

Gold Nanoparticles from Plant Materials: Green Extraction, Biological Synthesis and Its Beneficial Properties for Cosmeceutical Applications

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ABSTRACT

Green technologies have become trends among researchers and it is developing as the current demand is increased towards products that are processed through green technologies. In this regard, green extraction and green synthesis of gold nanoparticles (GNPs) from plants are presented and discussed. Rapid development in green extraction makes the researchers are competing in providing the best extraction techniques which will use safe extracting solvent, low energy consumption, and did not release hazardous materials as residues of the processes. The same thing goes for the green synthesis of GNPs, plant extracts are used as reducing agent and it does not release any hazardous residues as compared to chemical synthesized GNPs. The application of the GNPs in this paper is reviewed on their properties that are beneficial for cosmeceutical applications. Even though the application of GNPs in the cosmeceutical application in research papers is relatively unexplored, but it has a high potential to be studied since there is existing research that recognizes the properties played by GNPs. The properties that are mostly studied by researchers are an antioxidant, anti-inflammatory, and antibacterial activity that is found to be advantageous in the production of cosmeceutical products.

Keywords:

Green technologies, green extraction, gold nanoparticles, cosmeceutical.

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1. Introduction

The extraction process is important in the development of a product. The extraction process itself will determine the types of a compound extracted, concentration and purity. Nowadays, most researchers tend to implement green extraction in research procedures. Green extraction is design

procedures that reduced energy consumption, the use of a safe solvent, the usage of natural products or renewable sources of samples, and obtains high quality of extracts [1], [2].

There are several extraction processes established, however not all of them can be considered green extractions. Generally, the extraction process is divided into two, which are conventional methods and non-conventional methods. Conventional methods are consist of Soxhlet extraction, maceration, and hydrodistillation, meanwhile, non-conventional methods are subcritical water extraction (SWE), supercritical carbon dioxide extraction (SCDE), microwave-assisted extraction (MAE), and ultrasound-assisted extraction (UAE) [3]–[5]

Plant extraction now becomes the highlight of the most research to produce safe, clean, and environmentally care products. It is due to plant is having their bioactive compound which is valuable because of its special characteristics and functions which are useful to be produced as many products such as in medical, pharmaceutical, cosmeceutical, and food products [6]. Bioactive compounds are defined as secondary metabolites that have effects in pharmacological and toxicological effects in man and animals [7]. To extract specified bioactive compounds, several methods need to be compared to identify a suitable extraction method. As the research progresses, the identified and suitable method will be focused to produced high yields and quality extracts [8]–[11].

Synthesis of gold nanoparticles (Au-NPs) from plants is a modern technology that produces nano-sized particles which have specific benefits in the targeted area [12], [13]. The process in the synthesis of nanoparticles has been developed from the chemically synthesized nanoparticles to the biological or green synthesized nanoparticles. These developing methods give a lot of advantages to the environments since the green synthesis of Au-NPs did not release the hazardous chemicals and produce safe products.

Au-NPs from plant extract is having several special characteristics and it is beneficial to be used in several applications. The application of Au-NPs is generally found in the medical and pharmaceutical fields. Currently, Au-NPs can be found in the cosmeceutical products marketed in the drug store, but the sources and type of Au-NPs synthesis were mostly not listed on the label. It is commercialized for it several special characteristics such as antioxidant activity and anti-inflammatory activity. Even though the Au-NPs from plant extracts in the cosmeceutical application were relatively unexplored, but there are abundant advantages and benefits of it that are valuable to explore and study.

2. Green extraction of plant materials

The awareness to produce high-quality and safe extracts has been increases among researchers. Thus, there are so many green extraction methods invented and modified to get the best condition for the extraction to happen. There are several methods classified as green extraction that currently been widely utilized. In this review paper, the green extraction methods of plants discussed are subcritical water extraction (SWE), supercritical carbon dioxide extraction (SCDE), microwave-assisted extraction (MAE), and ultrasound-assisted extraction (UAE). The performances of the listed green extraction methods for plants are stated in Table 1.

