STARCH-BASED PRODUCTS FOR AGRICULTURE

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Abstract. Starch is a promising raw material for producing a variety of useful products for improving agricultural technology. Experimental plastics made with starch have potential application as biodegradable mulch film, planters, containers, and a variety of other plastics used in agriculture. Encapsulation of pesticides within a biodegradable starch matrix shows promise for keeping pesticides where targeted, improving safety in handling pesticides, and increasing efficiency of weed control. Super Slurper, a starch-based product, is gaining increasing acceptance in agricultural applications because of its tremendous water-absorbing characteristics. It is finding application as a seed coating agent for improved germination and seedling establishment and as an agent for dipping roots of bare-rooted seedlings before transplanting. Improved stand and increased yield are benefits of using Super Slurper in these agricultural applications.

Introduction

Rising prices and diminishing supplies of petroleum and natural gas have had a significant impact on agriculture even though this industry uses only about 3% of the energy consumed in the United States. In addition to fuel usage, agriculture as well as other industries continues to use a higher percentage of available petroleum as organic chemicals in applications such as pesticides and plastics.

In 1978, 8.1% of our total oil and natural gas was consumed by the petrochemical industry to produce these organic chemicals. In 1979 this percentage increased as the industry increased its output of chemicals by 26%, but total petroleum consumption remained essentially the same as in 1978. Within the next few years this percentage is expected to double, which will undoubtedly be reflected in higher prices for agricultural chemicals.

Since many crop yields are plateauing, in part because we may have reached a cost-effective peak relative to the application of chemical fertilizers (1), agriculture is especially sensitive to increasing costs of petrochemicals.

One approach that may partially alleviate increasing chemical costs depends upon the development and use of agricultural products as substitutes

1The mention of firm names or trade products does not imply that they are endorsed or recommended by the U.S. Department of Agriculture over other firms or similar products not mentioned.
or alternatives to petrochemicals. Starch is one such product; it is produced in excess of food and feed demands and offers potential as an alternate raw material for the synthesis of useful agricultural products. In 1979, the six major U. S. cereal crops contained nearly 470 billion pounds of starch.

During the past few years, this laboratory has been conducting basic research to develop technologies based on starch that might benefit agriculture, especially in the areas of biodegradable and water-soluble plastics, encapsulated pesticides, moisture retention aids, and products for removing heavy metals from processing water.

Starch in Plastics

Techniques have been developed for substituting starch for significant amounts of petroleum-derived chemicals used to manufacture plastics. It is not only the renewable aspect of starch that has piqued the interest of industry, but also the potential of starch to impart varying degrees of water solubility and biodegradability. One commercial process now uses starch to produce water-soluble laundry bags. These bags are used by hospitals to keep the laundry staff from coming in contact with soiled or contaminated clothing. The bags and their contents are placed directly into the washing machine, where the bags dissolve and allow the clothing to be washed. Similar water-soluble films may be suitable for packaging chemical pesticides to improve safety during handling.

Water-insoluble, biodegradable plastics have been produced in this laboratory from starch (2). The most promising formulations contain about 40% starch and varying levels of poly(ethylene-co-acrylic acid) and polyethylene. Rate of fungi attack, physical properties, and weatherability studies suggest that these plastics could have several agricultural applications especially as mulch film and containers for transplanting crops. Farmers now use an estimated 60 million pounds of petroleum-derived polyethylene mulch film to boost crop yields by 50 to 350% by improving soil moisture retention, reducing loss of added fertilizer, and keeping down weed growth. Use of biodegradable mulch film would eliminate the estimated $100 per acre cost to remove and dispose of the nondegradable film. Farmers also have expressed a need for some 50 other new plastic materials to further improve agricultural technology. Many of these relate to biodegradable plastics that could be used in the planting, growing, and harvesting of crops.

