International Journal of Chemical Studies 2018; 6(2): 1150-1157

International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2018; 6(2): 1150-1157

Received: 01-01-2018
Accepted: 02-02-2018

Foliatini
Department of Chemical Analysis, Polytechnic of AKA Bogor, Bogor 16154, Indonesia

Nurdiani
Departement of Industrial Waste Treatment Polytechnic of AKA Bogor, Bogor 16154, Indonesia

Correspondence
Nurdiani
Departement of Industrial Waste Treatment Polytechnic of AKA Bogor, Bogor 16154, Indonesia

Biosynthesis of anisotropic nanogold using binahong (*Anredera cordifolia*) Leaves extract as a morphology controlling agent

Foliatini and Nurdiani

Abstract
Synthesis of anisotropic gold nanoparticles has been successfully conducted using raw phytochemicals from binahong leaves, extracted by boiling the leaves in double-distilled water. The synthesis was conducted in one step, i.e. by mixing the gold precursor with the extract of binahong leaves at certain ration, and heating with the aid of microwave irradiation. The as-synthesized gold nanoparticles were characterized by UV-Vis spectrophotometry and Transmission Electron Microscopy (TEM).
The results showed that the blue colloidal anisotropic gold nanoparticles can be formed at several condition : extract from first, second or third boiling, at volume ratio of gold precursor : extract of 1 : 1 and 1 : 2, and $AuCl_4^-$ of ≥ 0,6 mM. The stability of the gold nanoparticles were high at volume ratio of gold precursor : extract of 1 : 1 and when using extract from first boiling.

Keywords: anisotropic gold nanoparticle, binahong leaves, morphology controlling agent

Introduction
In recent years, gold nanoparticles have been extensively studied by researchers, in term of their unique optical properties which related to the interaction between localized plasmonic excitations with light. Many demonstrations of the high performance of gold nanoparticles as sensors, catalysis system, and surface enhanced Raman spectroscopy (SERS) have been reported [1, 2, 3, 4]. The performance of the nanoparticles significantly affected by their size and shape, in which some application required small and sphere form of nanoparticles [5, 6, 7]. However, anisotropic form of gold nanoparticles also attracted many researchers in biomedical fields since they played an important role in the photothermal therapy for cancer treatment. The applicability of gold nanoparticles in photothermal therapy is attributed to the capability of the nanoparticles in absorbing of near infrared region of radiation [8].
There are several requirements for the nanoparticles which applied in the pharmaceutical and biomedical fields, including high biocompatibility and low toxicity. The use of chemical reducing agent with a certain level of toxicity in the bottom-up synthesis must be avoided. The characteristics of nanoparticles were significantly affected by the preparation method [9]. Thus the controlling in the steps of the preparation method and the selection of reagents in the synthesis of metal nanoparticles shall be taken into account.
The reduction method of metal precursor in the synthesis of metal nanoparticles with the aid of biomolecules extracted from part of plants, have been developed rapidly in recent decade, due to the high effectivity of the synthesis and the absence of nontoxic substances. The biomolecules from the extract usually have bulky structure, thus not only play a role as bioreductor but also as stabilizer for the as-formed nanoparticles. Several extract from these plants have been studied for the purpose, such as, Tamarind leaves [10], *Azadirachta indica* (Neem) leaves [11], geranium leaves [12], aloe vera (*Avena sativa)* [13], *Silybum marianum* [14], star fruit (*Averrhoa bilimbi)* [15].
Binahong is one of tropical plant indigeneous to Indonesia and the leaves is usually used as herbal medicine. Previous study reported abundant flavonoid content of the binahong leaves, thus the leaves are potential as a source of reducing agent for green synthesis of metal nanoparticles [16]. According to our knowledge, there has been no research discussing the synthesis of anisotropic gold nanoparticles using binahong leaves.
Besides the particle size, the particle shape is also such a factor that influence greatly to the characteristics of the nanoparticles [17]. Several studied showed that nonspherical particles,

such as rod, triangle prism, cubic, and hollow cubic have higher activity both for sensor or as part of drug delivery system.
In this study, the synthesis of anisotropic gold nanoparticles by using extract from binahong leaves was evaluated in term of morphological and optical characteristics.

Material and Method
General experimental procedures
The Binahong (*Anredera cordifolia*) was harvested from local area in Bogor, West Java. Chemical reagent such as double-distilled water, hydrochloric acid, sodium hydroxide, were purchased from Merck. All chemicals used were of analytical grade.
The Binahong (*Anredera cordifolia*) leaves were extracted using aquabidest by cutting the leaves in small pieces and boiling it in double-distilled water using magnetic stirrrer for 20 minute.
The bottom-up synthesis of anisotropic gold nanoparticles was selected using extract of binahong (*Anredera cordifolia*) leaves as reducing agent and stabilizer and the heating process was accomplished by microwave irradiation.

Sample preparation
A certain volume of 0.5 mM $HAuCl_4$ was poured in beaker glass and added by extract until a total volume of 20 mL. The beaker glass was put in the microwave oven and heated for 2-3 minutes. The change of solution color from yellow to red or purple/magenta indicated that the nanoparticles were formed. The colloidal solution of the nanoparticles were sentrifuged at 3000 rpm for 30 minutes, and readily to be characterized.

