NOTE

Encapsulation Efficiency and Release Kinetics of Solid and Liquid Pesticides Through Urea Formaldehyde Crosslinked Starch, Guar Gum, and Starch + Guar Gum Matrices

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ABSTRACT: This article presents our preliminary experimental data on the release kinetics and encapsulation efficiency of urea formaldehyde (UF) crosslinked matrices of starch (St), guar gum (GG), and starch + guar gum (St + GG) for the controlled release of solid (chlorpyrifos) and liquid (neem seed oil) pesticides. The data reveal variable release rates in relation to the polymer type and especially the pesticide type. It is possible to slow the release rates of pesticides using cheaply available materials such as starch and guar gum. © 2001 John Wiley & Sons, Inc. J Appl Polym Sci 82: 2863-2866, 2001

INTRODUCTION

Starch (St) and guar gum (GG) are the naturally occurring biodegradable polymers, which, after derivatization/crosslinking,1,2 can be effectively used as the encapsulating membrane materials in the controlled release (CR) of agrochemicals. In recent years, the development of modified naturally occurring polymers as CR devices in agroindustries has emerged as a new technology with a better commercial viability than the use of the conventional synthetic polymers since these are known to create some environmental concern.3-5 Therefore, research has been ongoing to find a suitable alternative and film-forming membrane material that can be safely used in agroindustries.2 This is very essential in the present day to alleviate or minimize the toxic effects of some of the widely used pesticides. In this pursuit, we undertook extensive research on the development of environmentally safe CR agroproducts.6 Most recently, Hong and Park7 reported the possibility of using polyurea microcapsules to encapsulate both liquid and solid bioactive compounds, but these systems are not cost-effective in agroindustries.

A process for the encapsulation of pesticides using urea formaldehyde (UF) crosslinked starch8 and guar gum8 matrices was reported in the earlier literature. In continuation of this research, we report here preliminary experimental data on the effect of the physical nature of naturally occurring core material such as starch and guar gum on its encapsulation efficiencies as well as the release kinetics of a solid pesticide (chlorpyrifos) and a liquid pesticide (neem (Azadirachta Indica A. Juss.) seed oil (NSO)). Chlorpyrifos is an organophosphorous compound used against pests like white grub and holotrichi consangueine blanch. However, when chlorpyrifos is applied to plants or mixed...
Preparation and Characterization of Interpenetrating Network Beads of Poly(vinyl alcohol)-grafted-Poly(acrylamide) with Sodium Alginate and Their Controlled Release Characteristics for Cypermethrin Pesticide*

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ABSTRACT: Interpenetrating network polymeric beads of poly(vinyl alcohol)-grafted-acrylamide with sodium alginate have been prepared by crosslinking with glutaraldehyde. Cypermethrin, a widely used pesticide, was loaded with 80% efficiency in these hydrogel beads. The beads were characterized by Fourier transform infrared spectroscopy to confirm the grafting. Scanning electron microscopy was used to know the morphology of the beads. Equilibrium swelling experiments indicated that swelling of the beads decreased with an increase in crosslinking. The in vitro release studies were performed under static conditions and the release data have been fitted to an empirical relation to estimate the transport parameters. The diffusion coefficients have been calculated for the transport of pesticide through the polymeric beads using the initial time approximation method. These values showed decrease with increasing crosslinking as well as increasing pesticide loading. © 2002 John Wiley & Sons, Inc. J Appl Polym Sci 84: 552-560, 2002; DOI 10.1002/app.10306

Key words: poly(vinyl alcohol)-grafted-poly(acrylamide); sodium alginate; hydrogel; interpenetrating polymeric network beads; cypermethrin

INTRODUCTION

In order to control pests like flies, nematodes, fungi, white grub, and the larva of chaffer beetles that are considered to be the serious soil pests for groundnut and several other crops, it is necessary to apply cypermethrin to the soil. Under soil conditions, the residual toxicity of the pesticide used should be minimum in order to avoid the possible cytotoxicity of the plants as well as to alleviate the environmental pollution problems. In our earlier papers1-4 published from this laboratory, several hydrophilic polymers have been used in the controlled release (CR) of pesticides. The parameters that affect the properties of such CR formulations are dependent upon the nature and type of the polymer used. Further investigations are being carried out in our laboratory to use the appropriate polymeric matrices in order to achieve an effective CR of drugs and pesticides.5,6 The inter-
pH-Sensitive Acrylic-Based Copolymeric Hydrogels for the Controlled Release of a Pesticide and a Micronutrient