Subcritical water extraction (SWE) or pressurized hot water extraction (PHWE) is a green extraction method that uses water as a solvent to extract phenolic compounds, proteins, and amino acids [14]. Pressure and temperature play the main roles in SWE, as at ambient condition, water is extremely polar, meanwhile, as the conditions vary, the polarity of water could change, depending on its dielectric constant values [1], [15]. In the subcritical water extraction, factors that may affect the research procedure are pressure, temperature, time, solid to solvent ratio, and particle size depending

on the plant chosen as raw materials [14], [16]–[19]. There is research conducted in the optimization *Salvia Officinalis L.* using SWE [20]. It was found that the optimum process parameters are at a temperature of 201.5°C, extraction time of 15.8 minutes, and pure water as a solvent. In the other study, the optimization process parameter in SWE of *Coriandrum Sativum* seeds was the temperature of 200°C, the pressure of 30 bar, and extraction time of 28.3 minutes [21].

Supercritical carbon dioxide extraction (SCDE) is listed as established green extraction which can extract the samples without leaving any solvent on them. Supercritical carbon dioxide extraction has been commonly used because of its moderate critical temperature and pressure, however, this method is less effective to extract more polar compounds due to its low solubility [22]. To extract polar compounds effectively, co-solvent which has higher polarity was used [23]. There are several studies on the optimization of SCDE that were done to identify the optimum significant factors in extraction. A study conducted using SCDE to extract oil from *Hippophae* "Thamnoides L. found the optimum conditions were extraction pressure of 27.6 MPa, the temperature of 34.1°C with a flow rate of 17.0 L/h, and extraction time of 82 minutes [24]. The other research optimization of SCDE using *Piper Nigrum L.* found the optimum process parameters were the pressure of 266 bar, the temperature of 47°C, time of 150 minutes [25]. From the findings, factors that may attribute to the performance of supercritical carbon dioxide are pressure, temperature, time, and flow rate [24], [26].

Microwave-assisted extraction (MAE) is classified as green extraction because it provides fast, uniform, and localized extraction that is an economical energy-saving procedure [27]. Microwave-assisted extraction works by increasing the internal pressure in plant structure as it disrupts the cell structure to extract the bioactive compound out of the plant [28]. An extraction of *Zea Mays L.* using MAE found that the optimum condition in extracting anthocyanins was extraction time of 19 minutes, solid to solvent ratio of 1:20, and microwave power of 555W [29]. Meanwhile, the optimum condition for MAE of *Zingiber Zerumbet* was ethanol concentration of 44%, microwave power of 518W, the irradiation time of 38.5 seconds, and solid to liquid ratio of 38 mL/g [30]. Factors that may affect the extraction are microwave power, time, pH, solid to solvent ratio, and frequency [27], [28], [31]–[33].

Ultrasound-assisted extraction (UAE) is a green extraction because it is an efficient procedure that makes the extraction inexpensive, environmentally friendly, and less time-consuming [34]. Ultrasound-assisted extraction works to extract the bioactive compounds from the plant by producing the shockwaves as well to disrupt and diffuse the solvent into the cell structure is to make the extraction happen effectively [28], [34]. From a study of optimization of anthocyanins from *Rubus Idaeus L.* using UAE, the optimized process parameters identified were extraction time of 200s, ratio solvent to solid of 4:1, and ultrasonic power of 400W [35]. There are other findings in UAE of wheat bran, it was found that the optimum process parameter was ethanol concentration of 64%, extraction temperature of 60°C, and extraction time of 25 minutes [36]. In the process of ultrasounds-assisted extraction, the factors that affect the extractions to happen effectively are power, frequency, temperature, time, and ultrasonic intensities [35], [36].

Generally, subcritical water extraction (SWE), supercritical carbon dioxide extraction (SCDE), microwave-assisted extraction (MAE), and ultrasound-assisted extraction (UAE) are commonly used in the recent green extraction research procedure. All the reactors produced by the researchers might differ by their designs, but the function will be the same for each extraction procedure is to produce extracts that are safe and beneficial to be used in any industry.

