Al-Kimia, 10-2-2022, 180-191
Available online at: http://journal.uin-alauddin.ac.id/index.php/al-kimia

Utilization Waste Materials to Synthesize Nano Al_2O_3-CaO Photocatalyst using Infused Red Guava Leaves (*Psidium guajava* L.)

Siti Rodiah[1*], Riana Aprilia[1], Nina Ariesta[2]

[1]Chemistry, Faculty of Science and Technology, Universitas Islam Negeri Raden Fatah Palembang, Palembang 30267, Indonesia
[2]Chemistry, Faculty of Mathematics and Sciences, Nusa Bangsa University, Bogor 16166, Indonesia

**Corresponding Author: siti.rodiah_uin@radenfatah.ac.id*

Received: November,21,2022 /Accepted: December,12,2022
doi: 10.24252/al-kimiav10i2.33481

Abstract: *Diazinon, a very toxic pesticide for animals and humans, is widely used in the agricultural sector, so this pollutant needs to be reduced or eliminated in the environment through photodegradation using photocatalysts derived from metal oxides. The catalytic activity of metal oxides is enhanced by adding a support material and increasing the surface area by reducing the particle size to nano size. In this study, kaolin as a source of Al_2O_3 and golden snail shells as a source of CaO which used to synthesize Al_2O_3-CaO nanoparticles (NPs) with a simple and environmentally friendly method using plant infusions. Synthesis of Al_2O_3-CaO NPs using infused red guava leaves (Psidium guajava L.) had been done by utilized the secondary metabolites as reducing agents and stabilizers in the nanoparticle synthesis. FTIR analysis confirmed the presence of alumina (Al-O) groups at wave numbers 850 – 650 cm^{-1} and CaO at 3642 cm^{-1}. XRD analysis showed NPs Al_2O_3-CaO had cubic with the crystal size of 14.59 nm. The morphology of Al_2O_3-CaO NPs showed in the SEM pictures were agglomerated. Al_2O_3-CaO NPs degraded diazinon by 75% within 180 minutes under UV radiation. Thus, this research not only reduce golden snail shells as waste material, but also reduces water pollutant.*

Key word*: Al_2O_3-CaO nanoparticles; diazinon; infused red guava leaves; photocatalyst; waste.*

INTRODUCTION

Nanoparticles with a size of 1 – 100 nm have physical properties that are more characteristic than large particles. The main products made with these components have more surface area, smaller, lighter, stronger, more durable, and have unique physical and chemical qualities (Ramola, Joshi, Ramola, Chhabra, & Singh, 2019). The commonly used nanoparticles are derived from metal oxides which have high stability and good catalytic properties (Imtiaz, Farrukh, Khaleeq-Ur-Rahman, & Adnan, 2013). Nowadays, metal oxide nanoparticles were found to have many uses in industry, chemical, biological and catalytic fields because of their high catalytic properties, and relatively high oxide stability (Ghotekar, 2019). The metal oxide used in this study was Al_2O_3 which had the advantage of being resistant to high temperatures, large surface area, relatively stable, and had a high melting point (Mohamad et al., 2019). Kaolin is one of the abundant sources of Al_2O_3, contains 30.51% of Al_2O_3 after being calcined at 700 °C (Sri, Walmiki, G, & Kunci, 2015).

Kaolin is a mineral clay with the chemical formula $Al_2O_3.2SiO_2.2H_2O$ which can be applied as a material because it has relatively large pores, non-toxic, stable at high temperatures and abundant in nature (Pasi, Bratadireja, & Chaerunnisa, 2020). Based on the Central Bureau of Statistics (2007), the potential for kaolin reserves in Indonesia is approximately 66.21 million tons spread across Indonesia. The management of kaolin minerals in Indonesia, especially in Bangka Belitung Islands, had not carried out further development. Even today, kaolin mining in Bangka Belitung has long been abandoned. Kaolin samples used in this study were taken from abandoned mining ponds.

Based on government regulation number 25 of 2018 concerning increasing the added value of minerals, the management and development of kaolin minerals must be carried out so that they become one of the industrial raw materials and increase the added value of kaolin. The high Al_2O_3 content allows kaolin to be used as a source of Al_2O_3. Previous studies reported that Al_2O_3 NPs have been used in various fields such as as an addition to ceramic structures, in the textile industry, in protein separation/purification, as biosensors, drug delivery, wastewater treatment, bio-filtration, and as catalysts (Ghotekar, 2019). Al_2O_3 was used as a catalyst or solid catalyst support because its resistance to high temperatures, large surface area, high melting point and large pore structure (Riyadi & Mustikasari, 2017).