Result and Discussion
The treatment in the extract preparation may significantly influence the reducing capability of the extract and the role of morphology controlling of the as-nanoparticles. The previous study have been reported that extract of binahong leaves obtained by boiling the leaves in certain condition, played as bioreductor in the formation of red colloidal gold nanoparticles [18].
In this experiment, we conducted the synthesis of anisotropic gold nano-particles using extract of two kinds of binahong leaves, i.e. fresh and dried leaves. The characteristic of the as-obtained gold nanoparticles were first examined in the term of their UV-Visible spectra, i.e. surface plasmon resonance (SPR) wavelength and the stability of the optical properties. The gold nanoparticles in small size have appearance as red solution with SPR peak in the range of 520 nm - 530 nm, whereas the large ones tend to be purple solution with SPR peak ≥ 540 nm [19]. Nonspherical form of gold nanoparticles appear as blue colloidal solution, with two SPR peaks, namely transversal and longitudinal peak. The transversal SPR peak lay at 530 nm and the longitudinal one at above 600 nm [20].
The stability of the nanoparticles can be examined by the color change of the colloidal solution, the wavelength shift in the SPR peak, and the phase separation of the solution, followed by precipitation. The stability of the nanoparticles were assayed in the room temperature and certain length of time.
Figure 1 revealed that the extract of both the fresh or dried binahong leaves can be applied in the synthesis of gold nanoparticles, with different characteristics for different types of extract.

Fig 1: The colloidal solution of gold nanoparticles synthesized at $AuCl_4^-$ concentration of 0.4 mM and 0.6 mM by using extract from fresh and dried binahong leaves after preparation (left) and after 10 days (right)

The colloidal nanoparticles resulted from extract of fresh leaves have red purple to high intensity of dark blue appearance, while the colloidal nano-particles from extract of dried leaves have purple color, at the same gold precursor concentration. Although in the synthesis of anisotropic gold nanoparticles, the purple solution also desirable than the red solution, however, after a storage time of 10 days, the colloidal solution from the extract of dried leaves showed a sign of instability. The instability was observed from the phase separation and formation of coagulated particles that settled down to the bottom of the tubes. The phenomenon was resulted from the uncontrolled aggregation process of the particles. It can be concluded that the aggregation process was greatly influenced by the leaves condition.
The purple color of the nanoparticles synthesized by dried leaves indicated the formation of particle with large size and heterogeneous shape. The size allowed the particles to lay close in contact and interact each other by van der Waals attraction, triggering aggregation of particles.
Even though the gold nanoparticles synthesized by extract of fresh leaves also have low stability, appeared from the flocs suspected as stabilizer from extract, which peeled off the surface of the nanoparticles, however, the color of the solution may remain stable. This phenomenon indicated that gold nanoparticles synthesized by extract of fresh leaves were more stable than that synthesized by extract of dried leaves. Thus, in the next step of synthesis, the dried leaves was not selected as reducing agent in the synthesis of gold nanoparticles.
UV-Vis spectrum of the gold nanoparticles were in agreement with the color of the colloidal solution. Gold nanoparticles from extract of dried leaves, especially at precursor ($AuCl_4^-$) concentration of 0.6 mM give wavelength at higher number (Figure 2). The lowest wavelength was obtained for gold nanoparticles from extract of fresh leaves at $AuCl_4^-$ concentration of 0.4 mM. At $AuCl_4^-$ concentration of 0.6 mM, for the same extract, the SPR wavelength was 582 nm, and the color solution was dark blue, and almost similar to black due to the very high intensity. Based on this result, the next

step of the research was conducted using extract of fresh leaves at precursor concentration more than 0.6 mM. The optimization process was also conducted to yield homogeneous nonspherical nanoparticles.

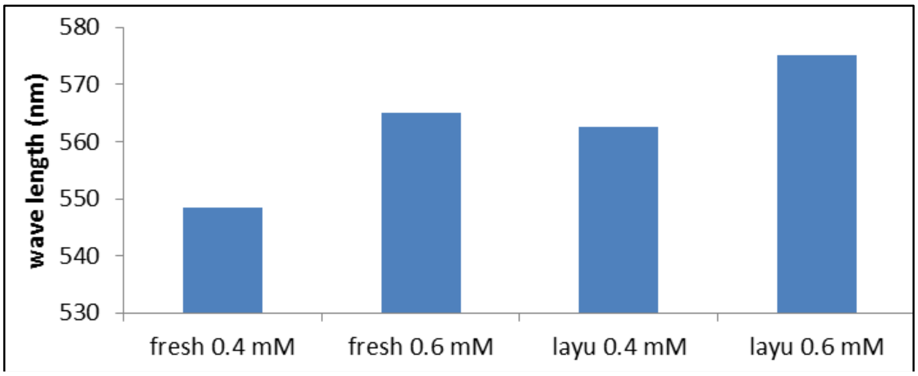

Fig 2: The histogram depicting the relation between the type of binahong leaves and $AuCl_4^-$ concentration and the wavelength of the SPR peak

The influence of extract condition was also evaluated using extract with different number of boiling replication. Figure 3 showed that colloidal gold nanoparticles solution from extract of first boiling have visually no difference in appearance compared to the second and third one. The trend was followed by all of $AuCl_4^-$ concentration. When the $AuCl_4^-$ concentration was 0.2 mM, the colloidal nanoparticle solution was red purple, at $AuCl_4^-$ concentration of 0,4 mM, the colloid was purple and at higher concentration (0.8 – 1.0 mM), it was blue.

