraction techniques. *Nanomaterials Recycling*, 10, 209–222.
[5] Khan I., Saeed K., and Khan I. (2019). Nanoparticles: properties, applications and toxicities. *Arabian Journal of Chemistry*, 12(7), 908–931.
[6] Mekuye B. & Abera B. (2023). Nanomaterials: an overview of Synthesis, classification, characterization, and applications. *Nano Select*, 4(8), 486–501.
[7] Perna, Anubhav D., & Gupta R. (2021). Nanoparticles: an overview. *Drugs and Cell Therapies in Haematology*, 10(1), 1487–1897.
[8] Shinde, M. U., Patwekar, M., Patwekar, F., Bajaber, M. A., Medikeri, A., Mohammad, F. S., & Jawaid, T. (2022). Nanomaterials: A potential hope for life sciences from bench to bedside. Journal of Nanomaterials, 2022(1), 5968131.
[9] Zhou X. Q. et al. (2023). Zinc oxide nanoparticles: Synthesis, characterization, modification, and applications in food and agriculture. *Processes*, 11, 1-23.
[10] Mandal A. K. et al. (2022). Current research on zinc oxide nanoparticles: Synthesis, characterization, and biomedical applications. *Nanomaterials*, 12(17), 1-31.
[11] Preethi S. et al. (2020) Synthesis and characterization of chitosan/zinc oxide nanocomposite for antibacterial activity onto cotton fabrics and dye degradation applications. *International Journal Biological Macromolecules*, 164, 2779–2787.
[12] Al-darwesh M. Y., Ibrahim S. S., & Mohammed M. A. (2024). A review on plant extract mediated green Synthesis of zinc oxide nanoparticles and their biomedical applications. *Results in Chemistry*, 7, 1-18.
[13] Islam F. et al. (2022). Exploring the journey of zinc oxide nanoparticles (ZnO-NPs) toward biomedical applications. *Materials*, 15, 1-31.
[14] Lakshmipriya T. & Gopinath S. C. B. (2020). Introduction to nanoparticles and analytical devices. *Materials*, 1–29.
[15] Osman A. I. et al. (2024). Synthesis of green nanoparticles for energy, biomedical, environmental, agricultural, and food applications: A review. *Enviromental Chemistry Letters*, 22, 841-887.
[16] Agarwal H., Kumar S. V., & Rajeshkumar S. (2017). A review on green Synthesis of zinc oxide nanoparticles - an eco-friendly approach. *Resource-Efficient Technologies*, 3(4), 406–413.

[17] Eddy D. R. et al. (2024). A review of recent developments in green Synthesis of TiO2 nanoparticles using plant extract: Synthesis, characterization and photocatalytic activity. *Inorganic Chemistry Communications*, 165, 112531.
[18] Faisal, S., Jan, H., Shah, S. A., Shah, S., Khan, A., Akbar, M. T., & Syed, S. (2021). Green synthesis of zinc oxide (ZnO) nanoparticles using aqueous fruit extracts of Myristica fragrans: their characterizations and biological and environmental applications. ACS omega, 6(14), 9709-9722.
[19] Alqarni L. S., Alghamdi M. D., Alshahrani A. A., & Nassar A. M. (2022). Green nanotechnology: recent research on bioresource-based nanoparticle synthesis and applications. *Journal of Chemistry*, 1-31.
[20] Kazemi S. et al. (2023). Recent advances in green synthesized nanoparticles: from production to application. *Materials Today Sustainability*, 24, 100500.
[21] Samuel M. S. et al. (2022). A review on green Synthesis of nanoparticles and their diverse biomedical and environmental applications. *Catalysts*, 12, 1-24.
[22] Abdelbaky A. S., Mohamed A., Sharaky M., Mohamed N. A., & Diab Y. M. (2023). Green approach for the Synthesis of ZnO nanoparticles using *Cymbopogon citratus* aqueous leaf extract: characterization and evaluation of their biological activities. *Chemical and Biological Technologies in Agriculture*, 10(63), 1-23.