Table 1. Green extraction and its performance

Extraction method	Plant	Part of the plant	Solvent	Condition of extraction	Result	Ref.
Subcritical water extraction (SWE)	<i>Zingiber Zerumbet</i>	Rhizome	Distilled Water	Temperature: 130 - 170°C Pressure: 2.0 MPa Time: 20-40 mins	Extracts: zerumbone Optimum condition: Temperature: 170°C Time: 20 mins	[37]
	<i>Curcuma Longa L.</i>	Rhizome	Deionized water	Temperature: 120, 130, 140, 150 & 160°C Pressure: 10, 15, 20 & 25 bar Particle size: 2, 1, 0.71 & 0.6 mm Time: 6, 10, 14, 18, 22 mins	Extract: Curcumin Optimum condition: Temperature: 140°C Pressure: 10 bar Particle size: 0.71 mm Time: 14 mins	[38]
	<i>Citrus Unshiu Markovich</i>	Fruit peel	Purified water	Temperature: 130-190°C Pressure: 3 MPa Time: 15 mins	Extract: Flavanoids Optimum condition: Temperature: 130°C Time: 15 mins Solute to solvent ratio: 1/34	[18]
	<i>Hedyotis Diffusa</i>	Whole plant	Ultrapure water	Temperature: 120-200°C Pressure: 0.6 - 3.0 MPa Time: 10 - 15 mins Particle size: 20 – 100 mesh Solvent/Solid Ratio: 20 – 40 mL/g	Extract: Ursolic acid Optimum condition: Temperature: 157°C Solvent/solid ratio: 30 mL/g Mesh: 80	[19]
	<i>Garcinia Mangostana Linn</i>	Fruits pericarp	Pure water	Temperature: 120-180°C Pressure: 1-5 MPa Time: 30-50 mins	Extracts: Xanthone Optimum condition: Temperature: 180°C Pressure: 3MPa Time: 150 mins	[14]
	<i>Black Camellia Sinensis</i>	Leaves	Purified water	Temperature: 100, 125,150 & 175°C Particle size: 0.5, 1 and 2 mm	Extracts: Caffeine Optimum condition: Temperature: 175°C	[39]

				Water flow rate: 1,2 & 4 g/min	Particle size: 0.5mm Water flow rate: 2 g/min Time: 180 mins	
Supercritical Carbon Dioxide Extraction	<i>Curcuma Amada Roxb.</i>	Rhizome	Compressed CO ₂	Pressure: 100 – 350 bar Temperature: 40 – 60 °C Time: 5 – 15 hours	Extract: Phenolic compound Optimum condition: Pressure: 350 bar Temperature: 60 °C Time: 15 hours	[40]
	<i>Thymus Vulgaris</i>	Leaves	Compressed CO ₂	Pressure: 200 bar Temperature: 40 °C Time: 90 – 240 mins Flow rate: 0.5 – 2.0 mL/min	Extract: Essential oil Optimum condition: Pressure: 200 bar Temperature: 40 °C Time: 180 mins Flow rate: 2.0 mL/min	[41]
	<i>Passiflora Edulis F.</i>	Fruit seed	Compressed CO ₂	Pressure: 15, 20 & 25 MPa Temperature: 40 & 50 °C Time: 200 mins Flow rate: 1.5 & 3.0 cm ³ min ⁻¹	Extract: Essential oil Optimum condition: Pressure: 25 MPa Temperature: 50 °C Time: 200 mins Flow rate: 3.0 cm ³ min ⁻¹	[42]
	<i>Rosa Canina</i>	Fruit	Compressed CO ₂	Pressure: 20 – 45 MPa Temperature: 40 – 80 °C Time: 2.5 hours Flow rate: 3 ml/min	Extract: Lycopene Optimum condition: Pressure: 45 MPa Temperature: 80 °C Time: 2.5 hours Flow rate: 3 ml/min	[43]
Microwave- assisted extraction	<i>Opuntia Ficus Indica</i>	Stem barks	Ethanol	Microwave power: 400-600 W Ph: 1.5 - 3 Time: 1 - 3 mins Solid to liquid ratio: 2/20 – 2/50 g/mL	Extracts: Pectin Optimum condition: Microwave power: 517 W Ph: 2.26 Time: 2.15 mins Solid to liquid ratio: 2g/30.6 mL	[31]
		Leaves	Ethanol and water	Microwave power: 100-300 W Time: 2-20mins	Microwave power: 100-300 W Time: 2-20 mins	[28]