Although this laboratory is not equipped to conduct field testing of the starch-based films laboratory tests have demonstrated the films are attacked and decomposed into small particles when exposed to soil. The rate and extent of decomposition can be varied considerably by the method of preparation and level of starch used. Preliminary findings suggest that some sacrifice in physical properties over polyethylene are needed to formulate films with acceptable rates of biodegradation. Also, the starch-based films appeared to photodegrade too rapidly. This problem seems to be overcome by adding carbon black. Several films, formulated with carbon black, remained in good condition for 5 to 6 months of outdoor soil contact. For this development to provide the desired benefit to agriculture, we recognize the need for, and are trying to establish, cooperative efforts with both industry and agricultural scientists to prepare larger quantities and conduct more extensive testing.
Starch-Encapsulated Pesticides

During the past few years, processes for encapsulating various pesticides with modified starches have been developed. The primary interest is to improve pesticide efficiency through reduction of photodegradation and leaching rates, the need for immediate soil incorporation, and the toxic effect of pesticides to nontargeted organisms. The initial technique, which has been extensively evaluated, involved encapsulating pesticides within a starch xanthide matrix. In this process, an alkali dispersion of starch is reacted with carbon disulfide to form starch xanthate (0.1-0.3 DS). Pesticides are emulsified into this dispersion, and then an oxidant is added to crosslink the starch xanthate to an insoluble starch xanthide that entraps the pesticide in small cells within granular particles (3).

\[ \text{Starch-OH} + \text{CS}_2 + \text{NaOH} \rightarrow \text{Starch-OCSNa} \quad \text{(Xanthate)} \]

\[ \text{Starch-OCSNa} \rightarrow \text{Starch=OCSSCO-Starch} \quad \text{(Xanthide)} \]

Several USDA and university agronomists and entomologists at other locations have conducted greenhouse and field tests on various pesticides encapsulated by this technique. Their data are encouraging and indicate that less pesticide is needed to achieve the desired pest control. In one extensive study, Coffman and Gentner reported numerous instances in which starch-encapsulated formulations exhibited hericidal activity equal to or greater than the activity of twice the rate of a commercial nonencapsulated pesticide (4). For example, when encapsulated trifluralin was applied at 1.1 and 2.2 kg/ha of active agent, their activity against Italian ryegrass was equal to commercial trifluralin applied at 2.2 and 4.4 kg/ha, respectively, after 2 weeks (4).

In addition, it is believed that encapsulation can reduce possible toxic effects for those who handle pesticides during storage, shipment, and application because there is essentially no pesticide odor from the encapsulated pesticides. Hopefully, starch encapsulation can provide herbicide systems that will offer specific advantages needed in growing crops with plastic mulch and tunnels.

Starch in the Purification of Waste Water

A sulfur-containing starch derivative called insoluble starch xanthate (ISX) is effective in removing traces of heavy metal contaminants from industrial process water (5). The solid ISX can be added directly to contaminated water or incorporated into filters. Immediately upon contact with the soluble metals, ISX forms an insoluble metal complex that can be properly discarded or processed for recovery of the more expensive metals. A major problem in using activated sludge on farm land is the buildup of heavy metals. Extensive use of ISX could conceivably eliminate this problem. In addition, this technology provides the dual potential of increasing markets for starch-containing agricultural products and at the same time solving a pollution problem by permitting reuse of processing waters. About 30 companies have licensed the U. S. patent to use or produce ISX, and at least 100 metal-plating firms have installed the ISX treatment to meet EPA requirements.
Starch in Water Absorbents

Basic research on the chemical combination of starch with various synthetic materials has yielded new products having great potential for reducing our demand on imported petroleum and for providing useful consumer products.

Super Slurper, the first major product of this study, has received worldwide attention and numerous awards because of its unparalleled water-absorbing characteristics (6). It is commercially available as powder, flakes, or films that absorb hundreds of times their weight of water almost as fast as water can be added. The added water will evaporate from the wet product to leave a dry material that can again absorb the same amount of water. When small amounts of Super Slurper are coated onto seeds, the coating absorbs water and enhances germination and seedling growth. Application of Super Slurper in gel form to bare-rooted seedlings before transplant enhances seedling survival, overcomes transplant shock, and increases plant growth. Super Slurper is now used in commercial products for the absorption of body fluids such as urine, blood, and perspiration; in controlling forest fires; in several agricultural applications for establishing seedlings and transplants; and in industrial thickening applications. It may have application in removing water from fuel alcohol mixtures and in many other agricultural, industrial, and medical areas.

The concept of chemically combining synthetic materials with starch can lead to a variety of other products to meet specific requirements for diverse agricultural and consumer applications.

These and many other developments for using starch to meet a wide range of socio-economic goals are now available. Some have achieved limited industrial success; others simply await appropriate technology transfer and implementation.

References