[23] Fatoni A., Afrizal M. A., Rasyad A. A., & Hidayat N. (2021). ZnO Nanoparticles and its interaction with chitosan : profile spectra and their activity against bacterial. *Jurnal Kimia dan Pendidikan Kimia*, 6(2), 216-227.
[24] Umamaheswari A., Prabu S. L., John S. A., & Puratchikody A. (2021). Green Synthesis of zinc oxide nanoparticles using leaf extracts of *Raphanus sativus var. Longipinnatus* and evaluation of their anticancer property in A549 cell lines. *Biotechnology Reports*, 29, 1-9.
[25] Firisa S. G., Muleta G. G., and A. A. Yimer. (2022). Synthesis of nickel oxide nanoparticles and copper-doped nickel oxide nanocomposites using phytolacca dodecandra L'herit leaf extract and evaluation of its antioxidant and photocatalytic activities. *ACS Omega*, 7(49), 44720–44732.
[26] Rajkumar G., Panambara P., & Sanmugarajah V. (2022). Comparative analysis of qualitative and quantitative phytochemical evaluation of selected leaves of medicinal plants in jaffna, sri lanka*. Borneo Journal of Pharmacy*, 5(2), 93–103.
[27] Priyanka S., Dixit S., & Sahoo S. (2017). Phytochemical and biochemical characterizations from leaf extracts from Azadirachta indica: an important medicinal plant. *Biochemistry & Analytical Biochemistry*, 17(3), 6961–6979.
[28] Sa'adah S. M., Putri F. R., Ibtisam A. A., & Arrohmah R. S. (2023). Phytochemical analysis of secondary metabolite compounds of pandanwangi leaf extract (Pandanus amaryllifolius). *Journal of Natural Sciences and Mathematics Research*, 9(2), 135–142.
[29] Laxmi & Begum T. (2022). Phytochemical analysis of leaf extract of the medicinal plants. *Journal of Medicinal Plants Studies*, 10(6), 34–36.
[30] Ahmed M. et al. (2019). Phytochemical screening, total phenolic and flavonoids contents and antioxidant activities of citrullus colocynthis L. and Cannabis Sativa L. *Applied Ecology Environmetal Research*, 17(3), 6961–6979.
[31] Rhamdiyah F. K. and Maharani D. K. (2022). Biosynthesis of ZnO nanoparticles from aqueous extract of Moringa Oleifera L.: its application as antibacterial and photocatalyst. *Indonesian Journal of Chemical Science*, 11(2), 92–102.
[32] Setiani F. and Suyatno. (2024) "Synthesis and characterization of copper nanoparticles with bioreductor carica dieng (carica pubescens) seed extract. *Journal Pijar Mipa*, 19, 151–155.
[33] Sutoyo, S., Tukiran, & Khotijah, S. (2021). Antioxydant activity of the silver nanoparticles (AgNPs) synthesized using *Nephrolepisradicans* extract as bioreductor. *Journal of Physics:Conference Series*, *1747*(1).
[34] Wang Q., Mei S., Manivel P., Ma H., & Chen X. (2022). Zinc oxide nanoparticles synthesized using coffee leaf extract assisted with ultrasound as nanocarriers for mangiferin. *Current Research Food Science*, 5, 868–877.
[35] Oktavia, F. D. & Sutoyo, S. (2021). Skrining fitokimia, kandungan flavonoid total, dan aktivitas antioksidan ekstrak etanol tumbuhan *Selaginella doederleinii*. *Jurnal Kimia Riset*, *6*(2), 141–153.
[36] Sutoyo, S., Amaria, A., Sanjaya, I.G.M., Hidayah, R., Sari, D.P., Dwitarini, N., Oktavia, F.D., Fadzlillah, N.A. (2022).

Synthesis of nanoherbal from ethanol extract of indonesian fern *Selaginella plana* and antibacterial activity assay, *Tropical Journal of Natural Product Research*, 6(1), 44-49.