Why not consider cellulose derivatives for single use applications?

This monthly column is all about openly sharing expertise and knowhow with our readers, regardless of industry, product or service. The aim is to plant the seeds of inspiration, strengthen the knowledge base, and hopefully, lead to new opportunities and innovations.

While the column is being rolled out with the ideas of Prof. V.C. Malshe, an academician, researcher, innovator, consultant and businessman, it is open to one all. Simply write to editorial@chemicalweekly.com.

Options for single use plastics

There is a big movement to remove single use plastics. The job is difficult. Several solutions are being proposed. Some of the most common are:

- Use of biodegradable plastics like polylactic acid (PLA), poly (glycolic acid) (PGA), polyvinyl alcohol (PVA), starch-filled polyethylene, and polybutylene adipate terephthalate (PBAT).
- Addition of catalysts that would make the plastics readily degradable to safer, non-toxic molecules like carbon dioxide (CO_2), water, hydrocarbons, carboxylic acids, alcohols, ketones, etc.
- Use of alternate reusable, recyclable materials like metals, glass or paper.

Of these, some are practical, and should be considered and implemented.

Biodegradable plastics

Polybutylene adipate-co-terephthalate (PBAT), for example, is a polyester that is readily prepared from well-known raw materials like purified terephthalic acid (PTA), butylene glycol, and adipic acid. None of these raw materials is an agri-product, nor is there a possibility to derive them from a renewable raw material in near future, though there is a remote possibility of converting glucose to adipic acid by a sequence of reactions – oxidation, dehydration and hydrogenation. The cost of adipic acid so produced will be affordable only if it is produced on a very large scale. Other raw materials would continue to be petrochemical-derived.

Another much talked about polymer is PLA. It is derived from lactic acid, which, in turn, is produced by fermentation from maize, converted to a lactide, and then polymerised. Even though it is derived from agri-based raw materials, PLA is not readily biodegraded, needs a catalyst, and has a density higher than polyethylene (PE). Hence, its consumption (by weight) is about 1.5 times more than that of low density polyethylene (LDPE) or high density polyethylene (HDPE). As its price is currently 3-4 times that of HDPE, LDPE and polypropylene (PP), PLA replacement would be 4-6 times more expensive. Despite several announcements over last 30 years, the world is yet to see a large PLA manufacturing facility, and world production was below 500-kilotonnes till 2022.

At the same time, the requirement of single use, disposable plastics is increasing day-by-day, as the proposed substitutes are not able to take substantial share of non-biodegradable plastics like PE, PP and HDPE. Use of a food material (such as maize) to produce plastics is also being opposed by some organisations on grounds of poor sustainability.

Catalytic degradation of polyolefins

Some countries and some regulators have accepted catalytic degradation of polyolefins as a solution, while others still consider it nonviable.

A new worry in the form of microplastics has come about, and scientists have even found microplastics in human blood. That has retarded the possible introduction of additives that promote catalytic degradation of polyolefins on a large scale.

Biomass as a feedstock

The primary sources of biomass in India are agri-wastes like sugarcane bagasse, rice & wheat straw and husk, banana leaves, cotton stalk, foliage from forests, wood, twigs, etc. The cumulative annual availability of these types of wastes is estimated at about 840-mt. About 30% by weight of biomass is cellulose. Thus, there is a potential to gather and recover about 250-mt of cellulose every year.

Cellulose as a biopolymer raw material

Derivatives of cellulose such as cellulose triacetate (CTA), cellulose propionate (CP), cellulose acetate butyrate (CAB), and nitrocellulose (NC) have been products of commerce for over 100 years. These are environment friendly, fully biodegradable and renewable.

Every tonne of cellulose can yield about double the weight of cellulose acetates. This is 250 times more than what the country will ever need annually as disposable plastic.

CTA was introduced in cigarettes as a tar filter over 50 years ago in India. About 50-kt of the polymer is imported annually in India for this application. Not a single cigarette filter burns off during smoking. Has anyone seen a

Table 1: Comparative properties of PLA, PGA and CA

Parameter	Polylactic acid	Polyglycolic acid	Cellulose diacetate	Cellulose triacetate
Density[1][2][3]	1.24-1.50 g/cc	1.50 g/cc (for amorphous)		
1.71 g/cc (for crystalline)	1.25-1.35 g/cc	1.31-1.35 g/cc		
Melting point[1][2][3]	175°C	224-230°C	230°C	295°C
Tenacity [1][4][5][6]	3-6 g/den	5.5-7 g/den	1.2-1.8 g/den	3-5 g/den

single piece that did not biodegrade? Has anyone tried to collect the used cigarette filters with a view to recycle these in any other application? What these mean is that CTA is fully biodegradable; otherwise, it would have accumulated like many other industrial waste materials and single use plastics.

CTA has been used as fibre, for cinematographic films and can be processed by all major plastics forming processes including injection moulding and extrusion. But in many applications, CTA have been replaced by petrochemicals over time. CTA films, for example, have been replaced by polyester films, even though CTA continues to be used for cigarette filter, spectacle frames, high quality combs and even some membranes.

For many years, CAB was used in combs and in slide rules (for its dimensional stability), door handles, steering wheels and grips of the gear stick of expensive cars. Presently, the use of CAB is restricted to clear coats in automobiles.

All these uses of cellulose derivatives are time tested and proven. But, despite this existing body of knowledge, India does not produce CTA, CAB and even NC at sufficiently large scale.

One reason could be availability of acetic anhydride, which is locally produced only in small quantities. On the other hand, the Indian chemical industry is importing huge quantities of acetic acid and exporting ethyl acetate. About 200-kt of ethyl acetate is exported annually, consuming about 140-kt of acetic acid. If the industry can import 230-kt of acetic anhydride, use it for acetylation of cellulose, manufacture of 140-kt of CTA would be possible. This can meet a significant requirement of single use plastics in the form of films used in packaging. It can also substitute polyvinyl chloride (PVC), polyester and PP films in multi-layer packaging.

The dilute acetic acid obtained as a product of acetylation, can be converted to ethyl acetate for exports. Since the existing process for making ethyl acetate utilises wet ethyl alcohol, water in acetic acid would not be objectionable. The ethyl acetate industry, which is struggling to make ends meet, can get a fresh lease of life and can make profits by sale of high value CTA.

Physical properties of CTA make it a perfect substitute to PLA (Table 1).

Cellulose availability

Cellulose can be obtained from cotton linters, combing waste or derived from bagasse of which sugar industry has adequate surplus. India exports about 60-kt of cotton linters, a high-quality cellulose, and about 100-kt of fabric waste from hosiery industry. Some of it may be coloured. White waste, which could represent about 40-50% of total waste, is a valuable resource. It is pre-processed, bleached and mercerised, and hence is a very pure form of cellulose. The presence of spandex, which has become an important fibre in hosiery fabric, may, however, pose a problem of separation.

Concluding remarks

PLA is a biodegradable plastic that requires (per tonne) 1.05-acres land, 60-kl water, and 89,200-megajoules of energy for production. The polymer takes anywhere from six months to 80 years for biodegradation, and costs Rs. 300-350 per kg.

Cellulose derivatives – half natural and half synthetic – are, on the other hand, environmentally friendly.

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