	<i>Orthosiphon Stamineus</i>			Solvent to sample ratio: 20-8 mL/g	Solvent to sample ratio: 20-8 mL/g	
	<i>Hylocereus Spp.</i>	Fruits peel	Distilled water	Microwave power: 300, 450, 600 W Frequency: 2450 MHz Time: 5 & 10 mins	Extracts: Pectin Optimum condition: Microwave power: 450 W Time: 5 mins	[44]
Ultrasound- assisted extraction	<i>Polygonum Cuspidatum</i>	Root	Ethanol and water	Sonication power: 90 – 150 W Frequency: 40 kHz Ethanol concentration: 40 – 80% Temperature: 30 – 70 °C Time: 20 mins	Extracts: Resveratrol Optimum condition: Sonication power: 120 W Frequency: 40 kHz Ethanol concentration: 58.51% Temperature: 70 °C Time: 20 mins	[45]
	<i>Peumus Boldus Mol.</i>	Leaves	Distilled water	Sonication power: 10 - 23 W/cm ² Temperature: 10 - 70°C Time: 10- 40 mins	Extracts: Vegetal matrix material Optimum condition: Sonication power: 23 W/cm ² Temperature: 36°C Time: 40 mins	[46]
	<i>Fagopyrum Tataricum Gaertn.</i>	Fruits	Ethanol and water	Sonication power: 200 W Frequency: 40 kHz Ethanol concentration: 40 – 80% Solid to liquid ratio:1:10 – 1:50 g/mL Temperature: 40 – 80 °C Time: 10 – 50 mins	Extracts: Flavonoids Optimum condition: Ethanol concentration: 65% Solid to liquid ratio:1:40 g/mL Temperature: 65 °C Time: 35 mins	[47]
	<i>Punica Granatum L.</i>	Fruits peel	Methanol and deionized water	Frequency: 40 kHz Methanol concentration: 100, 75, 50, 25 & 0% Solvent to solid ratio: 50 g/mL Temperature: 60°C Time: 40 mins	Extracts: Bioactive compound Optimum condition: Frequency: 40 kHz Methanol concentration: 75% Solvent to solid ratio: 50 g/mL Temperature: 60°C Time: 40 mins	[48]

3. Biosynthesis of gold nanoparticles from plant extract

Green synthesis of gold nanoparticles (Au-NPs) from plant extracts has been the main interest for most researchers nowadays. The definition of the green synthesis of nanotechnology is the usage of biological organisms, plants biomass, or extract to produce nanoparticles [49]. Instead of using a chemical synthesis of nanoparticles that produce large hazardous by-products, the biological synthesis of Au-NPs from plants produces more stable and safe products to be applied in any targeted applications.

The green synthesis procedure that is generally utilized by the researchers is the plant extracts were mixed with chloroauric acid (HAuCl_4) at condition parameters selected based on the research needs [50]–[52]. Then the time for the reduction of the gold ion to happen is recorded. Au-NPs are categorized as inorganic nanoparticles and in the process of ion reduction, the solution may appear deep red to black in the mixture solution, however, the color may exhibit a lighter color as it is depending on the factors chosen by the researchers [53].