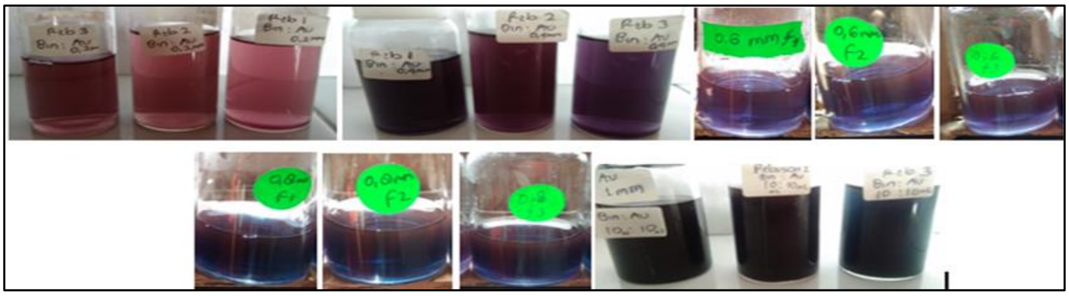

Fig 3: The colloidal solution of gold nanoparticles synthesized at $AuCl_4^-$ concentration of 0.2 mM, 0.4 mM, 0.6 mM, 0.8 mM and 1.0 mM, using extract from first (F1), second (F2), and third (F3) boiling

From the UV-Vis spectra of gold nanoparticles, it was shown that there was no significant difference in the wavelength of SPR peak as the number of boiling replication was varied (Figure 4). The result means that the boiling replication give no great difference in the morphology of nanoparticles. The phenomenon indicated that there was no significant change in the phytochemicals which play a role as reducing agent and stabilizer.

Among the variation in $AuCl_4^-$ concentration, $AuCl_4^-$ concentration of 0,6 mM yielded relatively constant wavelength, or little wavelength shift. It indicated that the concentration ratio of extract : Au precursor at the condition was the most effective in inhibiting interaction between particles, thus a slight change in the quantity of the active ingredients in the extract did not greatly affect the particles morphology.

The TEM characterization confirmed the nonspherical particles resulted at $AuCl_4^-$ concentration of 0.6 mM and 0.8 mM. (Figure 5).

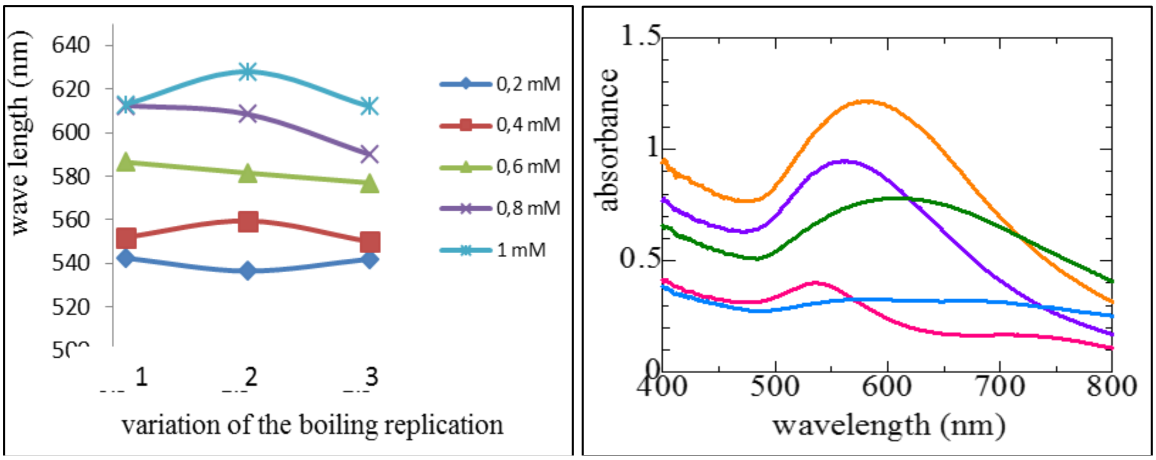

Fig 4: SPR spectra of gold nanoparticles at various $AuCl_4^-$ concentration (left) and the relation between boiling replication in the extraction process and wavelength of the SPR spectra

Deconvolution technique to resolve the curve of SPR spectra using Gaussian fitting program revealed two overlapped peaks for $AuCl_4^-$ concentration of both 0.6 and 0,8 mM (Figure 6). The doubled peaks indicated the presence of these two possibilities, first, large particles, second, nonspherical particles. It has been widely known that SPR spectra of rod- or triangle- shaped gold nanoparticles consisting transversal peak and longitudinal peak. Wavelength of longitudinal peak was influenced by aspect ratio (ratio of the between the long and short sides of the the rod shape), the tip shape of the rod particle, and volume of particle. The larger the aspect ratio, the wavelength of longitudinal peak shifted to the larger value [21].

According to the Figure 5, the overlapped peaks in the Figure 4 can be interpreted as the formation of nonspherical articles, such as triangle, rod, rhombic, cubic, or truncated form of these shapes. The formation of larger particles also occurred in this condition.

