Urea Modified Silica Nanoparticles: Next Generation Slow Release Plant Nutrients

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Abstract: Innovations in production of fertilizer and promotion of its efficient use are of critical importance to address major challenges related to the food and nutrient security of the people on our planet.

Of the several elements required by the plants through chemical fertilizers, the issues and challenges pertaining to Nitrogen dominate in the current commercial global agriculture. Considering the extensive use of fossil fuels in the production and the emission of greenhouse gases resulting from its use in agriculture, nitrogen fertilizers have the highest monetary value as well as impacts via pollution. In the quest of improving nitrogen use efficiency, nanotechnology has provided a template for designing new fertilizer systems.

In this study, the surface of silica nanoparticles have been modified using urea molecules. The nanohybrids were prepared using two novel methods; in-situ and ex-situ synthesis in order to obtain the most efficient slow release plant nutrient composition. In the in-situ method nanoparticles were synthesized in the presence of a urea matrix while in the ex-situ method urea modification was done after the synthesis of the nanoparticles were done. The resulted compositions were dried using conventional and microwave drying techniques.

The successful modification of silica nanoparticles by urea molecules was understood using several characterization techniques. The peak shifts in the Fourier transform infra-red spectroscopy analysis suggested that urea is bonded to silica nanoparticles through week hydrogen bonding while the presence of nanoparticles coated with urea was confirmed using scanning and transmission electron microscopic techniques. All the nanohybrids demonstrated slow release behavior of urea in water compared to pure urea according to slow release drug models. From the release data obtained it was confirmed that the drying method also affected the release behavior of urea. The best slow release compound was obtained via ex-situ synthesis approach coupled with microwave drying method. The release characteristic of urea from silica nanoparticles followed the Korsmeyer–Peppas model confirming an extended release behavior of nitrogen. This indicated that the release rate of urea is controlled by the rate of diffusion of urea through the silica matrix. These urea coated silica nanohybrids therefore, have the capacity to multiply into sustainable global fertilizer solutions.

Keywords: urea modified silica nanoparticles, slow-release, plant nutrients, kinetic models, drying method

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