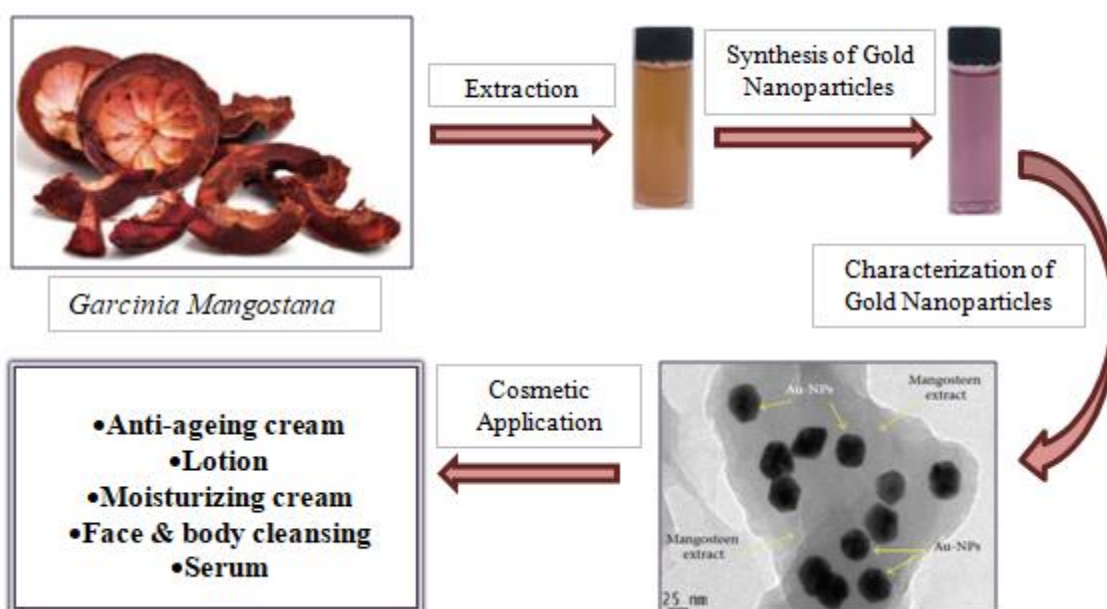


Figure 1. Schematic of plant green extraction and biosynthesis of gold nanoparticles [54]

A schematic diagram of plant green extraction and biosynthesis of gold nanoparticles is shown in Figure 1, illustrate the raw materials will go through the green extraction process, followed by biosynthesis of Au-NPs. The Au-NPs produced will be characterized its properties. Then, a range of cosmeceutical and personal care products formulated with gold nanoparticles of plant materials as active ingredients. The product formulated will go through several characterization processes to identify the capability of each product for commercialization.

3.1 Effecting parameters in the biosynthesis of Au-NPs

Various plants have been used in the synthesis of Au-NPs, as listed in Table 2 and illustrated in Figure 2. It could be from the rhizome, fruit peel, leaves, seed, root, and flower. In the synthesis of Au-NPs from plants, several factors need to be taken into considerations. These factors are extract concentration, metal ion concentration, reaction temperature and pH [55], [56].

In the synthesis of Au-NPs from olive leaves extracts, the results showed the extract concentration is having a significant effect on the morphology of Au-NPs synthesized [57]. It was stated that higher extract concentration will produce symmetrical nanoparticles. Synthesis of Au-NPs from *Sorbus Aucuparia* has analyzed the same results as the concentration of the extracts increased, it will increase the formation of Au-NPs as well as decreased the size of nanoparticles produced [58]. However, in the synthesis of Au-NPs of *Macrotyloma Uniflorum* and *Camellia Sinensis*, it showed at higher extract concentration, the size of Au-NPs is increased because of the stronger interaction between protective biomolecules and gold nanocrystals [59], [60]. Hence, in the synthesis of AU-NPS, it shows the morphology obtained is depending on the properties of plant extracts.

