GOLD NANOPARTICLE SYNTHESIS IN THE PRESENCE OF THE FLAVONOID QUERCETIN

Annika Holm*, Dr. Murielle Watzky*

Department of Chemistry and Biochemistry, University of Northern Colorado, Greeley, CO 80639

Department of Chemistry and Biochemistry

ABSTRACT Gold metal nanoparticles are of interest to the scientific community due to their potential applications as biosensors and/or in drug delivery. The goal of this project was to investigate the synthesis of gold nanoparticles, which could be biocompatible, via a 'green synthesis' method. This work looks at modifications of a literature procedure for the bottom-up synthesis of gold nanoparticles in the presence of the readily available flavonoid quercetin, which acts as both a reducing and stabilizing agent. Efforts were made to optimize synthetic reproducibility and nanoparticles stability. UV-visible spectroscopy was utilized to follow the reaction kinetics by monitoring changes in surface plasmon resonance for the gold nanoparticles. Other methods such as scanning electron microscopy with energy-dispersive X-ray were utilized to characterize the nanoparticles.

INTRODUCTION Nanoparticles are submicroscopic accumulations of atoms that are between 1 and 100 nm. The large surface to volume ratio of nanoparticles leads to both chemical and physical differences between a metallic nanoparticle and its bulk metal (Iravani 2011). They are of interest to researchers due to their antimicrobial properties and ability to more efficiently deliver drugs than current medicines. Nanoparticle-bound drugs are useful for their longer circulation times and more localized delivery than regular drugs. Because they cannot circulate broadly around the body, the side effects of nanoparticle bound drugs are limited (Mittal 2012). This project will look at the ability of flavonoid compounds to synthesize gold nanoparticles from gold metal ions. Nanoparticles can be synthesized in a "bottom up" one step process. The process involves reacting a solution of metal salt with a compound from plant extract that can act as a reducing and stabilizing agent. Rosa rugosa leaves have been used to synthesize gold and silver nanoparticles at room temperature within minutes (Rajan et al. 2015). Because they contain reducing agents such as water-soluble metabolites like alkaloids, phenolic compounds, and co-enzymes, plants are able to reduce metal ions (Mittal 2012). This project will look specifically at the flavonoid compound quercetin. The goal of this project is to better understand the chemical steps involved in the synthesis of gold nanoparticles with quercetin in order to control nanoparticle size and shape, as well as increase synthesis reproducibility. Other goals of this project are to understand the role of flavonoid compound in forming a complex with the metal ion in the metal salt and how complexation influences the reduction of metal ions by flavonoid compounds. UV-visible spectroscopy will be utilized to follow the reaction by monitoring changes in surface plasma resonance. To achieve those goals, $HAuCl_4$ will be reacted with quercetin in an aqueous solution. Attempts to optimize the synthesis of gold nanoparticles can be made by manipulating different variables, such as adjusting the pH with a strong base, adding heat, or adding ethanol to increase quercetin solubility. SEM, AFM, DLS, and powder XRD can be used to characterize the nanoparticles once they are formed.

EXPERIMENTAL

Nanoparticles synthesis: Ten milliliters of a 1 mM solution of $HAuCl_4$ in nanopure water were placed in a 50-mL round-bottom flask and warmed to 40 ^{0}C in a water bath. Half a milliliter of a 2 mM solution of quercetin in 10 mM NaOH was warmed to 40 ^{0}C in a water bath and added to the round bottom flask in a single purge. The reaction was then run for 15 minutes with stirring in a 40 ^{0}C in a water bath.

UV-vis spectra: The reaction mixtures were diluted in a 1:2 ratio with nanopure water prior to taking the UV-vis spectra.

SEM/EDX sample preparation: Samples for scanning electron microscopy (SEM) and energy dispersive x-ray analysis (EDX) were prepared by centrifuging the reaction mixture, removing the supernatant, then redispersing the pellet in nanopure water. Drops of the redispersed solutions were placed on carbon double-sided tape on an aluminum support and left to evaporate.

RESULTS AND DISCUSSION

Figure 1. Reaction mixture

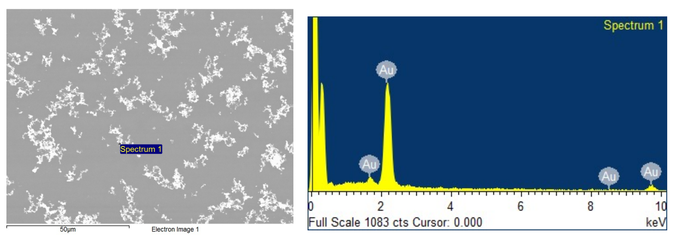
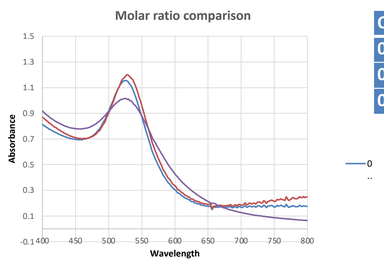


Figure 2. (left) SEM image and (right) EDX analysis of redispersed gold nanoparticles prepared with a 0.2:1 molar ratio of quercetin to gold.

RESULTS AND DISCUSSION, con't



QC: Au molar ratio	λ_{max} (nm)
0.1 :1	531 $\pm$ 3
0.2:1	524 $\pm$ 2
0.4:1	524

Table 1 Wavelength maxima from replicates for three different molar ratios

Figure 3 UV-vis spectra of representative reaction mixtures for three different molar ratios of quercetin to gold

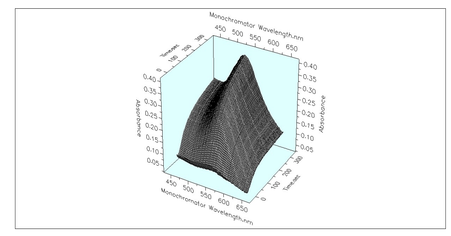


Figure 4 Preliminary results showing the growth of the surface plasmon resonance peak over a 5-minute period using stopped flow kinetics (here half-concentrations were used).

