Biodegradable Plastic Packaging Material

Poly(lactic acid) cup before and after adding hot water.

Interest in biodegradable disposable plastic items has steadily grown over the last decade. With packaging materials, the reduction in usage of raw materials, re-use, and recycling is of course the best route to a sustainable lifestyle. However in practice, for various reasons, much of the material ends up being discarded to a landfill or accidentally shows up as litter. For these instances, it is advantageous to have a plastic material that would biodegrade when exposed to environments where other biodegradable materials are undergoing decay.

What is ‘biodegradable’?

Biodegradation is degradation caused by biological activity, particularly by enzyme action leading to significant changes in the material's chemical structure. In essence, biodegradable plastics should breakdown cleanly, in a defined time period, to simple molecules found in the environment such as carbon dioxide and water.

During the process of biodegradation, the large molecules of the substance are transformed into smaller compounds by enzymes and acids that are naturally produced by microorganisms. Once the molecules are reduced to a suitable size, the substances can be absorbed through the organism cell walls where they are metabolized for energy.

Biodegradable plastic materials

Currently available degradable plastic materials can be broken down into two main groups: polyester polymers and synergistic/hybrid polymers.

The Polyesters

Aliphatic polyesters have attracted interest as biodegradable plastic materials; however they typically have poor physical and mechanical properties like strength, flexibility, heat resistance, etc. Synthetic biodegradable polymers, made from petroleum-based, raw materials have inferior mechanical properties e.g. low heat deflection temperature and low elongation failure (brittle). They will also begin to hydrolyze at modest temperatures in the presence of moisture and further decreasing mechanical properties. Although expensive to make, these biodegradable polymers are ideal for use in specialized, high margin applications such as medical devices (e.g. dissolving, drug delivery systems, tissue engineering scaffolds and bone repair etc.).

Another well known aliphatic polyester is poly(lactic acid). PLA is a synthetic polymer made from fermented sugars extracted primarily from food crops. It has many of the same undesirable mechanical properties, as petroleum-based polymers but degrade only at artificially elevated temperatures.

Degradation of PLA typically occurs at elevated temperatures (above heat deflection temperatures), such as conditions existing in an industrial compost operation. In low temperature environments where initial hydrolysis occurs slowly, biodegradation of PLA proceeds very slowly if at all.

Another family of biodegradable polyesters is known as polyhydroxy alkanoates (PHA's). One of the more notable polymers in this class is polyhydroxy butyrate (PHB), and like the synthetic aliphatic polyesters, it has the same poor physical and mechanical properties, and an additional disadvantage of being quite expensive. PHB was augmented to create polyhydroxy butyrate-valarate (PHBV), which has much better, and more useful, thermoplastic qualities. Since these materials are produced by microorganisms as an emergency food source, they are, by design, easily biodegradable.

For degradable polyesters, the best improvement in physical properties is obtained by synthetically creating a polyester copolymer. Using this technique, the polymer can be tailored to balance the excellent physical and mechanical characteristics of the aromatic polyester groups with the degradation and subsequent mineralization of the aliphatic groups. These polymers are also readily mixable with pure aliphatic polyesters like PLA, or natural polymer like cellulose, to form a hybrid, degradable polymer with improved performance.

Synergistic or hybrid polymers

Synergistic polymers are typically intimate mixtures of oil-based and naturally occurring polymers where the two have some chemical affinity for each other, so that once mixed they could not be mechanically separated.

The intimate mixing of the natural and synthetic polymers can be taken one step further: where the attraction of the synthetic and natural polymers is enhanced by grafting other chemically compatible groups along the chains of the natural and/or synthetic polymers.

Low-level synergistic enhancement does not materially impact the physical and mechanical properties of the original synthetic polymer. Therefore, the product applications are not restricted beyond what would normally be expected for the unamended polymer. Since the additive itself will not degrade the polymer or affect processing, the ability for recycling or reuse of the plastic article will be similarly unaffected.

Conclusion

Conventional polymer technologies have been able to tailor materials that can meet the market need of both cost and performance. There is infrastructure in place for recycling and/or re-use of many of these materials, which is the most desirable destination in the life cycle of the packaging product. With inclusion of a synergistic additive, such as that used by FP International, then the materials would also be well-suited for the less desirable destinations, such as landfills or litter.

The other biodegradable polymer options have no recycle infrastructure, and could possibly be viewed as having been designed to be thrown out. However, the fact that many of these polymers, like PLA, are limited to biodegradation in only commercial compost facilities, further decreases the potential for a desirable end-of-life scenario.

Moreover, while the bacterially produced polyesters (PHBIPHV) would biodegrade in a more general disposal scenario, they are particularly cost-prohibitive for most packaging applications.

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