Available online at www.sciencedirect.com
ScienceDirect
Bioresource Technology 99 (2008) 547–554
BIORESOURCE TECHNOLOGY

Preparation and properties of a double-coated slow-release NPK compound fertilizer with superabsorbent and water-retention

Lan Wu [a,b], Mingzhu Liu [a,*], Rui Liang [a]

[a] *Department of Chemistry and State Key Laboratory of Applied Organic Chemistry, Lanzhou University, Lanzhou 730000, PR China*
[b] *College of Chemical Engineering, Northwest Minorities University, Lanzhou 730030, PR China*

Received 28 September 2006; received in revised form 29 December 2006; accepted 30 December 2006
Available online 22 February 2007

Abstract

A double-coated slow-release NPK compound fertilizer with superabsorbent and water-retention was prepared by crosslinked poly (acrylic acid)/diatomite – containing urea (the outer coating), chitosan (the inner coating), and water-soluble granular fertilizer NPK (the core). The effects of the amount of crosslinker, initiator, degree of neutralization of acrylic acid, initial monomer and diatomite concentration on water absorbency were investigated and optimized. The water absorbency of the product was 75 times its own weight if it was allowed to swell in tap water at room temperature for 2 h. Atomic absorption spectrophotometer and element analysis results showed that the product contained 8.47% potassium (shown by K_2O), 8.51% phosphorus (shown by P_2O_5), and 15.77% nitrogen. We also investigated the water-retention property of the product and the slow release behavior of N, P and K in the product. This product with excellent slow release and water-retention capacity, being nontoxic in soil and environment-friendly, could be especially useful in agricultural and horticultural applications.

Keywords: Diatomite; Chitosan; Slow release; Water-retention; NPK compound fertilizer

1. Introduction

The growth of plants and their quality are mainly a function of the quantity of fertilizer and water. So it is very important to improve the utilization of water resources and fertilizer nutrients. One method of reducing fertilizer nutrient losses involves the use of slow- or controlled-release fertilizers. There are three types of these fertilizers: slightly soluble materials, such as urea-formaldehyde; materials for deep placement, such as urea supergranules; and coated fertilizers (Jarosiewicz and Tomaszewska, 2003). Coated fertilizers are physically prepared by coating granules of conventional fertilizers with various materials that reduce their dissolution rate. The release and dissolution rates of water-soluble fertilizers depend on the coating materials.

Chitosan is a highly deacetylated derivative of chitin, one of the most abundant natural and biodegradable polymers. It has been widely applied in the biomedical, pharmaceutical, and agricultural fields. In many of these applications chitosan is extremely attractive due to its biodegradability, biocompatibility, and nontoxicity (Borzacchiello et al., 2001). Therefore, the soluble fertilizer coated by chitosan would be an ideal slow release formulation.

Superabsorbent polymers can absorb a large amount of water compared with general water absorbing materials in which the absorbed water is hardly removable even under some pressure. Because of their excellent characteristics, superabsorbent polymers had been widely used in agriculture and horticulture (Lokhande and Gotmare, 1999). Recently, research on the use of superabsorbent polymers as water managing materials for the renewal of arid and desert environment has attracted great attention, and encouraging results have been observed as they can reduce irrigation water consumption, improve fertilizer retention

* Corresponding author. Tel.: +86 931 8912387; fax: +86 931 8912582.
E-mail address: m-zliu@163.com (M. Liu).

0960-8524/$ - see front matter
doi:10.1016/j.biortech.2006.12.027

in soil, lower the death rate of plants, and increase plant growth (Nge et al., 2004; Lokhande and Varadara, 1992). However, its application in this field has met some problems because most of these polymeric superabsorbents are based on pure poly(sodium acrylate), and then they are too expensive and not suitable for saline-containing water and soils (Li et al., 2007; Lin et al., 2001). Recently, the preparation of polymer/clay superabsorbent composite has attracted great attention because of their relative low production cost, excellent water-retention and their considerable applications in agriculture and horticulture. Diatomite (a kind of clay mineral), as a good substrate for superabsorbent composite materials, is a kind of lightweight sedimentary rock composed principally of silica microfossils of aquatic unicellular algae. Compared with the layer structure of silicates mentioned above, diatomite has three-dimensional network configuration, and the void is up to 80–90%. Besides, there are isolated and hydrogen boned hydroxyl groups detected on the surface of diatomite (Gao et al., 2005). So it has strong hydrophilicity and can be as one of component of superabsorbents (Khraisheha et al., 2005).