Catalytic activity of Al_2O_3 was increased through the addition of CaO as supporting material. CaO has been used as Al_2O_3 support for photodegradation 2,4,6-trinitrophenol, because CaO was semiconductor material that safe for humans and animals, had high catalytic activity and high adsorption (Imtiaz et al., 2013)(Anantharaman, Ramalakshmi, & George, 2016), so CaO was quite potential as a catalyst support material (Etuk, Etuk, & Asuquo, 2012). Golden snail shells are natural material that contains 61.95% of CaO after being calcined at 800 °C. In addition, the catalytic activity also can be increased by expanding the surface area through reducing the particle size to nano-sized.

There are several methods of synthesizing nanoparticles. The different method used to yield nanoparticles include microwave techniques, mechanical milling, homogeneous precipitation, spray pyrolysis, thermal evaporation, organometallic synthesis, and homogeneous precipitation. These techniques, however, are frequently pricy, labor-intensive, and hazardous to the environment. The presence of some toxic chemicals involved in the chemical methods, may have hazardous effects (Vijayakumar, Mahadevan, Arulmozhi, Subramanian, & P.K, 2018). Chemical reduction methods are widely chosen in synthesizing nanoparticles because they are easy, environmentally friendly, relatively inexpensive, and have the possibility to produce nanoparticles on a large scale. Most of nanoparticles were synthesized using toxic and hazardous solvents or reagents such as hydrogen, alcohol, sodium boron hydride, sodium citrate, etc., that requiring high energy and high pressure, so that not environmentally friendly (Abisharani, Kumar, Arthanareeswari, & Kamaraj, 2019; Rahmadani, Side, & Putri, 2020). Therefore, an environmentally friendly synthesis was developed by utilizing secondary metabolites of plants such as flavonoids, tannins, alkaloids, and terpenoids (El-Gendy, Nassar, & Speight, 2021) as reducing and stabilizing agents. The synthesis of nanoparticles with bio-reductants is called biosynthesis. Furthermore, the majority of bioprocesses take place at standard air pressure and temperature, which results in significant energy savings, high yield, and low cost (Abisharani et al., 2019).

Previous researches had utilized extracts Casuarinaceae (Ramola et al., 2019), Cymbopogon citratus (Ansari et al., 2015), Pedalium murek (Sivaprakash et al., 2019), Psidium guajava L. (Bose & Chatterjee, 2016)(Somchaidee & Tedsree, 2018) leaves to synthesize of CaO NPs, Al_2O_3 NPs, Al_2O_3-CaO NPs, and Ag and Fe NPs (Bose & Chatterjee, 2016)(Somchaidee & Tedsree, 2018) respectively. Other studies had also reported that red guava leaves contain steroids, flavonoids, alkaloids, saponins, and polyphenols in the form of 7.82% tannins which have the potential as stabilizing and reducing agents (Sudira, Merdana, & Qurani, 2019)(Zheng, Zhao, Wu, Wang, & Zou, 2021)(Yana, 2018). Secondary metabolites used to synthesis NPs of previous research were extracted using the maceration method with organic solvents, while in this study, the researchers offered a simple and environmentally friendly preparation method using an abundant solvent, namely water distilled and treated through the infusion method. The water-soluble heterocyclic constituents of the infusion samples were responsible for the formation and stabilization of NPs. The extraction of the constituents was carried out through heating so that more compounds were attracted and the process went faster.

The synthesized nanoparticles were used as a photocatalyst in the degradation of diazinon. Diazinon is widely used in the agricultural sector to remove pests on corn, sugarcane, coconut, rice and fruit crops. This pesticide is very toxic to animals, humans and the environment and can cause death, so the use of diazinon in the environment must be reduced (Khoiriah, Wellia, Gunlazuardi, & Safni, 2020). The synthesized nanoparticles were used to degrade pesticide pollutants of diazinon with mass variations of 5 mg, 10 mg, 15 mg, 20 mg, 25 mg. The degradation results were analyzed using UV-Vis spectrophotometry and GC-MS. Fourier Transform InfraRed (FTIR) analysis was used to ensure that the support material (CaO) has combined with Al_2O_3. Crystal structure, phase identification, and crystalline particles size was determined using X-ray Diffraction (XRD) analysis, while morphology of Al_2O_3-CaO NPs were examined by using scanning electron microscope (SEM) analysis.

RESEARCH METHODS

Materials and Tools

Samples used in this study such as red guava leaves, golden snail shells and kaolin. Red guava leaves and golden snail shells were collected from South Sumatera and kaolin was taken from an abandoned kaolin mine pond in Bangka Belitung, Indonesia. The chemicals HCl, NaOH were purchased from Merck, while aquadest and diazinon reagents were from Pudak Scientific.

