COLLEGE OF SCIENCE
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Research and Creative Experience for Undergraduates Program (RCEU)
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New and Optimized Green Synthesis of Silver Nanoparticles Using Mullein

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Scope of Work

A biennial weed, Verbascum *thapsus* (Common Mullein) was recently added to the list of green reducing agents that produce silver nanoparticles (AgNPs).[1] Expanding on this literature our team investigated a new process utilizing a "Sun Tea" as compared to a control tea produced at 90°C - maintained for one hour (as used in other green synthesis methods). Novel trials were conducted at the natural pH and varying pH (buffered at 3.2, 7.4, and 9.0) and at both room temperature (RT 19.5°C) and elevated temperature (ET 60°C). All trials produced spherical AgNPs and are characterized as shown herein.

Background

Traditional metal nanoparticle (NP) formation processes use hazardous and expensive chemicals, therefore green reducing agents requiring only the plant and metal salt in solution have colossal import. Open chain sugars in plants are effective agents that reduce metal cations to base metal (e.g.: Ag^{+1} to Ag^{0}) enabling spontaneous formation of nuclei. These nuclei undergo growth until stabilized by a capping agent. Plant amino acids and proteins provide these caps on the nascent NPs, promoting uniform particle size for use in biomedical and electronic applications. [2] [3]

Figure 1: Verbascum *thapsus* grown locally and used in this experiment.

Characterization and Proof of Concept (POC)

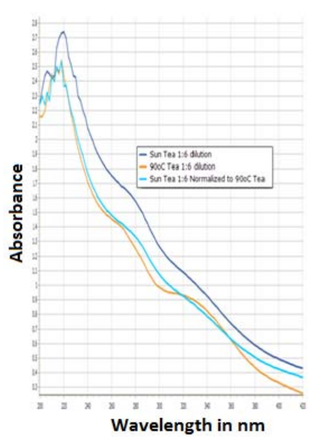


Figure 2: Tea Normalization.

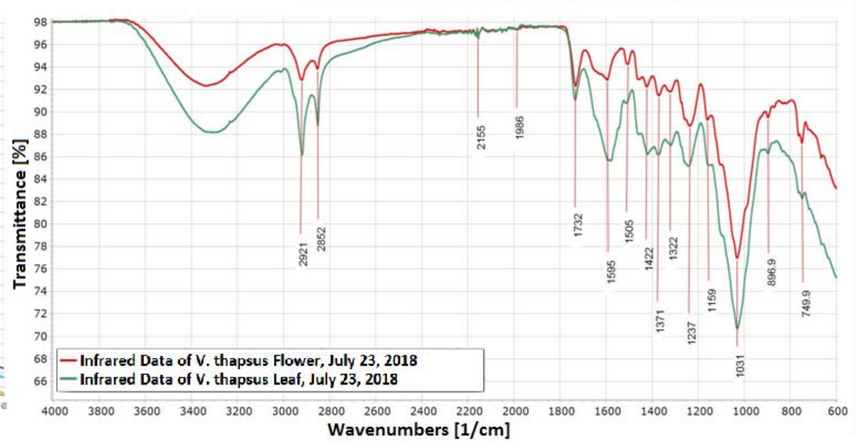


Figure 3: Fourier-transform infrared spectroscopy of flower and leaf.

	$AgNO_3$	Sun Tea	90°C Tea	Control	pH 3.2	pH 7.4	pH 9.0
pH	5.84	6.8	7.52	RT 5.67 / ET 5.99	RT 3.20 / ET 3.29	RT 7.26 / ET 7.32	RT 8.23 / ET 8.35

Table 1: pH of reagents prior to reaction and post reaction.