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ABSTRACT: Acrylic-based copolymers of methyl methacrylate (MMA) and methacrylic acid (MAA) have been prepared by solution and bulk polymerization techniques using benzoyl peroxide (BPO) as an initiator. Three polymers were prepared with a varying ratio of MMA/MAA. In an effort to increase the hydrophilicity of the matrix, one MMA/MAA polymer was prepared by adding an additional amount of 2-hydroxyethyl methacrylate (HEMA). All the polymers were crosslinked in situ by ethylene glycol dimethacrylate (EGDMA). These polymers were characterized by Fourier transform infrared spectroscopy and differential scanning calorimetry. Viscous flow characteristics were determined from solution viscosity and rheological measurements. Dynamic and equilibrium swelling experiments were carried out under varying pH conditions (i.e., 0.1N NaOH, 0.1N HCl, and double-distilled water). Partially crosslinked hydrogels show varying hydrophilicity because of the presence of carboxylic acid groups making them pH-responsive. Swelling increased with an increasing number of —COOH groups on the polymer backbone and the hydrophilicity varied with changing pH. Cypermethrin, a widely used pesticide, and cupric sulfate, a model micronutrient, were loaded into these pH-sensitive hydrogels to investigate their controlled release characteristics. The in vitro release rates of both compounds have been carried out under static dissolution conditions at 30°C. Release data have been fitted to an empirical relation to estimate transport parameters. The release results have been discussed in terms of the varying hydrophilicity of the hydrogel network polymers. © 2002 Wiley Periodicals, Inc. J Appl Polym Sci 87: 394–403, 2003

Key words: hydrogels; cypermethrin; cupric sulfate; controlled release; transport properties; microencapsulation; stimuli-sensitive polymers

INTRODUCTION

Hydrogels are polymeric network structures absorbing large quantities of water (an absorption of nearly a thousand-fold water when compared to the dry mass of polymer).1 In arid areas, the use of hydrogels in sandy soil (macroporous medium) may increase the water-holding capacity, thus improving the quality of plants.2,3 Hydrogels in soil applications facilitate an increased water sorption, minimizing the frequency of irrigation and water loss due to evaporation. In recent years, the use of pH-sensitive hydrogels in soil applications is increasing because soil has an alkaline pH and therefore, development of hydrogels that are responsive to alkaline media is important.1,2 Additionally, in agricultural areas, it is advantageous to have a hydrogel that can encapsulate a toxic pesticide or micronutrient so as to regulate its safe release to the environment.3,4 Because copper sulfate is highly water-soluble and cypermethrin is almost water-insoluble, their encapsulation using a common hydrogel is advantageous. In the earlier literature, many kinds of superabsorbing hydrogels have been reported for use in soil applications.1,5

In a previous study,6 we reported the preparation of pH-responsive polymeric hydrogels for the release of bioactive molecules. In continuation of this work, we now report the synthesis of pH-responsive hydrogels for the encapsulation of a pesticide (cypermethrin) and a micronutrient (cupric sulfate) because these are essential for the growth and yield of agricultural crops.7,8 However, their excessive use or handling without proper encapsulation or safety measures might be hazardous to human health and hygiene. To control the release characteristics as well as to vary the rigidity of the hydrogel matrices, we have treated them with organic solvents. In a previous study by Katine et al.,9 bulk polymerization was used to produce a similar type of hydrogel by using methacrylic acid (MAA) and methyl methacrylate (MMA) monomers at different ratios in the presence of N,N'-methylen-bisacylamide as the crosslinking agent, but the...
Hydrogels as controlled release devices in agriculture

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Abstract—Recently, there has been a great deal of research activity in the development of hydrogels as controlled release devices. The present review provides a brief introduction to various methods of synthesis, properties, types of hydrogels, and cross-linking agents which have been used for the preparation of hydrogels exhibiting suitable properties for agricultural applications.

Keywords: Hydrogels; controlled release; pesticides.

