Synthesis and Utility of Starch Based Polymers- A Short Review

Ritwick Sinha

*La Martiniere for Boys, Kolkata, West Bengal, India.*

Abstract: *The present study is a modest attempt to develop a method of synthesis and examine the utility of starch based polymers in agro-medicinal fields. The enviromental impact of the pestilent synthetic plastic is profound; production may be cheap, however, disposal is difficult. Incineration of these non-biodegradable polymers leads to generation of toxic, hazardous fumes detrimental to human health and welfare. In addition to the dangers, petroleum resources are limited; so, generation of such non-biodegradable, synthetic polymers on an industrial scale cannot be sustained for a fesible, economically productive time period.*

I. Introduction

The polymers that can be broken down rapidly by enzyme based catalyst reactions are called biodegradabl polymers. The enzymes are produced by microorganisms. When the polymer is buried as waste, microorganisms present in the soil can degrade the polymer. One method of making a polymer biodegradable involves inserting a hydrolysable ester group into the polymer.

The ester link being a weak link is suceptable to enzyme catalysed hydrolysis.

Among the most common biodegradable polymers are polyglycolic acid (PGA), polylactic acid (PLA) and polyhydroxy butyrate (PHB).
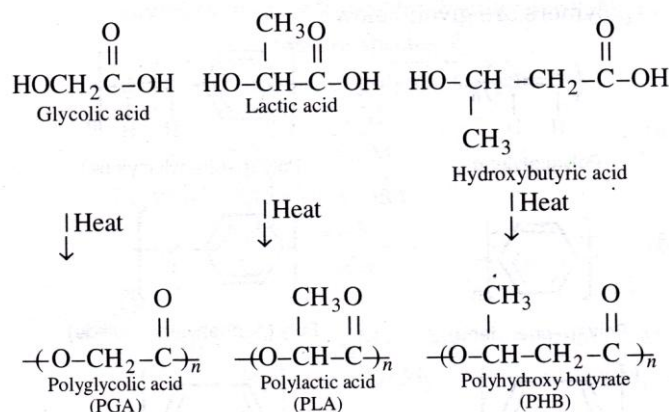
The biodegradable polymers are primarily used in agriculture and medicine. Intensive research in these fields has resulted in the development of specialized commercial products.

This concept of Green chemistry was introduced in 1990. It refers to the production of articles of daily use using chemicles in an enviromnentally friendly and cost effective manner.

II. Classification:

Natural polymers

The are called natural polymers because they are formed during the growth cycles of organisms within their cells due to a plethora of metabolic processes.

Common polymers produced by bacteria and fungi include hyduromic acid and pullulan.

Starch is a polymer of hexacarbon monosaccharide–D-glucose. It is extremely abundant in corn seeds, potato tubers, and the roots and stems of other plants. The D-glucose structure can exist both in open chain and in ring forms; the ring configuration is ascribed to D-glucopyranose. The pyranose ring is a more thermodynamically stable structure and it constitutes the sugar structure in the solutions.
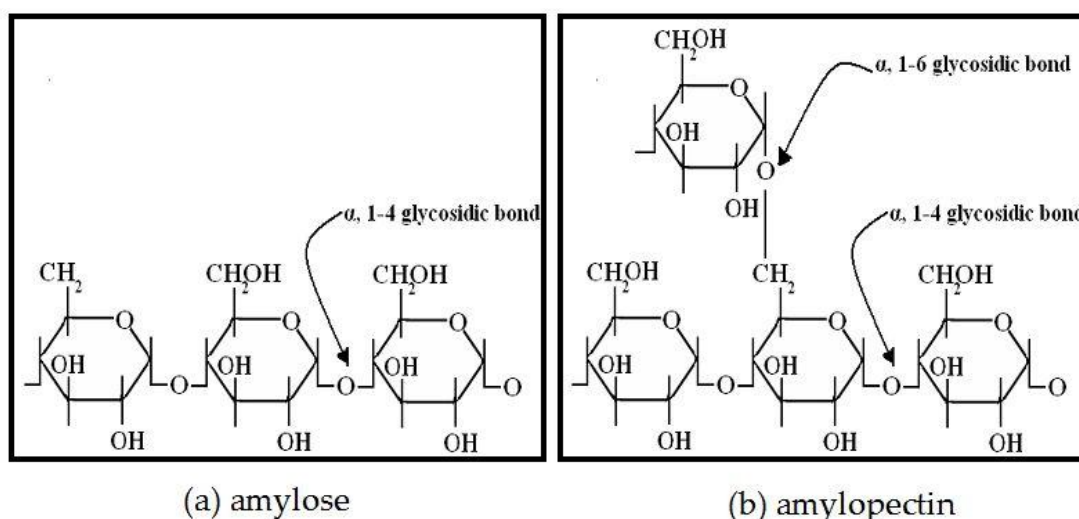
Starch

Starch is mainly composed of D-glucopyranosis polymers bound by 1,4- and 1,6-glycoside links. These links are formed between the first carbon atom (C1) of one molecule and the fourth (C4) or sixth (C6) of the second one. As the aldehyde group on one end of a starch polymer is always free, these starch polymers always possess at least one reducing tip. The other end of the polymer is an irreducible tip.