Methods

Sample Preparation

NPs Al_2O_3-CaO was synthesized using Al_2O_3 from kaolin and CaO from golden snail shells by adding infused red guava leaves as reducing and stabilizing agents. Kaolin was used as Al_2O_3 source. Al_2O_3 was prepared by dissolving 1 gram of kaolin in 10 ml of 6 M HCl at 90 °C for 2 hours. Then added 6 M NaOH solution until alkaline to separate the impurities. After that, it was calcined at 750 °C for 4 hours to obtain alumina then characterized by FTIR (Ramdhani, Yanuar, Zulkifli, & Sarwana, 2018). CaO had been prepared from golden snail shells and used by previous research (Rodiah, Erviana, Rahman, & Budaya, 2020). Infused red guava leaves were prepared by washing the leaves in running water, then boiled 5 grams of clean red guava leaves in 100 ml of distilled water at 60 °C for 15 minutes, then cooled and filtered to obtain an infusion (Taba, Parmitha, & Kasim, 2019).

Synthesis Al_2O_3-CaO NPs

Al_2O_3-CaO nanoparticles were synthesized by precipitation method from Al_2O_3 and CaO. Al_2O_3 was prepared from kaolin, that activated by acid to remove the impurities and to produce a higher surface area and better adsorption properties (Irawati et al., 2013). Preparation of catalyst was form 2 g of Al_2O_3 and 1 g of CaO were dissolved in 10 ml of infused red guava leaves for 1 hour. After that, it was calcined at 400 °C for 3 hours to obtained Al_2O_3-CaO NPs, then the nanoparticles were characterized using XRD, SEM, and FTIR.

Photocatalytic Degradation of Diazinon

Al_2O_3-CaO NPs were added to 20 ml of 11 ppm diazinon solution. Al_2O_3-CaO NPs mass was variated of 5 mg, 10 mg, 15 mg, 20 mg, and 25 mg then irradiated under UV radiation for 180 minutes for each. The centrifuged mixture was analyzed by UV-Vis spectrophotometry at a wavelength of 247.5 nm (Irawati, Sunardi, & Suraida, 2013). Samples were analyzed by GC-MS to determine the fragmentation of diazinon.

RESULTS AND DISCUSSION

Characteristics of Al_2O_3-CaO NPs

The remaining impurities present in the sample such as water molecules, CO_2 and other volatile molecules were also removed by calcination at 750 °C and to activate the surface site of the catalyst. The water-soluble heterocyclic constituent in infused red guava leaves played an important role in the formation and stabilization of nanoparticles (Ghotekar, 2019). Red guava leaves contain polyphenolic metabolite compounds in the form of tannins which have the ability as reducing and stabilizing agents, where in the tannin structure there were adjacent hydroxyl groups so that they was able to donate electrons to metals by releasing hydrogen atoms from the hydroxyl group (Amin, Mahardika, & Fatimah, 2020; Widia, Zulhadjri, & Arief, 2018). These metabolite components converted metal compounds (metal ions) into metals (oxidation number of 0) with specific nanoparticle sizes (Vijayakumar et al., 2018).

The initial color of the solution of Al_2O_3-CaO nanoparticles using infused red guava leaves is yellow pale (Fig. 1A), after heating the solution becomes brownish red (Fig. 1B) as shown in Figure 1. The color change was due to the reduction process of Al and Ca metal ions by tannin compounds where the hydroxyl groups in tannins reduced metal ions to form nanoparticles (Rahmadani et al., 2020). The synthesized Al_2O_3-CaO NPs showed white crystals as shown in Figure 2.