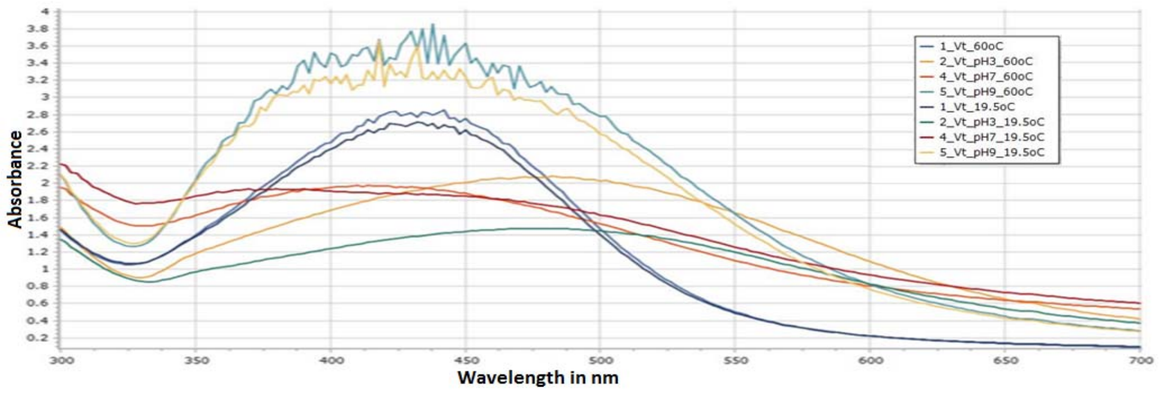


Figure 4: POC of Change in Spectrum as Functions of pH and Temperature Variance.

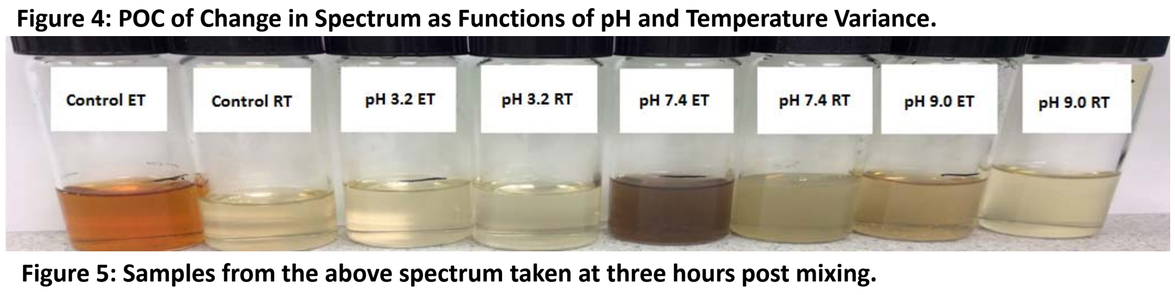


Figure 5: Samples from the above spectrum taken at three hours post mixing.

Data and Results

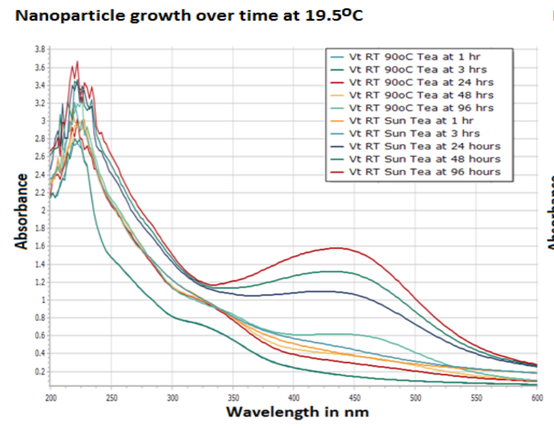


Figure 6a: Sun Tea vs. 90°C Trial at 19.5°C.