1. INTRODUCTION

Recently, hydrogel-based pesticide release devices have become very popular. They consist of a pesticide in a polymer network in the form of a microcapsule or granule. Such systems exhibit many advantages, including controlled or slow release of the core active ingredient (AI) — leading to longer application intervals, reduction in dosage, stabilization of the core AI against environmental degradation (light, air, humidity, and micro-organisms), reduction in mammalian toxicity and human mucous-membrane irritation, reduction in phytotoxicity or fish toxicity, reduction in evaporation and leaching, reduction in environmental pollution and drift, increase in the number of target organisms, and ease of handling of the toxic materials. However, a proper design of the encapsulation system is very important to achieve the desired release characteristics.

In order to obtain optimal performance for the microencapsulated products, time-dependent or site-specific release is desirable. Thus, it is important to
Synthesis and Characterization of Polyacrylamide-Grafted Chitosan Hydrogel Microspheres for the Controlled Release of Indomethacin

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ABSTRACT: Microspheres of polyacrylamide-grafted-chitosan crosslinked with glutaraldehyde were prepared and used to encapsulate indomethacin, a nonsteroidal anti-inflammatory drug. The microspheres were produced by the water/oil emulsion technique and encapsulation of indomethacin was carried out before crosslinking of the matrix. The extent of crosslinking was analyzed by Fourier transform infrared spectroscopy and differential scanning calorimetry. Microspheres were characterized for drug-entrapment efficiency, particle size, and water transport into the polymeric matrix as well as for drug-release kinetics. Scanning electron microscopy confirmed the spherical nature and surface morphology of the particles with a mean particle size of 525 μm. Dynamic swelling experiments suggested that, with an increase in crosslinking, the transport mechanism was from Fickian to non-Fickian. The release of indomethacin depends upon the crosslinking of the network and also on the amount of drug loading. This was further supported by the calculation of drug-diffusion coefficients using the initial time approximation. The drug release in all the formulations followed a non-Fickian trend and the diffusion was relaxation-controlled. © 2002 Wiley Periodicals, Inc. J Appl Polym Sci 87: 000-000, 2002

Key words: Indomethacin, Hydrogel, Microspheres, Polyacrylamide-grafted-chitosan.

INTRODUCTION

Polymeric microsphere hydrogels have been extensively used in the delivery of several drugs.1-6 The preparation of such microspheres is generally based on the water/oil (w/o) emulsion technique.7 It was found in our previous articles8-13 that a number of modified forms of natural polymers can be used for the delivery of drugs. The main advantages of using such natural polymers are that they can be biocompatible and biodegradable and produce no systemic toxicity upon administration.14,15 Several biopolymers belonging to the class of polysaccharides have some inherent disadvantages such as poor mechanical strength, uncontrolled water uptake, and microbial contamination. To overcome these problems, efforts have been made to develop chemically modified matrices by combining them with synthetic monomers.16-18 In our earlier research efforts,4,11 we developed hydrogels of polyacrylamide (PAAm) grafted with natural polymers. In pursuance of this goal, we continue to develop newer polymeric systems and present here the procedure to modify chitosan by grafting with PAAm.

The microspheres were prepared by the w/o emulsion method using glutaraldehyde (GA) as the crosslinking agent. Indomethacin (IM), a nonsteroidal anti-inflammatory drug (NSAID), was used as a model drug and loaded before crosslinking of the matrix. The advantages of such formulations containing NSAID over the conventional-dosage forms were reported earlier12,13,18; such formulations help to minimize the serious gastric irritation side effects of the conventional-dosage NSAID formulations. The microspheres prepared were characterized by Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), and laser-beam particle-size analysis. Microspheres were evaluated for their thermal behavior, water-transport properties, as well as in vitro drug-release kinetics.

EXPERIMENTAL

Materials

Chitosan (medium molecular weight solution of 0.002 g/dL with a viscosity of 15.524 mPa s) was purchased from the Aldrich Chemical Co. (Milwaukee, WI). Acrylamide (AAm), acetic acid, potassium persulfate, a polysorbate-80, GA (25% w/w) solution, and liquid paraffin were all purchased from S.D. Fine Chemicals (Mumbai, India). Indomethacin, USP grade (Sigma-