Can biobased polymers replace their fossil analogues?

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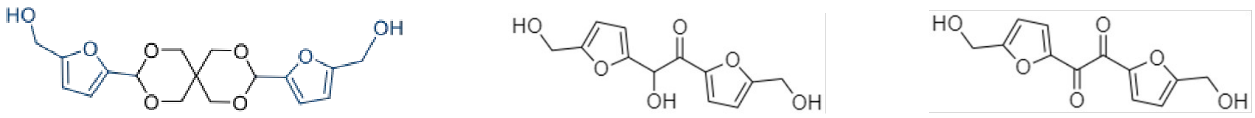
The worldwide production of plastics is growing with ever increasing speed. The reason is simple: plastic is fantastic. However, it comes with a price: the plastic waste is also increasing with unwanted effects like accumulation in the marine environment and in nature. Furthermore, incineration of waste plastic results in carbon loss caused by the CO_2 emission, where the latter contributes to undesirable climate change. Recycling and reuse of waste plastic seams in general not to be economically viable although small locally based recycling schemes exist. However, a real change gamer will be legislative demands on more recycling. Another alternative is the biobased polymers. A few companies have expressed the desire to be fossil free in the near future. One example is the toy company LEGO that already since 2018 uses biobased PE flexible elements, where it doesn't compromise the critical mechanical demands on the building bricks. Biobased monomers (BM) like the sugar cane-based PE are all considerably more expensive than the fossil-based originals. Scale-up of other interesting BMs are in progress although the industrial involvement is sluggish. One example is the 5-hydroxymethyl furfural (5-MHF, Fig. 1), that can be produced in one step from fructose [1]. To minimize crosslinking of HMF molecules under acidic conditions and at high temperatures, a reactor has been designed and is being tested for scaling up the process. 5-HMF can be the source of a number of high value base chemicals [2] useful e.g. for polyesters, polyamides and polyurethanes. One particularly important example is furan dicarboxylic acid (FDCA, Fig. 1) that can be prepared enzymatically from 5-HMF via whole cell catalysis [3]. FDCA is the cornerstone in poly(ethylene furanoate) (PEF).

5-HMF FDCA Adipic acid 2,5-Bishydroxymethylfuran

Fig. 1 Key building blocks and monomers for biobased polyesters, polyamides and polyurethanes.

The rigid spirocyclic diol (Fig. 2) based on 5-HMF and pentaerythritol has enabled the production of sustainable rigid polyurethane coatings and foams. Another new biobased building block is 5,5'-bis(hydroxymethyl)furion (DHMF, Fig. 2) prepared by carboligation of two 5-HMF molecules using chemical catalysts or enzymes. Oxidation of DHMF results in 5,5'-bis(hydroxymethyl)furil (BHMF, Fig. 2). DHMF and BHMF are currently investigated as cross-linkers for polyurethane binders with application in floor coatings.



Spirocyclic diol DHMF BHMF

Fig. 2 Novel biobased building blocks for polyesters and polyurethanes

The future of biobased polymers seems to rely on the availability of biobased monomers and polymers in addition to the companies' willingness to pay the higher production cost of both monomers and polymers.

Acknowledgments

The Swedish Foundation for Strategic Environmental Research (MISTRA) is acknowledged for funding the research programme Sustainable Plastics and Transition Pathways (STEPS).

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