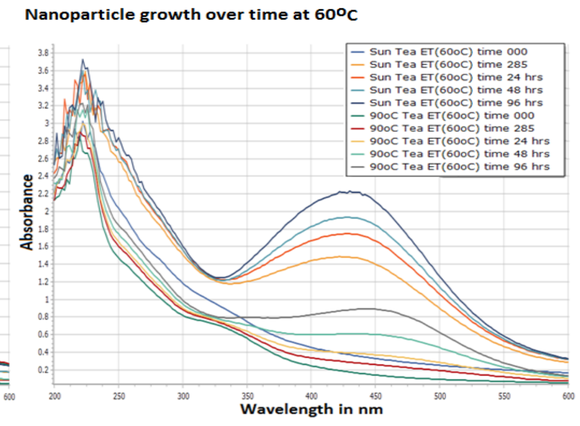


Figure 6b: Sun Tea vs. 90°C Trials at 60°C.

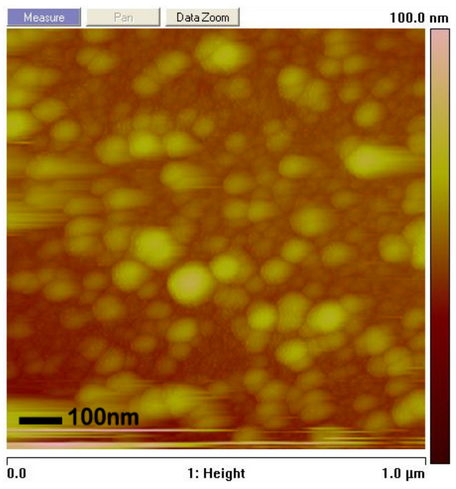
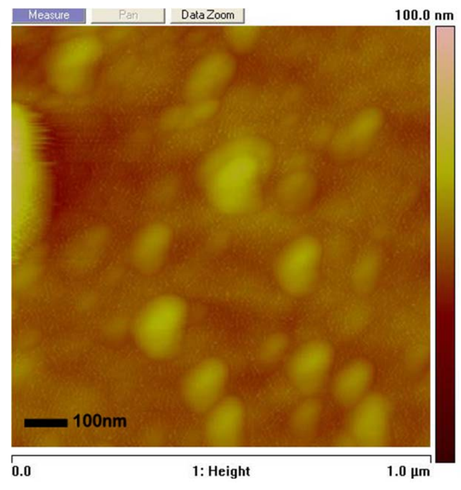
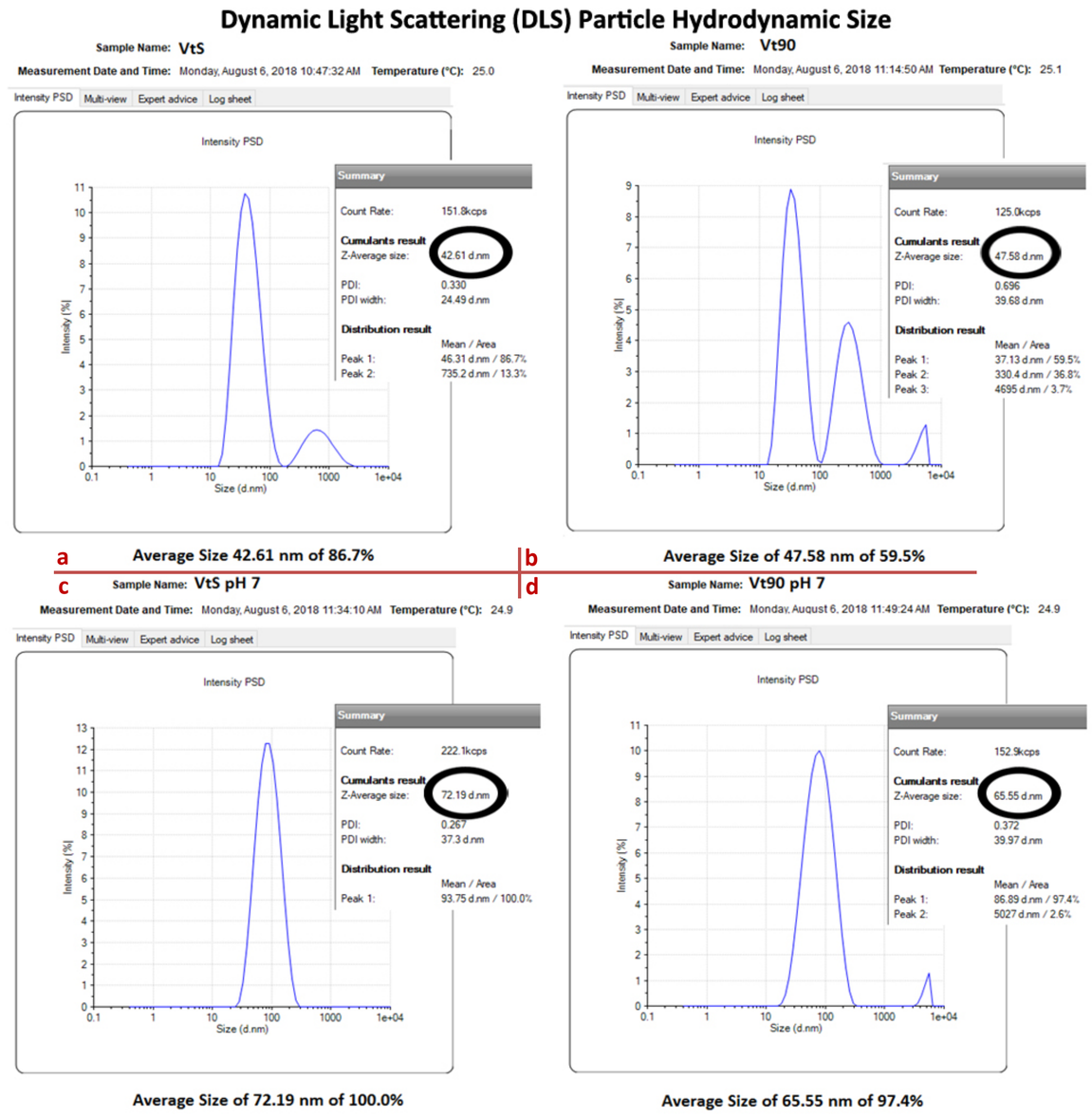