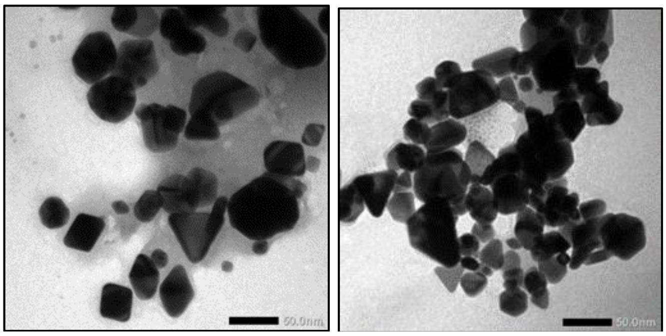

Fig 5: TEM image of gold nanoparticles at $AuCl_4^-$ concentration of 0.6 mM (left) and 0.8 mM (right)

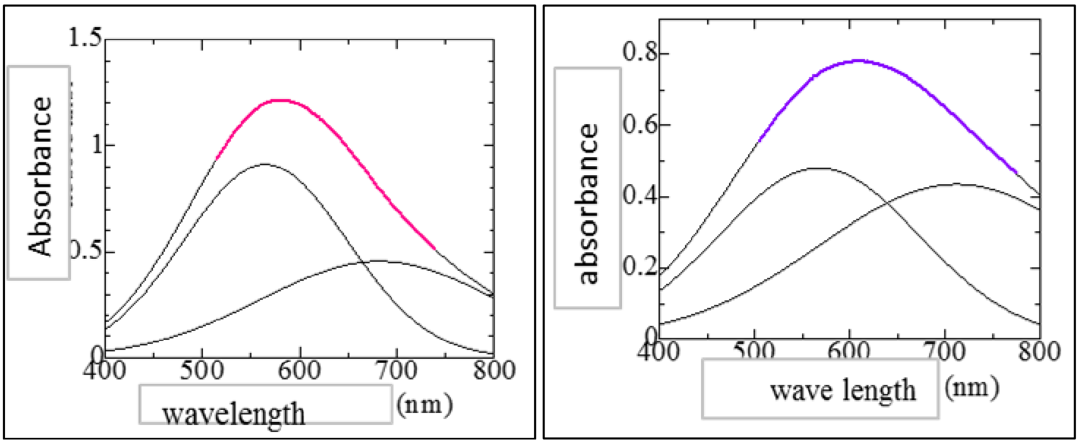

Fig 6: The result of deconvolution technique using Gaussian fitting program of gold nanoparticles synthesized by extract of binahong leaves from second boiling process at $AuCl_4^-$ concentration of 0.6 mM (left) and 0.8 mM (right)

In the selection of optimum extract condition, stability of the colloid is one of the parameters that must be considered. To evaluate the stabillity, the as-prepared colloidal nanoparticles were left at room temperature, and examined at various storage time. The result revealed that after seven days, the colloidal nanoparticles solution synthesized by extract from second and third boiling were not stable and yielded phase separation (Figure 7).

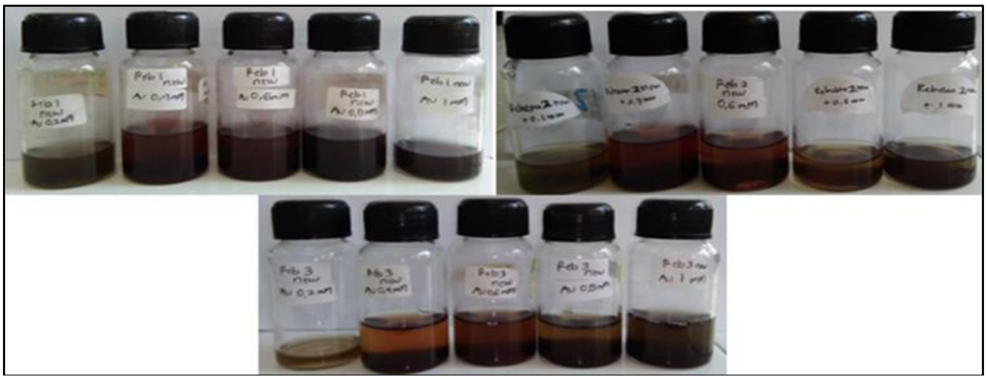

Fig 7: The colloidal solution of gold nanoparticles synthesized by using binahong leaves extract from first (left, top), second (right, top) and third (bottom) boiling, after 7 days

2. Volume ratio of $AuCl_4^-$: extract

Previous study has explained that concentration ratio of metal precursor: extract which acts as both reducing agent and stabilizer greatly affect the morphology of nanoparticles [22]. Figure 8 (top, left) showed that ratio of 1:2 yielded red colloidal nanoparticles solution indicating small size and spherical shape. At ratio of 2:1 the colloid was blue and at ratio of 4:3 and 1:1 the purple color was obtained. This phenomenon related to the prediction that the larger particles were yielded at the ratios.

Figure 8 revealed that highest wavelength SPR peak occurred at ratio of 2:1, with the value of about 600 nm. Besides, the peak was broadened, indicated that it consisted of more than one peak.