Studies on starch's chemical properties and structure have established that it is composed of two components,

both also polysaccharides: amylose (20–35%) and amylopectin. The ratio of these components varies, subject to the source of origin. Amylose is a linear polymer, whereas the amylopectin molecule is substantially bigger and branched. These structural differences cause marked differences in starch's characteristics and functions.

Amylopectin, dominant in most starch kinds, is a branched polymer of substantially larger size than amylose. Amylopectin consists of ☐ 1,4bonded glucose segments, linked by 1,6 bonds at the branching sites. Estimates are that around 4–6% of bonds in a standard amylopectin molecule appear to be 1,6 links, which results in over 20,000 branchings in a molecule, although the branchings are not large. Studies suggest a bimodal size distribution of polymer chains: namely small and large chains. Small chains have an average degree of polymerization (DP) of about 15, whereas the bigger chains have DPs of around 45. This unique configuration contributes to the crystalline nature of amylopectin and to ordered arrangements of amylopectin molecules within the starch granule. The branched chains of amylopectin behave just like those of amylose, but in the case of amylopectin whole chains–or more often their fragments–can be twisted spirally

*Amylose*from different botanic sources shows varying degrees of polymerization (DPs), about 1500–6000, whereas the considerably bigger amylopectin molecules exhibit DPs from around 300000–3000000. From these figures and from the molecular weight (MW) of anhydrous glucose (162), the MW of amylose can range from 243 000 up to 972 000. Reports say, however, that amylose from potato starch is of 1000000 MW, but its mean molecular weight is usually under 500 000. The MW of amylopectin varies between 10000000 and 500000000.

(a) amylose   (b) amylopectin

III. Methodology

The experiment was performed with the primary objective being the creation of a biodegradable plastic film in a cost effective manner.

The ram materials used in this study include Glycerol (Propan-1,2,3-triol) and potato starch extracted by the dehydration of potato pulp.

For the creation of an experimental ammount of the film, the following procedure was carried out:

Water and potato starch were combined in a 5:1 ratio. To this, about 2ml of concentrated hydrochloric acid and 3ml of glycerol were added.
The mixture was heated until a gel-like consistency was achieved.
The solution was then neutralized using sodium hydroxide solution.
The gel was then dried in a heating cabinet at 90 degrees Celsius.

Thus, the plastic film was created.

IV. Applications:

Medical Applications

The developed biodegradable synthetics serve as surgical implants in the blood vessels, in orthopedic surgery as implantable matrices for controlled long-term drug release in an organism, and as absorbable surgical sutures, as well as for eye treatment. Recently the term "biomaterial" has been defined as a non-living material used in medical device applications for interaction with a biological system. It is important that the term

"biocompatibility" was also formulated; it determines how a tissue responds to foreign material. Biocompatibility is the ability of a material to coexist with some host's reactions in a specific use.

Surgical Sutures

Tissue damage causes loss of structural integrity: a deep cut in soft tissue or a bone fracture, for example, may or may not be capable of spontaneous healing. Insertion of material or an instrument to hold the wound edges together may facilitate the therapy. The classic example is application of sutures to hold both deep and surface wounds together. When the healing is complete, the sutures are redundant and may disturb healthy tissues. It is then helpful for the material to be removable from the site either physically or by degradation.

Synthetic, absorbable sutures were developed in the 1960s, and thanks to their good compatibility in tissues are widely used in general and tracheobronchial surgery. The sutures used most often are multifilament, with good handling characteristics. The most popular and commercially available are the sutures made from PGA, PLA and their copolymers. For laying continuous sutures, however, braided sutures with non-smooth surfaces are not useful. In such cases only mono- filament sutures with smooth surfaces are useful, because PGA or PLA proved to be too stiff and inflexible. The more flexible polydioxanones and polyglyconates can be used as sutures thanks to their low bending moduli. In addition, polymers of polycaprolactone are also bioabsorbable, elastic materials, so their clinical use is under study.