Metal ion could be one of the factors that can be taken into consideration in the synthesis of Au-NPs. In both research conducted in producing AU-NPS from *Chenopodium album* and *Sorbus Aucuparia* extracts, once the metal ion concentration is increased, the particle size of Au-NPs increased [58], [61]. A similar pattern also found in the synthesis of Au-NPs of *Rosa Rugosa* leaves extracts, as the particle sizes are directly proportional to the concentration of metal ions [62].

The temperature is also affecting the synthesis of Au-NPs as the temperature was found to be a significant factor in the optimization of synthesis parameters of Au-NPs synthesis from *Aegle Marmelos* [63], [64]. For *Gnidia Glauca* flower extracts, the optimum temperature for the synthesis of Au-NPs is 50°C [65]. It was observed that there is no synthesis to happen at a lower temperature as 4°C and 20°C, meanwhile, the rate of reaction at 30°C and 40°C were not as optimum as 50°C. The same pattern was occurred in the synthesis of Au-NPs from *Tanacetum Vulgare*, as the temperature was increased from 25°C to 150°C, the rate of reaction of Au-NPs produced is increased [66]. In contrast, there are several Au-NPs can be produced rapidly at room temperature using *Hibiscus Rosa Sinensis*, *Mangifera Indica*, *Murraya Koenigii*, and *Rosa hybrida* extracts [67]–[70].

There is a study showed that a variety of shapes of Au-NPs such as decahedral, hexagonal, isosahedral, irregular, and rod-shaped could be produced depending on reaction medium pH [71]. In a study of producing Au-NPs from *Momordica Charantia*, it was analyzed the optimum pH is 10 which produced spherical nanoparticles and gives the most stable pH for AU-NPS synthesized [72]. Other research conducted found, Au-NPs synthesized from *Aegle Marmelos* showed that the optimum condition for synthesis is at pH 8.5 with spherical, cubical, and triangular shapes [63].

Process conditions in the synthesis of Au-NPs are found to be varies depending on the plant extracts used. It was proved that extract concentration, metal ion concentration, temperature, and pH play an important role in the green synthesis of Au-NPs from plant extracts.

Table 2: Au-NPs of plant extract

Part of the plant	Plant	Condition of synthesis				Result			Ref.
		Extracts	Metal ion	Temp. (°C)	pH	Time	Size (nm)	Morphology	
Rhizome	<i>Zingiber Officinale</i>	5mL extracts	1 mM HAuCl ₄	50°C	9	180 mins.	5 – 20	Fcc triangular, truncated triangular or hexagonal shaped	[73]
	<i>Momordica Cochinchinensis</i>	1mL extracts	20mL 0.01mM HAuCl ₄ .3H ₂ O	Room	-	24 hrs.	16	Spherical, triangular and hexagonal shaped	[74]
	<i>Dyosma Pleiantha</i>	1mL extract	10mL 1mM HAuCl ₂ aqueous solution	30 – 60°C	-	20 mins.	127	Spherical shaped	[75]
	<i>Curcuma Longa L.</i>	0.25mL curcumin solution (Curcumin,NaOH &H ₂ O)	1mL 1mM HAuCl ₄ + 8mL water	Room	-	2 hrs.	5 – 20	Triangles and hexagons shaped	[76]
Leaves	<i>Nepenthes Khasiana</i>	10mL extracts	90mL 0.001M HAuCl ₄	Room	-	3 hrs.	50 - 100	Triangular and spherical shaped	[77]
	<i>Dracocephalum Kotschyi</i>	2.0mL extract	10mL 1mM HAuCl ₄	30 – 90°C	2,4,6 & 8	10 mins	7.9 - 22.63	Spherical or near spherically shaped	[78]
	<i>Lavandula Angustifolia</i>	1.0mL extract	10mL 0.5mM HAuCl ₄	22 – 25°C	-	4 hrs.	34-300	Quasi-spherical and triangular shaped	[79]
	<i>Tamarindus Indica L.</i>	1.0mL extract	10mL 0.27mMHAuCl ₄	Room	10	70 mins	52 ± 5	Spherical shaped	[80]