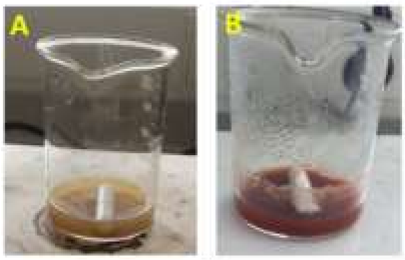

Figure 1. Color change in solution of Al_2O_3-CaO NPs

Figure 2. Synthesized Al_2O_3-CaO NPs

FTIR analysis of Al_2O_3 of this study is shown in **Figure 3**. The absorption area of 1000 – 435 cm^{-1} showed the presence of Al_2O_3 peaks (spectra A), which the absorption of Al-O bond vibration appeared at 850 – 650 cm^{-1} particularly at wavenumbers of 734 cm^{-1} (Irawati et al., 2013; Widia et al., 2018). In the B spectra, the Al-O bond vibration appeared at 736 cm^{-1}. That also reported in previous research that Al-O vibrations peaks area was 850-650 cm^{-1} (Irawati et al., 2013). The presence of O-Ca-O, O-C, and OH bond only appeared in spectra B in area of 1410 cm^{-1} and 872 cm^{-1}, and 3642 cm^{-1} respectively. This indicates that CaO has been dispersed in Al_2O_3. These peaks appeared in NPs on this study was also reported in previous research that characteristics of the O-Ca-O, O-C and –OH groups were located in the 1450 cm^{-1}, 858 cm^{-1}, and 3640 cm^{-1} sequently. The O-H groups with sharp peaks were the characteristic of CaO standard (Ghazali, Kem, Jusoh, Abdullah, & Shariffuddin, 2019).

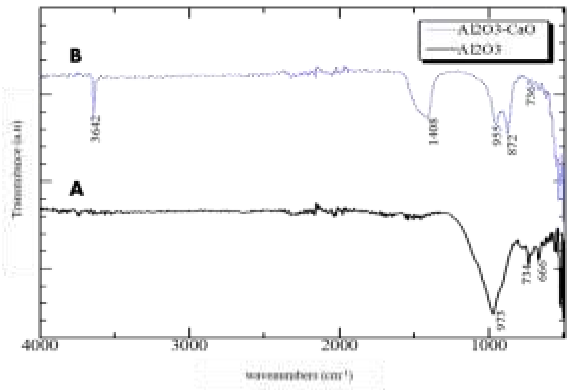

Figure 3. FTIR Spectra of Al_2O_3-CaO Nanoparticles

Figure 4 shows the diffractogram of Al_2O_3-CaO. The presence of Al_2O_3 at 2θ peaks at 5°, 35°, 37°, 46°, dan 57° with miller index (102), (104), (110), (202), and (116) respectively. The presence of CaO was shown with 2θ peaks at 32°, 64°, 67°, and 79° with miller index (111), (311), (222), and (400) sequently. The 2θ peak formed on the diffractogram corresponds to the standard database AMCSD No. 0009325 (Al_2O_3) and AMCSD No. 0008276 (CaO). The crystal size of NPs Al_2O_3-CaO was calculated by the formula Debye-Scherrer (Eq.1).

$$D = \frac{k\lambda}{\beta \cos\theta} \quad (1)$$

where D is the crystal size, β is the maximum half width (FWHM), λ is wavelength and θ is the Bragg angle at the diffraction peak. From these data, Al_2O_3-CaO nanoparticles had a cubic structure with a crystal size of 14.59 nm.

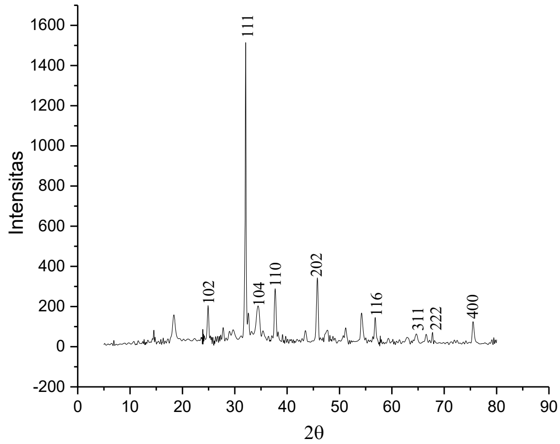

Figure 4. Diffractogram of Al_2O_3-CaO NPs

Morphology of the Al_2O_3-CaO NPs was determined by SEM analysis under 20 kV at a magnification of 10,000 and 20,000 as shown in **Figure 5A** and **5B**, respectively. At a magnification of 10,000 (Fig. 5A) showed that the particles were agglomerated and had an irregular shape. Agglomerated particles were seen more clearly at a magnification of 20,000 (Fig. 5B). Previous studies reported that the synthesis of Al_2O_3-CaO NPs using precursors and synthetic reagents resulted in agglomerated nanoparticles as reported in this study. Agglomeration occurred because of many chemical compounds contained in the infusion that played an important role in the synthesis. On the other hand, the influence of Nps electrostatic forces anda energy when the synthesis take place and the collisions between particles caused the particles to be agglomerated (Sari, Nurhasni, & Yaqin, 2017)(Masakke et al., 2015).