Bone-Fixation Devices

Although metal fixation is an efficient method for undisturbed bone treatment, bone and metal have completely different mechanical properties. The elasticity constant of bone is only a tenth that of implanted steel, whereas its tensile strength is 10 times lower. Because of this, removal of metal implants can bring about bone weakness and fracture can recur.

In contrast, biodegradable implants can adapt to the dynamic processes of bone healing through decreasing amounts of weight-bearing material. Over a few months the introduced material disappears and there is no need to operate on a patient to remove it. In this field, PGA, PLA, PHD, and polydioxanone can potentially be used. Polydioxanones have been recommended for clinical use to protect ligament augmentation, for securing ligament sutures, and as a sort of internal splinting suture to allow early motion after an operation.

Agricultural Applications

Since the introduction in the 1930s and 1940s of plastic films for greenhouse covering, chemical plant protection, and mulching in fields, polymer use in agriculture has developed at a great rate. All the main classes of polymers–that is, plastics, coating, elastomers, fibers, and water-soluble polymers–are nowadays used for controlled release of pesticides and nutrients, soil fertilization, seed coatings, and plant protection. Degradable plastics are also of serious interest as materials for crop mulching in fields or as agricultural plant containers. Their biodegradation mode (i.e., composting) is of great significance because it allows various biodegradable materials to be combined and processed into useful materials to improve the state of the soil.

Controlled Release of Agricultural Chemicals

Controlled release (CR) is a method by which active chemicals are provided to specific plant species at preset rates and times. Polymers are mainly used to control the delivery rates, mobilities, and periods of effectiveness of the chemicals. The main benefit of the CR method is that if fewer chemicals are used for the protected plants over the predetermined period, then the effect on the other plant species is less, while leaching, volatilization, and degradation are reduced. The macromolecular character of polymers is the key to reduction of chemical loss throughout the production.

CR polymer systems can be divided into two categories. In the first, the active agent is dissolved, dispersed, or encapsulated within the polymeric matrix or coating. Its release takes place through diffusion or after biological or chemical breakdown of the polymer. In the second category, the active agent either itself constitutes a part of the macromolecular backbone or is attached to it. Here its release is the result of biological or chemical cleavage of the bond between the polymer and bioactive agent.

Physical systems into which agricultural chemicals have been introduced include microcapsules, physical blends, and dispersions in plastics, laminates, hollow fibers, and membranes. Kinetic models for chemical release have been developed for each of the above systems.

Of the natural polymers, starch, cellulose, chitin, alginic acid, and lignin are used in CR systems. Their advantages are availability, relatively low cost, and biodegradability. Although these materials have functionality for derivatization, they have one significant drawback: that is, their insolubility in standard solvents for formulation, encapsulation, and dispersion. This drawback is overcome when a chemical is encapsulated in situ, with, for instance, gelatinized starch cross- linked with a chosen pesticide by calcium chloride or boric acid. As a consequence, the pesticide is trapped within the granular particles formed.

One of the most important applications of CR technology in agriculture is fertilization. Urea, a main nitrogen source, readily reacts with formaldehyde to form a polymer. The subsequent hydrolysis of polymer releases urea, so it is a simple and inexpensive CR system.

A small niche for degradable plastics is the use of polycaprolactone for small agricultural planting containers. It is not a broad field for use of biodegradable synthetics, but it is one of the few applications in which the polymer used undergoes biodegradation within a reasonable period. Polycaprolactone planting containers have been used in automated machine planting for tree seedlings. It was found that the polycaprolactone had undergone substantial degradation after being in soil for six months, having lost 48% of its original weight, with 95% weight loss within a year.

References

[1].   Duncan, R. and Kopecek, J. (1984) Soluble synthetic polymers as potential drug carriers. Journal of Advanced Polymer Science, **57**.
[2].   Andreopoulos, A.G. (1994) Plasticization of biodegradable polymers for use in controlled release. Clinical Materials, **15**.
[3].   Dubois, P. (1978) Plastics in Agriculture, Applied Science Publishers, London, 24 et al.
[4].   Buttrey, D. (1972) Modern Plastics International, **2**.
[5].   Frazza, E.J. and Schmitt, E.E. (1971) A new absorbable suture. Journal of Biomedical Materials Research, **15.**
[6].   Tokiwa, Y. and Suzuki, T. (1977) Hydrolysis of polyesters by lipases. Nature, **270**.
[7].   Fukumura, T. (1966) Two bacterial enzymes hydrolyzing oligomers of 6-aminocaproic acid. The Journal of Biochemistry, **59**, 537.