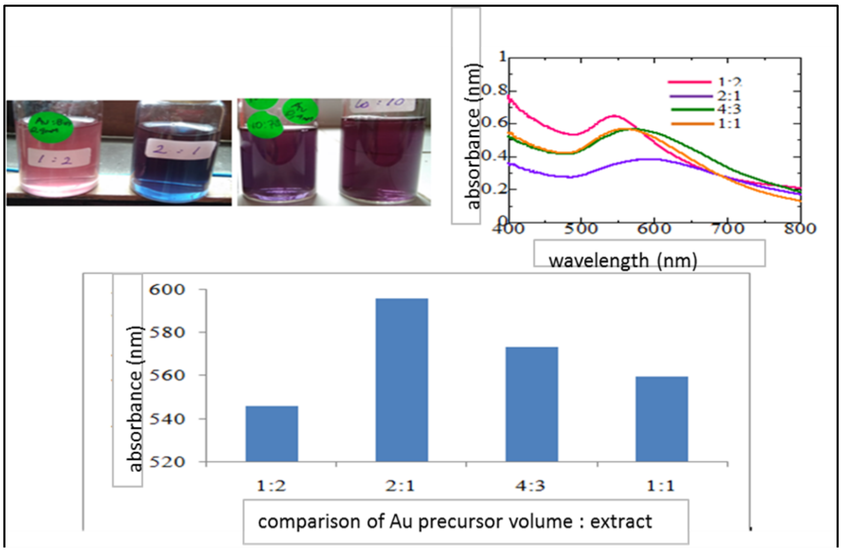

Fig 8: The colloidal solution of gold nanoparticles synthesized at volume ratio of gold precursor: extract of 1:2, 2:1, 4:3, 1:1 (top, left), their SPR spectra (top, right) and the diagram depicting the relation between the ratio and the SPR wavelength (bottom)

Even though at the ratio of 2: 1 peak at higher than 600 nm was present, it was not certain that the ratio was the optimum condition to obtain anisotropic gold nanoparticles, since the stability of the colloidal solution must be evaluated.

Figure 9 revealed that colloidal nanoparticles solution at ratio of 2: 1 was the most unstable solution compared to that of the other ratios, as shown by the phase separation after several days. The instability may come from intensive aggregation between particles. The ratio of 4: 3 also give the same result as ratio of 2: 1. The ratio of 1: 1 yielded the most stable nanoparticles, thus this ratio was selected as the optimum ratio for the anisotropic gold nanoparticles synthesis.

Fig 9: The stability of the gold nanoparticles synthesized at volume ratio of gold precursor: extract of 2:1, 4:3, and 1:1, after a certain storage time

3. Effect of $AuCl_4^-$ concentration

Figure 10 showed significant change in color as the $AuCl_4^-$ concentration increases, while maintain the volume ratio of gold precursor : extract constant. At $AuCl_4^-$ concentration of 0.2 mM, the colloid was light red with low intensity, indicated the low quantity of the nanoparticles, with mostly spherical shape. At higher concentration (0.4 mM) the colloid was magenta with high intensity, indicating the higher quantity of nanoparticles, with larger size. As the $AuCl_4^-$ concentration gets higher from 0.6 mM to 1.0 mM the blue colloidal solution was more intense, indicating the more intensive formation of nonspherical shape of nanoparticles.

Fig 10: The colloidal solution of gold nanoparticles synthesized at $AuCl_4^-$ concentration of 0.2 mM, 0.4 mM, 0.6 mM, 0.8 mM and 1.0 mM, by using binahong leaves extract from first (left, top), second (right, top) and third (bottom) boiling.

In term of SPR absorbance, the higher $AuCl_4^-$ concentration the higher the absorbance of SPR peak, since the relation between concentration and absorbance was relatively linear. As concentration of $AuCl_4^-$ was higher, the higher the amount of particle nuclei which will be reduced by the reducing agent in the extract. However, the increase only happened until a certain concentration, i.e. 0.8 mM, when the extract was from first and second boiling, or 0.6 mM, when the extract was from third boiling. At higher concentration than these concentration, the absorbance was lower, the peak become broader and the wavelength shifted to the higher value (Figure 11).

