Self-assembled Nanostructures Based on Combinations of Poly(ethylene glycol) and Polyphenols.

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Introduction

Poly(ethylene glycol) (PEG) and polyphenol (Fig. 1) compounds, such as quebracho tannin (QT), self-assemble into nanostructures when combined in an aqueous solution. QT is of special interest because it forms nanostructures with PEG at physiological pH. Therefore, it has the potential to be used as a drug carrier.

It is hypothesized that the molecular weight and chemical structure of PEG affect the size of the nanostructures.

In this work, the effect of molecular weight and structure of PEG on the nanostructures size was studied. Two different structures were studied, 4 Arm PEG Stars (Fig. 2A) and brush like PEG structures (Fig. 2B) with a polymethacrylate backbone.

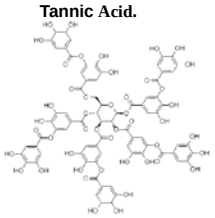

Fig. 1 Structure of tannic acid, a polyphenol

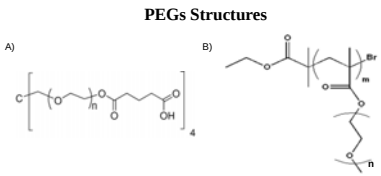

Fig. 2 A) Structure of the 4 Arm PEG star polymers. B) Structure of the PEG brush polymers with the polymethacrylate backbone.

Background

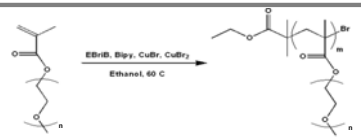

Figure 3. Schematic of brush polymer synthesis via ATRP.

Figure 4. The ether bonds of PEG allow it to form hydrogen bonds with polyphenols.

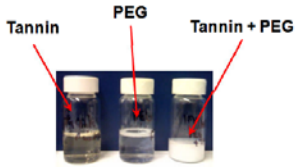

Figure 4. Tannic acid, a type of polyphenol, self-assembles into nanostructures in the presence of PEG.

Results

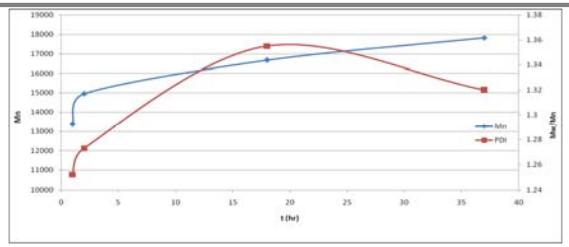

Fig. 6: Kinetics of an ATRP reaction using a 300 Da molecular weight monomer. Samples were taken at four different time intervals and the molecular weight of the polymer increased as expected. The final PDI at 37 hours was of 1.32.

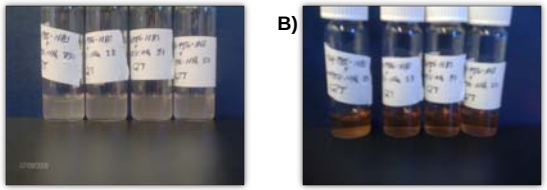

Figure 5. Quebracho tannin self-assembles into nanostructures with PEG but needs to be protected by reducing agents to block oxidation. A) QT and PEG immediately after preparing mixture. B) Same QT and PEG mixture as in [A] a day after mixture was prepared. The change in color is due to oxidation.

Results

Table 1: Particle Size of Nanostructures Formed by the 4 Arm PEG Star Polymers. The nanostructures of the 10 kDa and 20 kDa molecular weight 4 Arm PEG star polymers were measured using dynamic light scattering. The mixture was in a ratio of 1:2 (QT:PEG).

PEG	Reducing Agent	Effective Diameter (nm)	Polydispersity
4 Arm PEG Star 10k	None	241.6	0.066
	AA	297	0.042
	SD	269.5	0.06
4 Arm PEG Star 20k	None	166.8	0.119
	AA	232.7	0.075
	SD	213.6	0.181

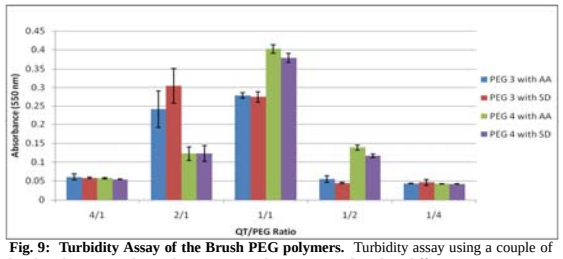

Fig. 9: Turbidity Assay of the Brush PEG polymers. Turbidity assay using a couple of brush polymers synthesized via ATRP. They were combined at different QT/PEG ratios with Ascorbic Acid (AA) and Sodium Dithionite (SD) to act as reducing agents.

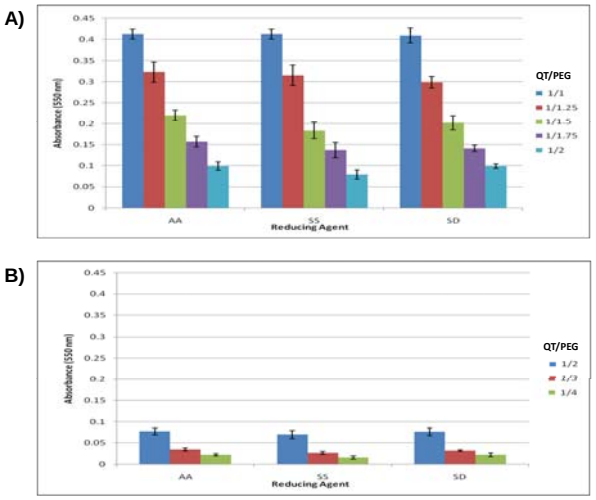

Fig. 8: Turbidity Assay of 4 Arm PEG Star Polymers. A) Turbidity assay using the 20 kDa molecular weight 4 Arm PEG star polymer. Higher absorbance is clearly shown at higher concentrations of QT. B) Turbidity assay using the 10 kDa molecular weight 4 Arm PEG star polymer.

Conclusions

•ATRP chemistry allowed for the control of the final molecular weight of the brush polymers with a low PDI.

•The 4 Arm star polymers formed nanostructures of 150-300 nm at a 1:2 (QT:PEG) ratio. The addition of reducing agents seemed to increase the size.

•The 4 Arm star polymers scattered the most light at the higher concentrations of QT.

•The brush polymers scattered light as well, with most of the scattering happening in the 1:1 (QT:PEG) ratio.

•QT was filtered through a neutral alumina column to get rid of the lower molecular weight components. The filtered QT showed no light scattering when combined with the brush PEGs. This appears to indicate that the lower molecular weight components of the QT caused the self-assembled nanostructures.

References

Braunecker, W.; Matyjaszewski, K. "Controlled/living radical polymerization: Features, developments, and perspectives." Progress in Polymer Science 2007, 32, (1), 93-146.

Matyjaszewski, K.; Xia, J. "Atom transfer radical polymerization." Chemical Reviews 2001, 101, (9), 2921-
2990.

Wang, J. S.; Matyjaszewski, K. "Controlled Living Radical Polymerization - Atom-Transfer Radical Polymerization in the Presence of Transition-Metal Complexes." Journal of the American Chemical Society 1995, 117, (20), 5614-5615.

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