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Biodegradable plastics

Making green packaging

Biodegradable plastics are `environment-friendly'; they have an expanding range of potential applications, and are driven by the growing use of plastics in packaging.

Advanced technology in petrochemical polymers has brought many benefits to mankind. However, it becomes more evident that the ecosystem is considerably disturbed and damaged as a result of the non-degradable materials for disposable items.

Our whole world seems to be wrapped in plastic. Almost every product we buy, most of the food we eat and many of the liquids we drink come encased in plastic.
The environmental impact of persistent plastic wastes is evoking more global concern as alternative disposal methods are limited. Incineration may generate toxic air pollution, and satisfactory landfill sites are limited. Also, the petroleum resources are finite and are becoming limited.

It becomes important to find durable plastic substitutes, especially in short-term packaging and disposable applications. Recently, the continuously growing concern of the public for the problem has stimulated research interests in biodegradable polymers as alternatives to conventional non-degradable polymers such as polyethylene and polystyrene etc.

Biodegradable plastics

Biodegradable plastics made with plant-based materials have been available for many years. Their high cost, however, has meant they have never replaced traditional non-degradable plastics in the mass market.

The area of degradable polymers, products and definitions has evolved considerably over the last 20 years. In the most general sense and/or good judgment "biodegradable" means that a substance is able to be broken down into other substances, with a significant change of chemical structure, by the activities of living organisms and is therefore unlikely to persist in the environment. With this definition, neither a time limit nor environmental conditions are prescribed and in this sagacity most materials could be classified as biodegradable. However, many materials will remain non-degraded in typical refuse conditions, such as a landfill, or will degrade to products with greater toxicity than the original material. Other terms that are of relevance here include photodegradable, where degradation results from the action of natural sunlight and disintegration, which is the falling apart into very small fragments of material caused by degradation processes.

Now-a-days a biodegradable plastic would typically be defined as one in which degradation results from the action of naturally occurring micro-organisms such as bacteria, fungi and algae. There are ranges of standards for biodegradable plastics. The requirements vary from 60 to 90% decomposition of the material within 60 to 180 days of being placed in a standard environment - this may be either a composting situation or a landfill.

A material that simply breaks up into smaller and tiny portions is no longer regarded as being biodegradable. Naturally occurring polymers include: polysaccharides e.g., starch from potatoes and corn, their derivatives, cellulose from marine crustaceans; proteins such as gelatin (collagen), casein (from milk), keratin (from silk and wool) and zein (from corn); polyesters such as poly hydroxy alkanoates formed by bacteria as food storage; lignin; shellac and natural rubber polylactic acid, jute, flux, silk, cotton can fall into the category of natural polymers where the monomer is produced by fermentation. The rate of degradation of each of these depends very much on their structural complexity, as well as the environmental conditions.

While there are a number of biodegradable synthetic resins, including: polyalkylene esters, polylactic acid polyamide esters, polyvinyl esters, polyvinyl acetate, polyvinyl alcohol, polyanhydrides. The materials mentioned here are those that exhibit degradation promoted by micro-organisms. This has often been coupled to a chemical or mechanical degradation step.

There are five different kinds of degradable plastic:

- Biodegradable,
- Compostable,
- Hydro-biodegradable,
- Photo-degradable and
- Bioerodable.

These can be either organically based from renewable resources or synthetic with a petroleum base.

Bioplastics

Compostable plastic: A plastic that undergoes biological degradation during the composting process (up to 2-3 months in a windrow) to yield carbon dioxide, water, inorganic compounds and biomass at a rate consistent with other known compostable materials and leaves no visually distinguishable or toxic residues.

Biodegradable plastic: A degradable plastic in which the degradation must result from the action of naturally occurring microorganisms over a period of time (up to 2-3 years in a landfill).

Degradable plastic: An oil-based plastic containing a chemical additive that undergoes significant change in its chemical structure causing it to break down into smaller particles. The degradation process is triggered only when material is exposed to specific environmental conditions (such as UV, heat and moisture). Residues are not food matter for microorganisms and are not biodegradable or compostable.

The range of degradable plastics now available includes:

- Starch-based products including thermoplastic starch, starch and synthetic aliphatic polyester blends, and starch.
- Naturally produced polyesters.
- Renewable resource polyesters such as PLA.
- Synthetic aliphatic polyesters .
- Aliphatic-aromatic (AAC) co polyesters.
- Hydro-biodegradable polyester such as modified PET.
- Water soluble polymer such as polyvinyl alcohol and ethylene vinyl alcohol.
- Photo-degradable plastics.
- Controlled degradation additive master batches

Applications and uses of Biodegradable plastics

Biodegradable plastics are a new generation of polymers emerging in the market. Biodegradable plastics have an expanding range of potential applications, and are driven by the growing use of plastics in packaging and the perception that biodegradable plastics are 'environmentally friendly', their use is predicted to increase. However, issues are also emerging regarding the use of biodegradable plastics and their potential impacts on the environment and effects on established recycling systems and technologies.