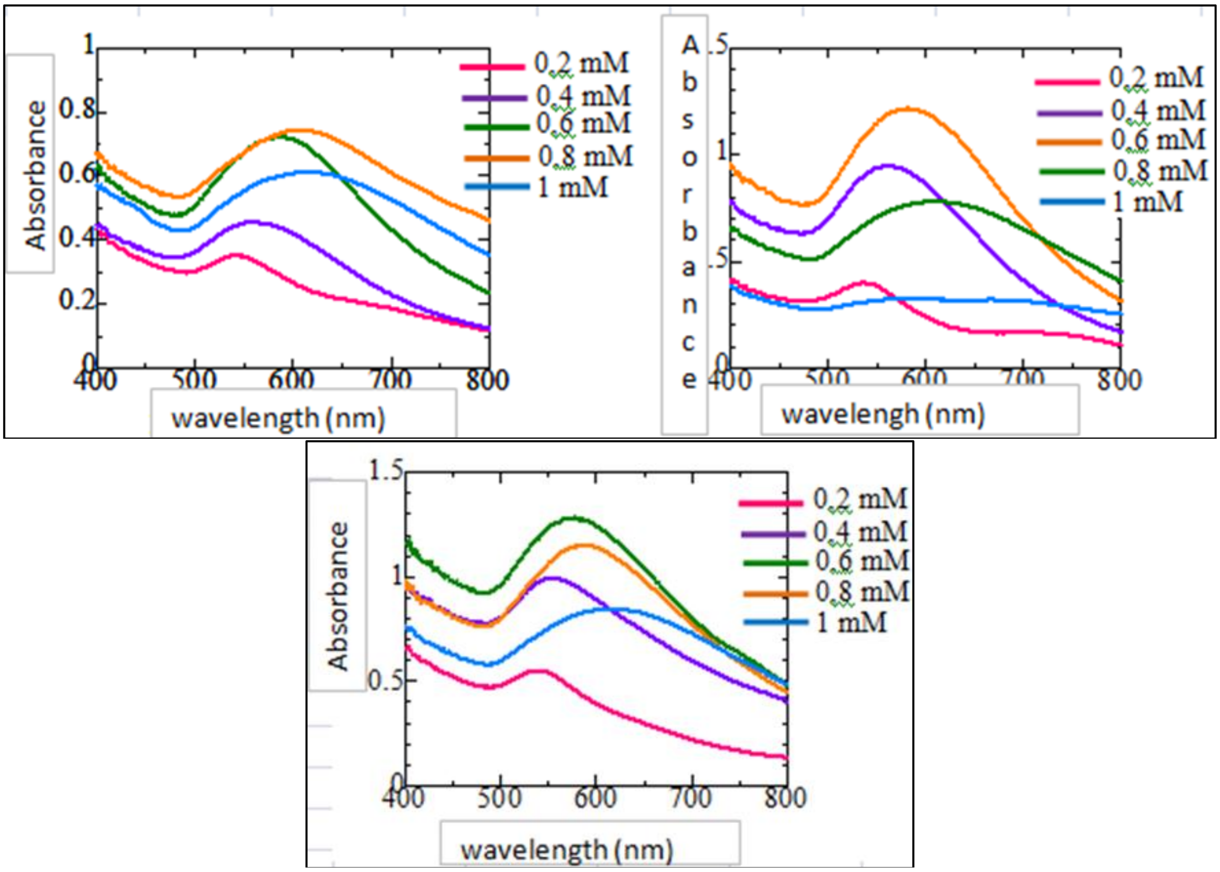

Fig 11: SPR spectra of gold nanoparticles synthesized at various $AuCl_4^-$ concentration by using extract of binahong leaves from first (left, top), second (right, top) and third (bottom) boiling

The trend of increasing wavelength as the $AuCl_4^-$ increases was clearly depicted in Figure 12. The increase was almost linear, and even linear when the extract was from second boiling. The wavelength shift of SPR peak was related to the change in particle size and shape.

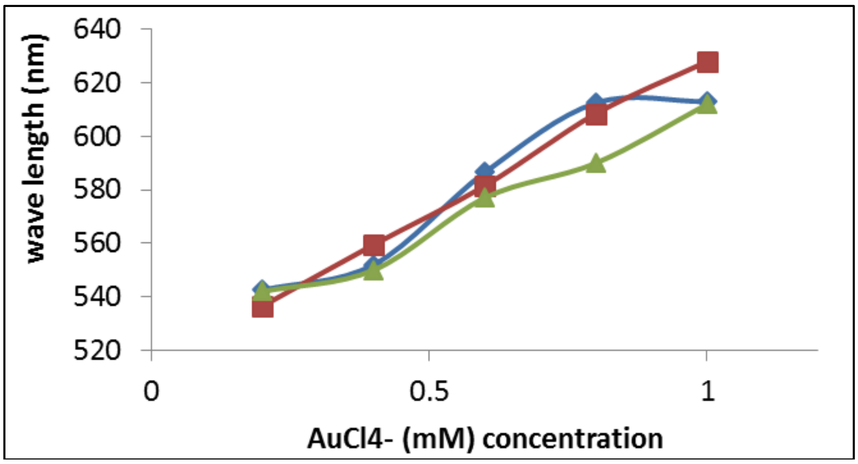

Fig 12: The relation between $AuCl_4^-$ concentration and wavelength of SPR peak of the gold nanoparticles synthesized by extract of binahong leaves from first, second and third boiling

The relation between wavelength of SPR peak and particle size was stated in the equation 1 [23].

$$\omega_s = Av_F/r \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

ω_s = frequency (in Hz), which related to the peak position, A = proportionality factor, which assumed to be unity, v_F = Fermi velocity = 1,4 x 10^8 cm/s, r = radius of metal particles.

According to equation 1, the larger r the smaller ω_s, means the larger wavelength. Although the equation only applies to metal particles in vaccuum condition, however ω_s or wavelength of UV-Vis spectrum from the equation can be used to predict the particle size. Thus, the data obtained in the experiment indicated the larger particles can be obtained by adjusting $AuCl_4^-$ concentration to be higher. Larger particles resulted from larger amount of nucleation. The high nuclei density allowed the interaction between nuclei or primary particles was more intensive, forming large cluster/ aggregates.