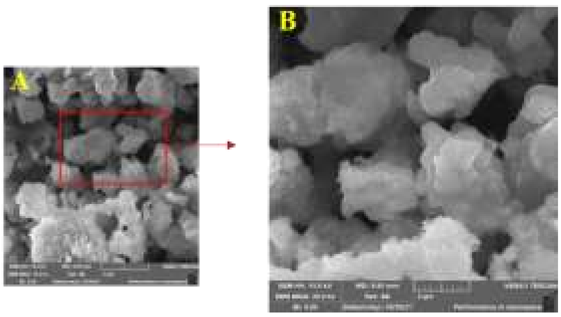

Figure 5. Morphology Al_2O_3-CaO NPs at (A) 10.000, (B) 20.000

Photocatalytic Degradation of Diazinon using Al_2O_3-CaO NPs

Activity of Al_2O_3-CaO NPs was observed through its performance to degrade diazinon. The maximum wavelength of diazinon analysis using UV-Vis spectrophotometry was 247,5 nm. The analysis data showed that the percent degradation increased with increasing catalyst mass from 0-0,21 %, then decreased at 0,28%-0,35% as shown in Figure 6. The highest amount of percent degradation was 75% of 15 mg catalyst. More increase the amount of catalyst, more increase the surface area of the catalyst so that increase the number of photon absorption on the surface that results in many •OH radicals that played an important role in the photocatalysis (Khoiriah et al., 2020). Decreasing of present degradation due to the increase in turbidity of excess catalyst mass, thereby preventing light from reaching the active cite of catalyst. The surface area of the catalyst is affected by the physical properties of the catalyst. Powdered solid catalysts have a larger surface area than agglomerated catalysts. Agglomerated Al_2O_3-CaO NPs had low surface area and may deactivated the active sites so that the photocatalytic performance of the NPs was decrease (Khoiriah et al., 2020)(Aprilianingrum & Fia, 2016)(Li et al., 2010).

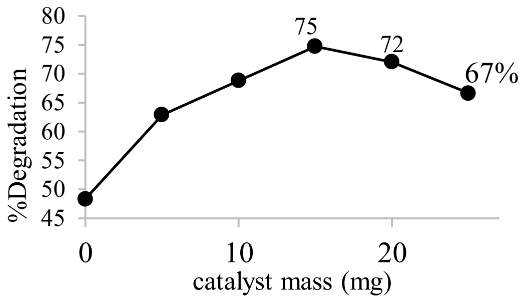

Figure 6. Line Graph of the Effect of Addition of Catalyst Mass

Diazinon decomposition was confirmed using Gas Cromatography and Mass Spectroscopy (GC-MS). Figure 7 peak intensity of diazinon before (RT of 7.27 minute) and after (RT of 7.25 minute) being degraded was decrease that proved diazinon had been successfully degraded.

Diazinon was degraded become fragments as shown in at mass spectra Figure 8. Three main fragments of diazinon were dietil fosfonat, 2-isopropil-6-metil-4-pyrimidinol (IMP), and diazoxon (Sakkas, Dimou, Pitarakis, Mantis, & Albanis, 2005) (Zhang et al., 2010). Diazoxone was derived from rearrangement of the thiono-thiolo diazinon through the substitution of sulfur with oxygen in the formation of P = S (Muñoz et al., 2011). Then, IMP was generated from the hydrolysis of diazoxone which involved breaking the P – O bond in the pyrimidine group (Zhang et al., 2010). •OH attacked on the –O– functional group of diazinon produced two by-products, namely diethyl phosphonate and IMP (Wang, Wang, & Shih, 2016). Fragmentation of diazinon was shown in Figure 9.