On the basis of the above background and our previous studies on superabsorbent polymers (Chen et al., 2005; Ma et al., 2004) and slow-release fertilizers (Liu et al., 2004; Guo et al., 2005; Liang and Liu, 2006), we prepared in this study a double-coated slow-release NPK compound fertilizer with superabsorbent and water-retention (DSFSW), whose inner coating was chitosan (CTS), and the outer coating was crosslinked poly(acrylic acid)/diatomite-containing urea (PAADU). The product we prepared not only has slow-release property but also could absorb a large amount of water and preserve the soil moisture at the same time. In addition, the outer coating (PAADU) could protect the inner coating (CTS) from mechanical damage. These were significant advantages over the normal slow-release or controlled-release fertilizers, which generally have only a slow-release property. The results indicated that the DSFSW could be found an application in agriculture and horticulture, especially in drought-prone regions where the availability of water is insufficient.

2. Experimental

2.1. Materials

Chitosan (CTS) was kindly provided by Jinxing Biochemical Co., Zhejiang, China. Its viscosity average molecular weight is 6.0×10^5 and its N-deacelylation degree is 90%. Acrylic acid (AA, chemically pure, Beijing Eastern Chemical Works, Beijing, China) was distilled under reduced pressure before use. Potassium persulfate (KPS, analytical grade, Xi'an Chemical Reagent Plant, Xi'an, China) and *N*,*N*′-methylene bisacrylamide (NNMBA, chemically pure, Shanghai Chemical Reagent Factory, Shanghai, China) were used as purchased. Diatomite, supplied by Shanghai Chemical Reagent Factory, Shanghai, China, was calcined at 450 °C, and the particle sizes less than 10 μm were about 90 wt%. It contains 14–16 wt% of calcium sulphate, 0.02 wt% of chloride and the content of iron is less than 0.05 wt%. The pH of the solution (10 wt% diatomite) is 6.5–7.5. NPK compound fertilizer was industrial grade and the others were all analytical grade. All of the materials used were available from commercial sources.

2.2. Preparation and characterization of PAADU

A series of samples with different amounts of diatomite, crosslinker, initiator, urea, and AA with different degrees of neutralization were prepared by the following procedure. Typically, AA (8.4 g) was dissolved in 19 mL distilled water and then neutralized with a proper amount of ammonia in a four-neck flask equipped with a stirrer, condenser, thermometer, and nitrogen line. Urea (3.8 g) and diatomite powder were added to the partially neutralized monomer solution. Under nitrogen atmosphere, a proper amount of NNMBA aqueous solution as a crosslinker was added to the solution, and the mixed solution was stirred on a water bath at room temperature for 30 min. The water bath was then heated slowly to 65 °C with vigorous stirring after the radical initiator KPS was charged to the mixed solution. After 4 h, the reaction was stopped. After it was cooled, the product was ground. A white powder PAADU was obtained, which was used as the outer coating material. The nitrogen content of PAADU was 19.8% determined by element analysis.

The ingredients of PAADU were analyzed using a Fourier Transform Infrared (FTIR) spectrophotometer (American Nicolet Crop., model 170-SX). The sample of PAADU was ground with dried KBr powder. The KBr disk was dried again and subjected to FTIR spectrophotometry.

2.3. Preparation of DSFSW

NPK compound fertilizer granules ranging from 2.36 to 2.85 mm in diameter were sieved and used for further experiments. During the sieving, we tried to remove granules that had defects on the surface.

The NPK compound fertilizer granule was placed into a rotary drum, and the CTS powder was stuck on the granules by means of epoxy dissolved in acetone. The adhesive was applied by spraying at regular time intervals. The process was finished until compact and homogeneous coating formed on fertilizer granule. The coated granules were dried to a constant mass at room temperature for 6 h. Then the CTS-coated NPK compound fertilizer granules were obtained.

CTS-coated NPK compound fertilizer granules were dipped in water and then were immediately placed on PAADU powder and shaken. In this manner, PAADU could adhere to the surface of CTS-coated NPK compound fertilizer and form the outer coating. After the granules