Fruit peel	<i>Garcinia Mangostana</i>	20mL peel extract	10 mM HAuCl ₄	Room	-	3 mins	32.96 ± 5.25	Spherical shaped	[54]
	<i>Momordica Charantia</i>	Peel extract	100 ppm HAuCl ₄	100°C	10	<5 second	10 – 100	Spherical shaped	[72]
	<i>Punica Granatum</i>	1.8mL peel extract	50mL AuCl ₃	Room	-	5 mins.	10 ± 1.5	Spherical shaped	[81]
	<i>Citrullus Lanatus</i>	10mL extract	100mL of 1mM HAuCl ₄	Room	-	1 hour	20 - 140	Spherical, triangular and cuboidal shaped	[82]
Seed	<i>Abelmoschus Esculentus</i>	40mL seed aqueous broth	60mL 1mM HAuCl ₄	Room	7	10 mins.	45-75	Uneven surface morphology	[83]
Root	<i>Morinda Citrifolia L</i>	3mL root extract	34mL 1mM HAuCl ₄	Room	-	≤12 hrs.	12.17 – 38.26	Spherical, triangle and hexagonalshaped	[84]
Flower	<i>Gnidia Glauca</i>	5mL flower extract	95mL 0.7mM HAuCl ₄	50°C	7	20 mins	10 – 150	Spherical shaped	[65]
	<i>Carthamus Tinctorius L.</i>	5mL flower extract	45mL 0.002M AuCl ₄	Room	-	30 mins	40 – 200	Triangle and spherical shaped	[85]
	<i>Bauhinia Purpurea</i>	1mL flower extract	9mL HAuCl ₄	60°C	-	30 mins	20 – 50	Cubic shaped	[86]
	<i>Alhagi Maurorum</i>	5mL flower extract	25mL 0.5mM HAuCl ₄	35°C	-	15 mins	12 – 24	Spherical shaped	[87]

4. Properties of Au-NPs that beneficial for cosmeceutical application

The extensive research of Au-NPs has been identified that several properties exhibit by Au-NPs synthesized by plant extracts are valuable for cosmeceutical applications. In this review paper, the antioxidant, anti-inflammatory, and antibacterial activity were identified to be favorable towards topical application cosmeceuticals products.

The antioxidant activity is important in the production of cosmeceutical products as it can give protection from the free radical activities which will affect the skin condition and accelerating skin aging [79], [88]. Au-NPs are found to have antioxidant properties that have the potential for anti-aging effects[89], [90]. Several studies have been done to identify the antioxidant properties of Au-NPs synthesized by plants. A study conducted proved that Au-NPs synthesized using *Nerium Oleander* leaves was exhibit antioxidant activity and it was increased as the concentration of Au-NPs increased [91]. Another research has proved in the identification of antioxidant activity of *Hovenia Dulcis*, as the concentration of Au-NPs increased, the antioxidant activities increased [92]. There are several findings stated that the Au-NPs synthesized is having higher antioxidants compared to raw extract itself and it was proved by Au-NPs synthesized from *Morus Alba* leaves [93].

The anti-inflammatory activity of Au-NPs will act as a protective response that will release the immune system chemicals. From the findings, there were several discoveries approved that Au-NPs from the plant are exhibit anti-inflammatory activity. A study was done using Au-NPs synthesized from *Viburnum Opulus L.*, *Sambucus Nigra L.*, and *Cornus Mas* in the production of dermatological creams [94]. The test was performed by using *in-vivo* and *in-vitro* approaches and the results show gold nanoparticles possess anti-inflammatory activity as stated as *Viburnum Opulus L.* has the best anti-inflammatory effects, followed by *Cornus Mas* and *Sambucus Nigra L.* There is another study of Au-NPs of *Prunus serrulata*, the research found the gold nanoparticles are having anti-inflammatory activity, thus suggest that its potential as a therapeutic agent [95]. A comparison of anti-inflammatory activity has been made between methanolic and Au-NPs of *Litchi chinensis* leaves extracts. From the research, it was found that Au-NPs of *Litchi chinensis* is having higher anti-inflammatory activity compared to its extract alone [96].