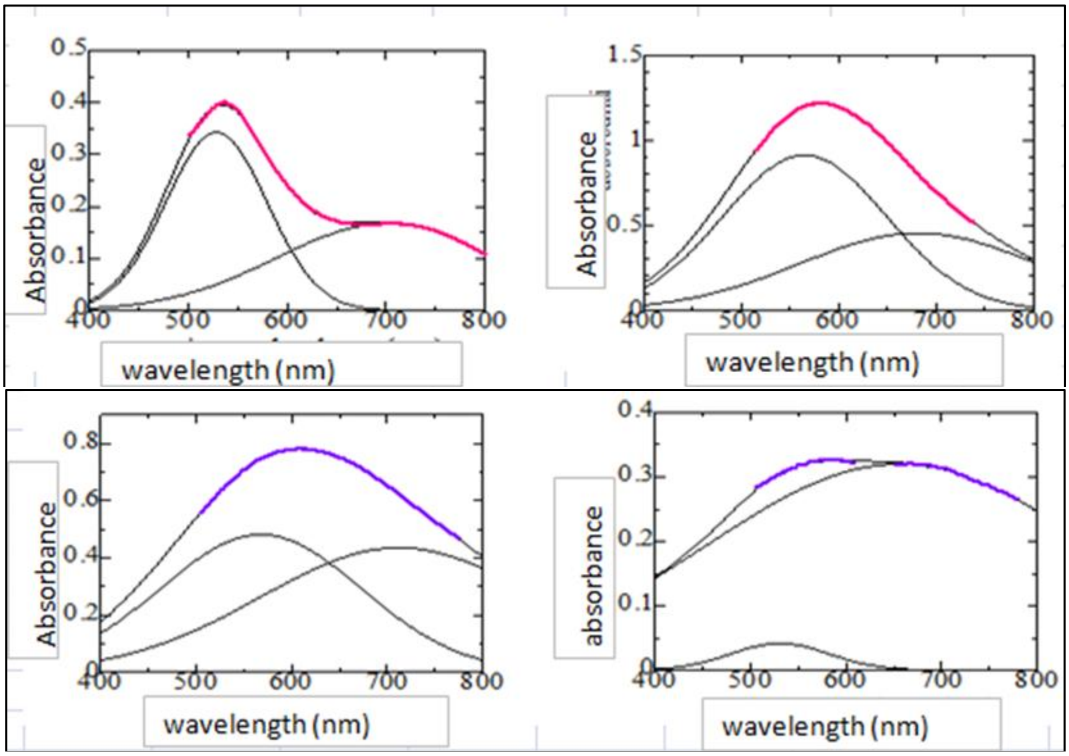

Fig 13: The result of deconvolution technique using Gaussian fitting program of gold nanoparticles synthesized at various $AuCl_4^-$ concentration of 0.2 mM (top, left), 0.6 mM (top, right), 0.8 mM (bottom, left), 1.0 mM (bottom, right)

The overlapped two peaks of SPR spectra of each concentration revealed that at the higher $AuCl_4^-$ concentration, absorbance of transversal peak decreases and that of longitudinal peak increases (Figure 13). This indicated that the formation of larger particle and/or nonspherical particles was more intense with the increase of $AuCl_4^-$ concentration.

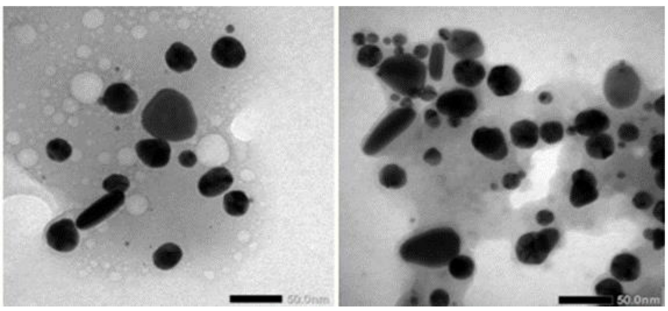

Fig 14: TEM image of gold nanoparticles synthesized at $AuCl_4^-$ concentration of 0.2 mM (left) and 0.4 mM (right)

Figure 14 revealed that the formation of nonspherical particles have been occurred since the $AuCl_4^-$ concentration was low, i.e. 0.2 mM. However, at low concentration, the amount of spherical particles was still dominant. This was in agreement with the overlapped peaks resulted from deconvolution technique. At $AuCl_4^-$ concentration of 0.2 mM and 0.4 mM, the nonspherical particles encountered have rod shape. The higher $AuCl_4^-$ concentration, the larger the amount of rod-shaped particles. When the $AuCl_4^-$ concentration was increased, the form of nonspherical particles was more various, such as triangle and rhombic. (Figure 5).

Conclusion

Nonspherical gold nanoparticles which observed visually as blue colloidal solution were successfully synthesized using extract of binahong leaves, which playes a significant role as reducing and morphological controlling agent. The triangle and cubic shape of nanoparticles can be obtained by using extract from first, second to third boiling, at $AuCl_4^-$ concentration $\geq$ 0.6 mM, and volume ratio of gold precusor : extract of 1 : 1 and 1 : 2.

Acknowledgements

This work was financially supported by Polytechnic of AKA Bogor. The authors are also grateful to the institution for providing several apparatus and instrumentation.

References

1. Barna Paul, Alka Tiwari. A Brief Review on the Application of Gold Nanoparticles as Sensors in Multi Dimensional Aspects. IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) e-ISSN: 2319-2402,p- ISSN: 2319-2399. 2015; 1(4):01-07.
2. Hamer M, Carballo RR, Rezzano IN. Polyallylamine-chlorophyllide derivatized gold and silver nanoparticles as optical probes for sensor applications. Sensors and Actuators B: Chemical. 2010; 145(1):250-253.