There is an extensive range of potential applications. Some of these include:
Film including over wrap, shopping bags, waste and bin liner bags, composting bags, mulch film, silage wrap, landfill covers, packaging - incl.O_2 & H_2O barriers, bait bags and cling wrap, flushable sanitary products, sheet and non woven packaging, bottles, planter boxes and fishing nets, food service cups, cutlery, trays, and straws.

Mulch film from biodegradable plastics

This kind of mulch film can be useful for farmers. Mulch films are laid over the ground around crops, to control weed growth and retain moisture. Normally, farmers use polyethylene black plastic that is pulled up after harvest and trucked away to a landfill (taking with it topsoil humus that sticks to it). However, field trials using the biodegradable mulch film on tomato and chilly crops have shown it performs just as well as polyethylene film but can simply be ploughed into the ground after harvest. It’s easier, cheaper and it enriches the soil with carbon.

Plantable Pots

Another biodegradable plastic product is a plant pot produced by injection moulding. Gardeners and farmers can place potted plants directly into the ground, and forget them. The pots will break down to carbon dioxide and water, eliminating double handling and recycling of conventional plastic containers.

Different polymer blends for different products

Depending on the application, scientists can alter polymer mixtures to enhance the properties of the final product. For example, an almost pure starch product will dissolve upon contact with water and then biodegrade rapidly. By blending quantities of other biodegradable plastics into the starch, scientists can make a waterproof product that degrades within 4 weeks after it has been buried in the soil or composted.

Composting the packaging with its contents

Compost may be the key to maximising the real environmental benefit of biodegradable plastics. One of the big impediments to composting our organic waste is that it is so mixed up with non-degradable plastic packaging that it is uneconomic to separate them. Consequently, the entire mixed waste-stream ends up in landfill.

By ensuring that biodegradable plastics are used to package all our organic produce, it may well be possible in the near future to set up large-scale composting lines in which packaging and the material it contains can be composted as one. The resulting compost could be channeled into plant production, which in turn might be redirected into growing the starch to produce more biodegradable plastics.

With intelligent use, these new plastics have the potential to reduce plastic litter, decrease the quantities of plastic waste going into landfills and increase the recycling of other organic components that would normally end up in landfills.

Whilst several biodegradable plastics are used for these applications worldwide, the current market penetration is low.

Environmental benefits of biodegradable plastics

There are several identifiable environmental benefits that may potentially be derived from the use of biodegradable plastics compared to conventional petroleum-based plastics.

These are:

Compost derived in part from biodegradable plastics increases the soil organic content as well as water and nutrient retention, while reducing chemical inputs and suppressing plant disease.

Biodegradable shopping and waste bags disposed of to landfill may increase the rate of organic waste degradation in landfills while enhancing methane harvesting potential and decreasing landfill space usage. Biodegradable landfill covers may also considerably extend landfill life.

The energy required to synthesize and manufacture biodegradable plastics is generally much lower for most biodegradable plastics than for non-biodegradable plastics. The exception is PHA biopolymers which consume similar energy inputs to polyethylenes. New feedstock for PHA should lower the energy required for their production.

Biodegradable plastics also offer important environmental benefits through, in many cases, the use of renewable energy resources and reduced greenhouse gas emissions.

Challenges ahead

Acceptance of biodegradable polymers is likely to depend on four unknowns:

(1) Customer response to costs that today is generally 2 to 4 times higher than for conventional polymers;

(2) Possible legislation (particularly concerning water-soluble polymers);

(3) The achievement of total biodegradability; and

(4) The development of an infrastructure to collect, accepts, and process biodegradable polymers as a generally available option for waste disposal.

In a social context biodegradable plastics call for a re-examination of life-styles. They will require separate collection, involvement of the general public, greater community responsibility in installing recycling systems, etc. On the question of cost, awareness may often be lacking of the significance of both disposal and the environmental costs, which are to be added to the processing cost.

Biodegradability is tied to a specific environment. For instance, the usual biodegradation time requirement for bioplastic to be composted is 1 to 6 months.

The development of starch-based biodegradable plastics looks very promising given the fact that starch is inexpensive, available annually, biodegradable in several environments and incinerable.

The main drawbacks the industry is running into are bioplastics' low water-barrier and the migration of hydrophilic plasticizers with consequent ageing phenomena. The first problem together with the cost factor is common to all other biodegradable plastics. These challenges have to be faced and solved accordingly to enter the niche market.

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