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Anthony Pavone, PE
Senior Principal Analyst

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Abstract

In June 2014, Avantium Technologies BV (The Netherlands) announced plans for the first industrial-scale plant for producing bio-based PEF polymer (polyethylene 2,5-furandicarboxylate), with financial support from an industrial consortium of Swire Pacific, The Coca-Cola Company, Danone, and ALPLA. PEF is a novel, 100% bio-based polyester resin with claimed better barrier, thermal, and mechanical properties than existing packaging materials, such as PET (polyethylene terephthalate). PEF is intended to replace PET in blow-molded cold beverage bottles. Furthermore, PEF can be used in fibers, films, and other polyester applications. The primary monomer in PEF is 2,5-furandicarboxylic acid (FDCA), which can be produced from 5-hydroxymethyl furfural (HMF) derived from C_6 sugar via chemical catalytic dehydration of sugar to 5-HMF, followed by selective oxidation of 5-HMF to FDCA. 5-HMF can also be produced via thermal pyrolysis. PEF is produced by copolymerizing FDCA dimethyl diester with ethylene glycol via transesterification and polycondensation. Its molecular weight is then increased to approximately 30,000 (required for bottle-grade PET) via solid state (melt phase) thermal polymerization. A parallel effort to produce FDCA from 5-HMF via enzyme fermentation, and polymerize it to PEF, is being developed by Corbion Purac.

The primary uses for conventional PET polymer are to produce bottle-grade resins for cold beverage containers (carbonated beverages and bottled water), and as polyester fiber, which, when blended with cotton fiber, produces a wide variety of textile fabrics useful in clothing. Bottle-grade PET resin is also used in industrial fibers. The plastic bottle beverage industry has been under intense pressure from environmentalists over the solid waste generated from discarded conventional PET-based bottles. It is believed that migration from hydrocarbon-based PET to a 100% bio-based plastic PEF bottle resin will relieve some of the environmental pressure; it could also result in lower-cost resins, given the long-term anticipated price increase in crude oil, which is the fundamental feedstock for producing PET from conventional feedstock PTA (purified terephthalic acid) and monoethylene glycol.

In this report, we develop the Class-3 process design and corresponding estimated production economics for producing industrial quantities of FDCA from C_6 sugar via catalytic dehydration and selective oxidation, and also the process design and corresponding production economics for producing industrial quantities of PEF resin from the combination of bio-based ethylene glycol and bio-based FDCA. Both efforts rely on our understanding of relevant process technology developed by Avantium Technologies BV.

Also included in this report is a review of Eastman Chemical Company's technology for the conversion of HMF and its derivatives to polymer-grade FDCA or polymer-grade DMF, based on our understanding of Eastman's US patents and patent applications. We also discuss similar process technology development efforts in the HMF/FDCA/DMF/PEF integrated product chain being pursued by DuPont, Corbion Purac, and AVA Biochem.

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IHS Customer Care:

Americas: +1 800 IHS CARE (+1 800 447 2273); CustomerCare@ihs.com
Europe, Middle East, and Africa: +44 (0) 1344 328 300; Customer.Support@ihs.com
Asia and the Pacific Rim: +604 291 3600; SupportAPAC@ihs.com