3. Mulisa Nemanashi-Maumelaa, Isaac Nongweb, Reagile Clifford Motenea, Bianca Leigh Davidsa, Reinout Meijbooma. Au and Ag nanoparticles encapsulated within silica nanospheres using dendrimers as dual templating agent and their catalytic activity. Molecular Catalysis, 2017; 438:184-196.
4. Navarro-Badilla RA, BrittoHurtado, M.Cortez-Valadez A.Perez-Rodriguez M.Flores-Acosta, A.Maldonado-Arce. SDS bubbles functionalized with Gold nanoparticles and SERS applications. Journal of Physica E Low Dimensional System and Nanostructure. 2017; 87:93-97.
5. Lili Wang, Shouying Huang, Baolin Zhu, Shoumin Zhang, Weiping Huang. Preparation and characterization of mesoporous TiO_2-sphere-supported Au-nanoparticle catalysts with high activity for CO oxidation at ambient temperature. Journal of Nanoparticle Research. 2016; 18:323.
6. Paramaconi Rodriguez, Daniela Plana, David J.Fermin, Marc TM Koper. New insights into the catalytic activity of gold nanoparticles for CO oxidation in electrochemical media. Journal of Catalysis. 2014; 311:182-189.
7. Sugunana A, Thanachayanontb C, Duttaa J, Hilborn JG. Heavy-metal ion sensors using chitosan-capped gold nanoparticles, Science and Technology of Advanced Materials, 2005; 6:335-340.
8. Raghunandan D, Bhat Ravishankar, Ganachari Sharanbasava D. Bedre Mahesh, Vasanth Harsoor, Manjunath S. Yalagatti, M. Bhagawanraju, A. Venkataraman. Anti-cancer studies of noble metal nanoparticles synthesizedusing different plant extracts, Cancer Nano, 2011; 2:57-65.
9. Driver Michael J. Modification of Gold Nanoparticles for SERS Application in Emulsion and Lipid Systems. 2014. http://scholarworks.umass.edu/masters_theses_2/83
10. Balaprasad A, Minakshi Chaudhary, Murali Sastry. Gold nanotriangle biologically synthesized using tamarind leaf extract and potentialapplication in vapor sensing synth react inorg metal. Org. Nanometal Chemistry, 2005.
11. Tripathy A, Ashok M Raichur, Chandrasekaran N, Prathna TC, Amitava Mukherjee. Process variable in biomimetic synthesis of silver nanoparticles by aqueous extract of Azadirachta indica (Neem) leaves. Journal Nanoparticles, 2010; 12:237-246.
12. Shankar SS, Absar Ahmad, Renu Pasricha andMurali Sastry. Bioreduction of chloroaurate ions by geranium leaves and its Endophyticfungus yields gold nanoparticles of different shapes. Journal Materials Chemistry, 2003.
13. Iravani S. Green synthesis of metal nanoparticles using plants. Green Chemistry Critical Review DOI:10.1039/c1gc15386b, 2011.
14. Gopalakrishnan R, Raghu K. Biosynthesis and characterization of gold and silver nanoparticles using milk thistle (Silybum marianum) seed extract. Hindawi Publishing Corporation. Journal of Nanoscience ID:905404, 2014.
15. Isaac RSRG. Sakthivel and Ch. Murthy. Green synthesis nanoparticles using Averrhoa bilimbi fruit extract. Hindawi Publishing Corporation. Journal of Nanoscience ID:906592, 2013.
16. Selawa W, Max Revolta, John Runtuwene, dan Gayatri Citraningtyas. Kandungan flavonoid dan kapasitas antioksidan total ekstraketanol daun binahong (Anredera cordifolia). Pharmacon Jurnal Ilmiah Farmasi, 2013; 2:1. ISSN 2302-2493.
17. Xueping Xie, Jinfeng Liao, Xiaoru Shao, Qianshun Li, and Yunfeng Lin. The Effect of shape on Cellular Uptake of Gold Nanoparticles in the forms of Stars, Rods, and Triangles. Sci Rep. 2017; 7:3827. Published online 2017 Jun 19. doi: 10.1038/s41598-017-04229-z
18. Li PC, CW Wei, CK Liao, *et al*. Photoacoustic imaging of multiple targets using gold nanorods.IEEE Trans. Ultrason. Ferroelectr. Freq. Control, 2007; 54:1642-1647.
19. Foliatini, Yoki Yulizar, Mas Ayu Elita Hafizah. Microwave-assisted Synthesis of Alginate Stabilized-Gold Nanoparticle, Makara J Sci., 2014; 18(4):111-118.
20. Dhruvinkumar Patel, Kurtis T James, Martin O Toole, Guandong Zhang, Robert S Keynton, Andre M Gobin. A High Yield, One Pot Dialysis-Based Process for Self Assembly of Near Infrared Absorbing Gold Nanoparticles. Journal of Colloid and Interface Science. 2015; 441:10-16.
21. Hoppe CE, Massimo Lazzari, Iván Pardiñas-Blanco, M. Arturo López-Quintela, 2006, One-Step Synthesis of Gold and Silver Hydrosols Using Poly(N-vinyl-2-pyrrolidone) as a Reducing Agent, Langmuir, 22:7027-7034.
22. Nurdiani, Latifah K. Darusman, Eti Rohaeti. Sintesis Adsorben Zeolit@AuNPs@MET menggunakan Ekstrak Daun Binahong (Anredera cordifolia) sebagai Bioreduktor Prekursor Au dan Karakterisasinya. Jurnal Hasil Penelitian Industri. 2015; 28:27-40.
23. Alvarez MM, Khoury JT, Schaaff G, Shafigullin MN, Vezmar I, Whetten RL. Optical Absorption Spectra of Nanocrystal Gold Molecules J Phys. Chem. B, 1997; 101:3706.