Antibacterial activity is crucial in medical and pharmaceutical fields as it will assist in the inhibition of selection bacterial from occurring and reoccurring in the targeted area. In research of conducting antibacterial activity of Au-NPs of *Pergularia Daemia* leaf extract, the results showed the Au-NPs are more effective towards gram-negative organisms such as *E.coli* and *Pseudomonas aeruginosa* compared to the gram-positive organism such as *Bacillus subtilis* [97]. It was suggested that it may have potential in the biomedical field by the significant effect of antibacterial activity. Other researchers are using Au-NPs capped with *Ocimum tenuiflorum*, *Azadirachta indica*, *Mentha spicata*, and *Citrus sinensis* respectively. Each of the Au-NPs produced found to be effective on both negative and positive gram bacteria inhibit the *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Klebsiella pneumoniae* [98]. As the results obtained in the research, these Au-NPs are found to have the possible potential for controlled drug delivery and biomedical imaging.

Generally, the synthesized Au-NPs from plants is usually focused in the medical and pharmaceutical field. Most researchers are fond to analyze the potential of Au-NPs in the treatment of several diseases, such as cancer and diabetes [99], [100]. Since gold nanoparticles have benefits as discussed, they can be advantageous for cosmeceutical applications.

Recently, Au-NPs from the plant is not widely used into cosmeceutical products as it is relatively unexplored. Even though there are marketed products are using Au-NPs, but to be realistic, as for now there are very limited research paper discussed the Au-NPs synthesized from the plant in

cosmeceutical products. It indicates that the development of cosmeceutical products from plant synthesized Au-NPs need to be explored to create more valuable products to be commercialized in the future. There are several properties of Au-NPs from the plant that are very beneficial were characterized and discussed. The previous study shows that the Au-NPs exhibit antioxidant and anti-inflammatory activity. These properties are very important and scientifically will give benefits and advantages for topical delivery especially in cosmeceutical applications. Even though the rate of anti-inflammatory activity could be vary depending on the plant extract used, in terms of cosmeceutical application, Au-NPs were suggested that can prevent any redness resulted from skin irritation with the application of Au-NPs cosmeceutical creams. Skin elasticity will be increased and blood circulation on the skin will be improved with the application of Au-NPs [101]. Permeation of Au-NPs through the skin was studied and it was found that spherical Au-NPs were not inherently toxic to human skin cells and as smaller the particle sizes, the easier Au-NPs permeates into skin structure[101], [102].

Despite the limited study on cosmeceutical products that using Au-NPs, it is not obligated the cosmeceutical manufacturer to produce cosmeceuticals products that include Au-NPs. The cosmeceuticals product that includes Au-NPs that available in the market are SAFI Rania Gold Concentrated Serum 50x and Nano Gold Firming Treatment manufactured by Winpro Unza and Chantecaille respectively[103]. These products are focused on anti-aging action which complements the properties of Au-NPs discussed earlier. However, these cosmeceutical products did not produce from Au-NPs synthesized from plant materials. It indicates that there are cosmeceutical products that use Au-NPs, but up-to-date there are no available marketed cosmeceutical products produced using Au-NPs synthesized by plant material.

5. Conclusion

The extensive review of green technologies in the extraction and Au-NPs synthesis of plant materials gives a broad understanding of the best process parameters that produced an extract at its optimum condition and synthesis of Au-NPs from plant extract, which is environmentally friendly. The application of gold nanoparticles in medical and pharmaceutical products has been broadly explored, thus foreseen the gold nanoparticles are more likely to be extensively utilized in the future. However, the production of cosmeceutical products from Au-NPs is relatively unexplored but, the Au-NPs from plant extract are having several properties that beneficial for the skin. These properties are antioxidant, anti-inflammatory, and antibacterial activity. Future studies could be done and explored about Au-NPs from plant extract in cosmeceutical products which will benefit the consumer.

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