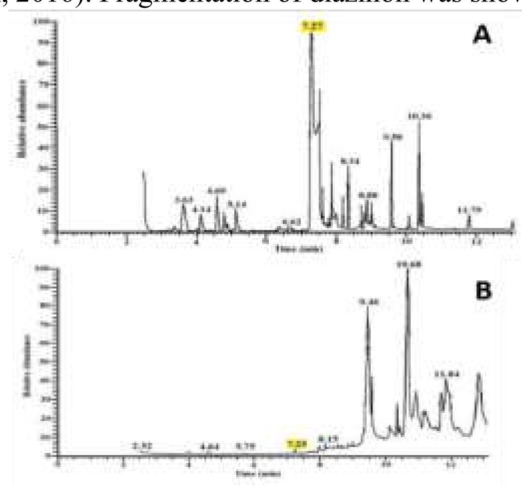

Figure 7. Spectrum GC Diazinon (A) Before (B) After Degradation

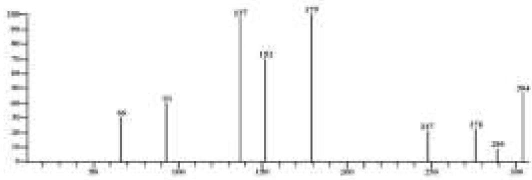

Figure 8. Spectrum Mass Diazinon

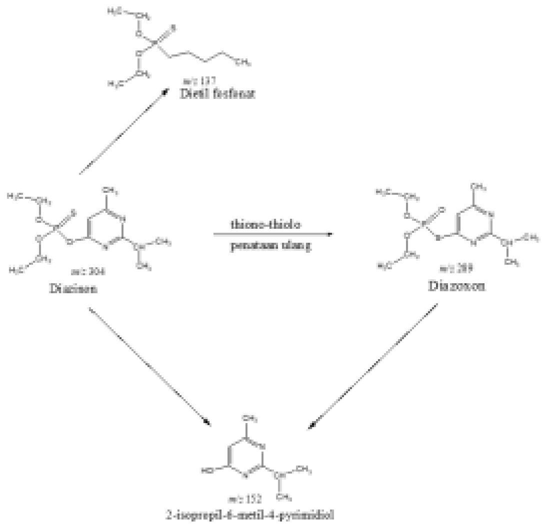

Figure 9. Fragmentation of Diazinon

CONCLUSIONS

Infused red guava leaves played an active role as reducing and stabilizing agents for the synthesis of Al_2O_3-CaO nanoparticles. The resulting nanoparticles obtained was white with a crystal size of 14.59 nm and agglomerated. Therefore, infused red guava leaves has the potential to be used for large-scale nanoparticle biosynthesis applications, but appropriate techniques to increase crystallinity and reduce agglomeration are needed. Percent degradation of diazinon using Al_2O_3-CaO NPs was 75% at optimum catalyst mass of 0,21 % for 180 minutes. Thus, of Al_2O_3-CaO NPs derived from kaolin and golden snail shell waste can be an alternative solution for handling golden snail shell waste and handling diazinon pesticide in waters. In addition, the bio-synthetic method applied by using infused red guava leaves also reduces environmental pollution.

REFERENCES

Abisharani, J. M., Kumar, S. D. R. D., Arthanareeswari, M., & Kamaraj, P. 2019. ScienceDirect Green synthesis of TiO2 Nanoparticles using Cucurbita pepo seeds extract. *Materials Today: Proceedings*, *14*, 302–307. https://doi.org/10.1016/j.matpr.2019.04.151

Amin, F., Mahardika, M., & Fatimah, S. 2020. Sintesis dan Karakterisasi Nanopartikel Emas menggunakan Bioreduktor dari Ekstrak Daun Berenuk. *Jurnal Ilmiah Teknik Kimia*, *4*, 54. https://doi.org/10.32493/jitk.v4i2.5101

Anantharaman, A., Ramalakshmi, S., & George, M. 2016. Green Synthesis of Calcium Oxide Nanoparticles and Its Applications. *Journal of Engineering Research and Application*, *6*(10), 27–31.

Ansari, M. A., Khan, H. M., Alzohairy, M. A., Jalal, M., Ali, S. G., Pal, R., & Musarrat, J. 2015. Green synthesis of Al_2O_3 nanoparticles and their bactericidal potential against clinical isolates of multi-drug resistant Pseudomonas aeruginosa. *World Journal of Microbiology and Biotechnology*, *31*(1), 153–164. https://doi.org/10.1007/s11274-014-1757-2

Aprilianingrum, & Fia, A. 2016. Optimasi dan Regenerasi Fotokatalis Ca1-xCoxTiO3 pada Proses Degradasi Metilen Biru dengan Sinar UV (Universitas Negeri Yogyakarta). Retrieved from http://eprints.uny.ac.id/id/eprint/40885

Bose, D., & Chatterjee, S. 2016. Biogenic synthesis of silver nanoparticles using guava (Psidium guajava) leaf extract and its antibacterial activity against Pseudomonas aeruginosa. *Applied Nanoscience (Switzerland)*, *6*(6), 895–901. https://doi.org/10.1007/s13204-015-0496-5

El-Gendy, N. S., Nassar, H. N., & Speight, J. G. 2021. Microbial Synthesis of Metal Nanoparticles. *Petroleum Nanobiotechnology*, *2021*, 143–199. https://doi.org/10.1201/9781003160564-3

Etuk, B. R., Etuk, I. F., & Asuquo, L. O. 2012. Feasibility of Using Sea Shells Ash as Admixtures for Concrete. *Environmental Science and Engineering A*, *1*, 121–127.