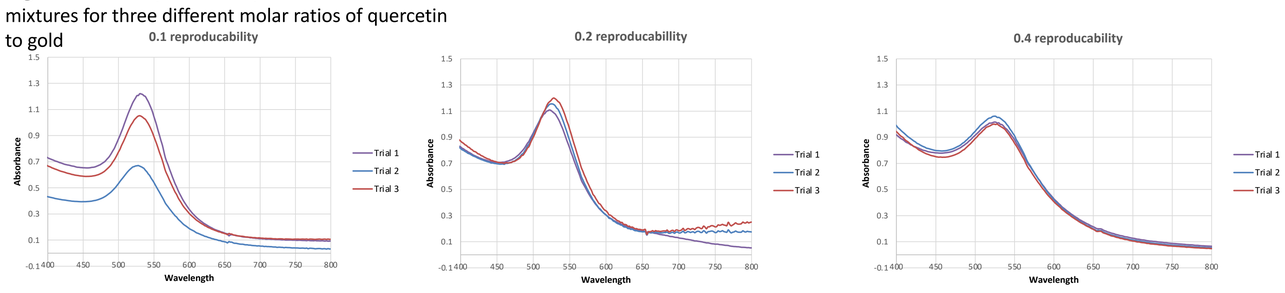


Figure 5 (left) UV-vis spectra from three replicates with 0.1:1 molar ratio; (middle) UV-vis spectra from three replicates with 0.2:1 molar ratio; (right) UV-vis spectra from three replicates with 0.4:1 molar ratio

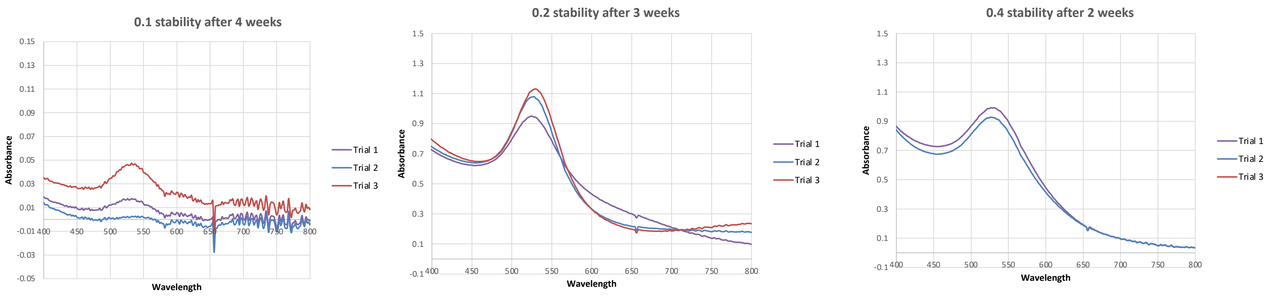


Figure 6 (left) UV-vis spectra of replicates with 0.1:1 molar ratio after 4 weeks; (middle) UV-vis spectra of replicates with 0.2:1 molar ratio after 3 weeks; (right) UV-vis spectra of replicates with 0.4:1 molar ratio after 2 weeks

Figure 1 shows the reaction mixture with a dark red color that is indicative of the formation of gold nanoparticles. Figure 2 displays SEM imaging and EDX analysis that confirm the formation of gold nanoparticles.
Figure 3 and Table 1 show the effect of varying the concentration ratio between quercetin and gold on the gold nanoparticles surface plasmon resonance (SPR). As the amount of quercetin increases in the reaction mixture, the absorbance of the SPR peak increases, indicating that more nanoparticles may form, while the wavelength at the peak maximum slightly decreases.
Figure 5 shows that the 0.1:1 molar ratio does not provide reproducible results, while the 0.2 and 0.4 molar ratios show better reproducibility.
Figure 6 indicates that the 0.1:1 and 0.2:1 molar ratios show less stability over time than the 0.4:1 molar ratio, although the solutions were aged over a different period of time.
Figure 4 shows only preliminary results as the stopped flow kinetics were performed using half of the normal reaction concentrations, for fear of saturating the detector. It shows the growth of the gold nanoparticles SPR peak over the first 5 minutes of reaction.
Future work will include dynamic light scattering (DLS) measurements for the nanoparticles hydrodynamic size and zeta potential.

ACKNOWLEDGEMENTS

Dr. Murielle Watzky, Chad Wangeline and the UNC Department of Chemistry & Biochemistry

REFERENCES

Iravani, S. (2011). Green synthesis of metal nanoparticles using plants. *Green Chemistry, 13*, 2638.
Mittal, A. K.; Chisti, Y.; Banerjee, U. C., Synthesis of Metallic Nanoparticles Using Plant Extracts. *Biotechnology Advances, 31*, 346-356.
Rajan, R., Chandran, K., Harper, S. L., & Yun, S. I. (2015). Plant extract synthesized silver nanoparticles: An ongoing source of novel biocompatible materials. *Industrial Crops and Products, 70*, 356-373.
Rawat, K. A., & Kailasa, S. K. (2014). Visual detection of arginine, histidine and lysine using quercetin-functionalized gold nanoparticles. *Microchim Acta, 181,* 1917-1929.