Figure 7a (left): Sun Tea Room Temperature trial. Atomic Force Microscopy (AFM) image of DLS sample shown in panel directly below.

Figure 7b (right): 90°C Tea Room Temperature trial. AFM image of DLS sample shown in panel directly below shows irregular particle size.





Figures 8a-d: DLS Hydrodynamic Particle Size of Room Temperature Trials.

Conclusions

In 100% of all trials the Sun Tea outperformed the 90°C Tea preparation. In 100% of all trials Ag nano-particles were formed. In all trials the 60°C elevated trials formed nanoparticles more rapidly. This may be beneficial in preventing aggregation due to Ostwald Ripening over time. We are investigating the nature of the nanoparticle as a function of buffering and infer that this may promote a more uniform particle distribution as shown in the DLS studies. [4]

Future Work

We will expand the work on pH and saturation. We will denature the Sun Tea with mixed proteases to observe loss of function. This impacts researchers who have been designing short chain amino acids. We plan on testing the nanoparticles on a human pathogen against nanoparticles without protein caps to see if these protein caps augment the existing biocidal nature of silver nanoparticles.

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Citations

(1) Elemike, E. E.; Onwudiwe, D. C.; Mkhize, Z. Mater. Lett. 2016, 185 (September), 452–455.
(2) Makarov, V. V; Love, A. J.; Sinitsyna, O. V; Makarova, S. S.; Yaminsky, I. V. 2014, *6* (20), 35–44.
(3) Zhao, Y.; Wang, S.; Li, Y.; He, Q.; Liu, K.; Yang, Y.; Li, X. Arch Pharm Res 2011, 34 (5), 703–707.
(4) Singh, M.; Sinha, I.; Mandal, R. K. *Mater. Lett.* 2009, *63* (3–4), 425–42.

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