Ghazali, S. S., Kem, K. L., Jusoh, R., Abdullah, S., & Shariffuddin, J. H. 2019. Evaluation of La-Doped CaO Derived from Cockle Shells for Photodegradation of POME. *Bulletin of Chemical Reaction Engineering & Catalysis*, *14*(1), 205–218. https://doi.org/10.9767/bcrec.14.1.3318.205-218

Ghotekar, S. 2019. Plant extract mediated biosynthesis of Al_2O_3 nanoparticles- a review on plant parts involved, characterization and applications," Nanochem Res, vol. 4, no. 2, pp. 163–169, 2019.Plant extract mediated biosynthesis of Al_2O_3 nanoparticles-. *Nanochem Res*, *4*(2), 163–169. https://doi.org/10.22036/ncr.2019.02.008

Imtiaz, A., Farrukh, M. A., Khaleeq-Ur-Rahman, M., & Adnan, R. 2013. Micelle-assisted synthesis of Al_2O_3.CaO nanocatalyst: Optical properties and their applications in photodegradation of 2,4,6-trinitrophenol. *The Scientific World Journal*, *2013*(March 2014), 1–11. https://doi.org/10.1155/2013/641420

Irawati, U., Sunardi, S., & Suraida, S. (2013). Sintesis dan Karakterisasi Gamma Alumina (ɤ-Al_2O_3) dari Kaolin Asal Tatakan, Selatan Berdasarkan Variasi Temperatur Kalsinasi. *Molekul*, *8*(1), 31. https://doi.org/10.20884/1.jm.2013.8.1.123

Khoiriah, K., Wellia, D. V., Gunlazuardi, J., & Safni, S. 2020. *Photocatalytic Degradation of Commercial Diazinon Pesticide Using C , N-codoped TiO 2 as Photocatalyst*. *20*(3), 587–596. https://doi.org/10.22146/ijc.43982

Li, G., Lv, L., Fan, H., Ma, J., Li, Y., Wan, Y., & Zhao, X. S. 2010. Effect of the agglomeration of TiO_2 nanoparticles on their photocatalytic performance in the aqueous phase. *Journal of Colloid and Interface Science*, *348*(2), 342–347. https://doi.org/10.1016/j.jcis.2010.04.045

Masakke, Y., Rasyid, M., Kimia, J., Fakultas, M., Alam, P., Negeri, U., Tata, D. 2015. *Biosynthesis of Silver Nanoparticles using Methanol Extract of Mangosteen Leaves (Garcinia mangostana L .)*. *IV*(1), 28–41.

Mohamad, S. N. S., Mahmed, N., Che Halin, D. S., Abdul Razak, K., Norizan, M. N., & Mohamad, I. S. 2019. Synthesis of alumina nanoparticles by sol-gel method and their applications in the removal of copper ions (Cu2+) from the solution. *IOP Conference Series: Materials Science and Engineering*, *701*(1). https://doi.org/10.1088/1757-899X/701/1/012034

Muñoz, A., Le, A., Le, S., Mellouki, A., Borrás, E., Daële, V., & Vera, T. 2011. *Chemosphere Studies on atmospheric degradation of diazinon in the EUPHORE simulation chamber*. *85*(3), 724–730. https://doi.org/10.1016/j.chemosphere.2011.06.044

Pasi, N. I., Bratadireja, M. A., & Chaerunnisa, A. Y. 2020. Study of Physicochemical Characteristics of Kaolin from Belitung Regency. *Indonesian Journal of Pharmaceutical Science and Technology*, *7*(2), 38. https://doi.org/10.24198/ijpst.v7i2.25675

Rahmadani, D., Side, S., & Putri, S. E. 2020. Pengaruh Penambahan PVA terhadap Ukuran Nanopartikel Perak Hasil Sintesis Menggunakan Bioreduktor Ekstrak Daun Sirsak (Annona muricata L.) Effect of Adding PVA to The Size of Silver Nanoparticle Synthesized Using Bioreductor Soursop Leaf Extract (Anno. *Jurnal Sainsmat*, *9*(1), 1–13. Retrieved from http://ojs.unm.ac.id/index.php/sainsmat

Ramdhani, E. P., Yanuar, E., Zulkifli, Z., & Sarwana, W. 2018. Sintesis Ɣ-Al_2O_3 Dari Zeolit Alam Sumbawa. *Jurnal Zarah*, *6*(2), 59–62. https://doi.org/10.31629/zarah.v6i2.691

Ramola, B., Joshi, N. C., Ramola, M., Chhabra, J., & Singh, A. 2019. Green Synthesis , Characterisations and Antimicrobial Activities of CaO Nanoparticles. *Oriental Journal Of Chemistry*, *35*, 4–7.

Riyadi, A. C. N., & Mustikasari, I. Y. 2017. *Studi Pembuatan Nanoktalis $γ$-Alumina dengan Metode Sol-gel*.

Rodiah, S., Erviana, D., Rahman, F., & Budaya, A. W. 2020. Modified CaO Catalyst from Golden Snail Shell (Pomacea canaliculata) for Transesterification Reaction of Used Cooking Oil. *Al-Kimia*, *8*(1), 83–92. https://doi.org/10.24252/al-kimia.v8i1.12173

Sakkas, V. A., Dimou, A., Pitarakis, K., Mantis, G., & Albanis, T. 2005. TiO_2 photocatalyzed degradation of diazinon in an aqueous medium. *Environmental Chemistry Letters*, *3*(2), 57–61. https://doi.org/10.1007/s10311-004-0091-6

Sari, R. N., Nurhasni, N., & Yaqin, M. A. (2017). Green Synthesis Nanoparticle ZnO Sargassum sp. Extract and The Products Charactheristic. *Jurnal Pengolahan Hasil Perikanan Indonesia*, *20*(2), 238. https://doi.org/10.17844/jphpi.v20i2.17905

Sivaprakash, G., Mohanrasu, K., Ravindran, B., Jin, W., Al, D. A., Soliman, M., Arun, A. 2019. Journal of King Saud University – Science Integrated approach : Al_2O_3-CaO nanocatalytic biodiesel production and antibacterial potential silver nanoparticle synthesis from Pedalium murex extract. *Journal of King Saud University – Science*, (xxxx).

Somchaidee, P., & Tedsree, K. 2018. Green synthesis of high dispersion and narrow size distribution of zero-valent iron nanoparticles using guava leaf (Psidium guajava L) extract. *Advances in Natural Sciences: Nanoscience and Nanotechnology*, *9*(3). https://doi.org/10.1088/2043-6254/aad5d7

Sri, E., Walmiki, T., G, M. L., & Kunci, K. 2015. *Sintesis Zeolit Y dari Kaolin Terbenefisiasi*.

Sudira, I. W., Merdana, I. M., & Qurani, S. N. 2019. Preliminary Phitochemical Analysis Of Guava Leaves (Psidium guajava L.) Extract As Antidiarrheal In Calves. *Advances in Tropical Biodiversity and Environmental Sciences*, *3*(2), 21. https://doi.org/10.24843/atbes.2019.v03.i02.p01

Taba, P., Parmitha, N. Y., & Kasim, S. 2019. Sintesis Nanopartikel Perak Menggunakan Ekstrak Daun Salam (Syzygium Polyanthum) Sebagai Bioreduktor Dan Uji Aktivitasnya Sebagai Antioksidan Synthesis of Silver Nanoparticles Using Syzygium polyanthum Extract as Bioreductor and the Application as Antioxi. *J. Chem. Res*, *7*(1), 51–60.

Vijayakumar, S., Mahadevan, S., Arulmozhi, P., Subramanian, S., & P.K, P. 2018. Green synthesis of zinc oxide nanoparticles using Atalantia monophylla leaf extracts: Characterization and antimicrobial analysis. *Materials Science in Semiconductor Processing*, *82*, 39–45. https://doi.org/10.1016/j.mssp.2018.03.017

Wang, C., Wang, C., & Shih, Y. 2016. Facilitated ultrasonic irradiation in the degradation of diazinon insecticide Sustainable Environment Research Facilitated ultrasonic irradiation in the degradation of diazinon insecticide. *Sustainable Environment Research*, *26*(3), 110–116. https://doi.org/10.1016/j.serj.2016.04.003

Widia, G., Zulhadjri, & Arief, S. 2018. *Penggunaan Ekstrak Daun Jambu Biji Merah Sebagai Reduktor Alami Dalam Green Hidrotermal Sintesis Nanopartikel Emas*.

3(32), 1–44.

Yana, Y. 2018. *Uji Ekstrak Daun Jambu Biji (Psidium guajava L .) Sebagai Ovisida Keong Mas (Pomacea canaliculata L.)*. Uiversitas Islam Negeri Raden Intan.

Zhang, Y., Zhang, W., Liao, X., Zhang, J., Hou, Y., Xiao, Z., Hu, X. 2010. Ultrasonics Sonochemistry Degradation of diazinon in apple juice by ultrasonic treatment. *Ultrasonics - Sonochemistry*, *17*(4), 662–668. https://doi.org/10.1016/j.ultsonch.2009.11.007

Zheng, B., Zhao, Q., Wu, H., Wang, S., & Zou, M. 2021. A Comparative Metabolomics Analysis of Guava (Psidium guajava L.) Fruit with Different Colors . *ACS Food Science & Technology*, *1*(1), 96–106. https://doi.org/10.1021/acsfoodscitech.0c00036