Ethanol, Biopolymers, and Xanthan Gum Use Corn As a Feedstock

Industrial uses of corn are expected to total 780 million bushels in 1995/96, up 4 percent from 1994/95. Ethanol sales in the reformulated gasoline market have been strong, despite the court-ordered elimination of the renewable oxygenate requirement. Several companies are manufacturing biobased polymers using polyhydroxybutyrate/valerate, starch, and polylactic acid. Cornstarch also is used to make xanthan gum, a popular ingredient in food, pharmaceuticals, and industrial products.

Industrial uses of corn are expected to total 780 million bushels in 1995/96, up 4 percent from the current forecast of 753 million for 1994/95 (table 2). Most of the increase is expected to be in the production of fuel alcohol, up 4 percent, versus only a 2-percent rise in industrial starch. In 1995/96, industrial uses are expected to account for 9 percent of total corn use, up from 8 percent in 1994/95.

Industrial use of starch tends to follow the economy. Thus, the slower economic growth expected in 1995/96 will likely slow starch use. In 1994/95, industrial starch is expected to account for 213 million bushels of corn, up 3 percent from 1993/94. The expanding economy late in 1994 and early 1995 helped increase starch use. However, the recent slowdown in economic growth will likely hold corn use for industrial starch to a 2-percent rise over the year before.

Preliminary prices for cornstarch, f.o.b. Midwest, are expected to average $12.18 per hundredweight (cwt) in 1994/95, down from $12.61 in 1993/94. Producers appear to be able to pass along higher raw material costs, because when corn prices rise, so do starch prices. For example, cash corn prices in central Illinois went up 9 cents from April to May 1995 and starch prices increased 24 cents per cwt. By August, starch prices had climbed another $1.20 to $13.85 per cwt, while corn prices were up 18 cents per bushel. As starch prices increase, industrial users are likely to begin searching for lower cost alternatives and, to the extent possible, shift away from starch.

The expected increase in production of fuel ethanol in 1995/96 is tied to the announced expansion of plants in Minnesota and Nebraska. These States have provided incentives to encourage the production of alcohol. On the other hand, current high prices for corn have made dry-milled alcohol production less profitable than in the past. Two companies announced they are stopping production at two plants, one in Ohio and one in North Dakota, where the State legislatures have limited funding for ethanol subsidies. In 1994/95, corn used to make fuel alcohol is expected to increase 18 percent from 1993/94, as the industry expanded to meet demands for oxygenates for reformulated gasolines and the winter oxygenated program.

Ethanol Use Up Despite Court Ruling

The reformulated gasoline program began on January 1, 1995, as mandated by the Clean Air Act Amendments of 1990. The program's renewable oxygenate requirement (ROR) was held up by a stay issued by the U.S. District Court of Appeals for the District of Columbia on September 13, 1994. The Court reversed the ROR in a unanimous decision by a three judge panel in early June 1995. The Administration immediately appealed the decision to the full Court, but that appeal was rejected at the end of July. The Administration is considering a final appeal to the U.S. Supreme Court. (For more information on the ROR and the court case, see the December 1994 issue of this report.)

Despite these unfavorable Court rulings, ethanol sales in the reformulated gasoline market have been strong. In the Chicago and Milwaukee markets, ethanol's market share was as high as 70 percent. Ethanol also fared well in the winter oxygenated fuel markets, capturing virtually 100 percent of the market in the Colorado front range, and maintaining sig-

Table 2--Industrial and food uses of corn, 1990/91-1995/96

Marketing year 1/	HFCS 2/	Glucose and dextrose 2/	Cereals and other products	Starch: Food uses	Starch: Industrial uses	Starch: Total 3/	Alcohol: Beverage	Alcohol: Fuel	Total industrial use 4/
					Million bushels				
1990/91	379	200	114	35	197	232	80	349	546
1991/92	392	210	116	36	202	237	81	398	600
1992/93	414	215	117	36	202	238	83	426	628
1993/94	442	223	118	37	207	244	83	458	665
1994/95 5/	460	230	118	38	213	250	84	540	753
1995/96 6/	475	235	118	38	217	255	84	563	780

1/ Marketing year begins September 1. 2/ High fructose corn syrup (HFCS), glucose, and dextrose are primarily used in edible applications, such as food and health-care products. 3/ Industry estimates allocate 85 percent of total starch use to industrial applications and 15 percent to food applications. 4/ Industrial uses of starch and fuel alcohol. 5/ Preliminary. 6/ Forecast.

nificant market share in other oxygenated fuel markets. On the other hand, ethanol has not gained significant market share in the Northeast reformulated gasoline market due to heavy competition from methyl tertiary butyl ether.

While ethanol's market share in conventional gasoline, oxygenated fuel, and reformulated gasoline have grown, ethanol is used primarily in the Midwest. Many analysts believe the costs of using ethanol in other markets, particularly the reformulated gasoline markets of the Northeast and California, is uncompetitive because of transportation and other distribution logistics. A possible solution is converting ethanol into ethyl tertiary butyl ether (ETBE) or other ethers at the refinery, blending ETBE with gasoline, and shipping the finished reformulated gasoline to market in common carrier pipelines.

On August 4, 1995, the Internal Revenue Service announced a new regulation that allows ETBE access to the excise tax exemption for ethanol blenders. The rule also allows refiners to claim the tax credit at the refinery, which means they no longer have to keep fuels that qualify for the tax exemption separate from other fuels in the pipeline and at the terminal. If this rule is effective in reducing the costs of using ethanol in reformulated gasoline, significant quantities of ETBE-blended fuels could be sold in the Northeast and California within the next year.

Biodegradable Polymer Technologies Continue To Improve

As environmental concerns regarding waste management continue to mount, biodegradable polymers could become an increasingly important piece of the waste management puzzle. The three main types of biobased-polymers—made using starch, polyhydroxybutyrate/valerate (PHB/V), and polylactic acid (PLA)—fit the "cradle to grave" design concept, which calls for the material to be recyclable and/or degradable.

Several companies claim to have developed 100 percent biodegradable resins using starch or starch-derived compounds in combination with other biodegradable additives and naturally occurring minerals. However, full biodegradability can occur only when these materials are disposed of properly in a biologically active environment, such as municipal composting or sewage treatment facilities. (For more information on biodegradability, see the special article on biopolymers in the June 1993 issue of this report.) In addition, not all claims of biodegradability are founded on accepted standards. The Institute for Local Self-Reliance (ILSR) is in the process of completing a study of various degradable polymers. The study is examining the commercial status of various technologies and evaluating the biodegradability claims made by various companies.

PHB/V Targets Markets in Europe

Polyhydroxybutyrate/valerate copolymers are being produced by Zeneca Bio Products of Wilmington, Delaware, a spin-off company from International Chemicals, Inc. Zeneca's plant is located in the United Kingdom and has capacity of about 600 metric tons (1.3 million pounds) of resin per year. PHB/V copolymers are produced by fermentation of a sugar feedstock (glucose is currently being used) by a naturally occurring microorganism. Zeneca's resulting BIOPOL resin can be designed to have many different physical properties, depending on the hydroxyvalerate content. PHB/V completely degrades in a biologically active environment to carbon dioxide and water. Zeneca is currently working with USDA's Agricultural Research Service in modifying the polymer matrix with various additives and testing degradability of the resulting polymers.

BIOPOL resins can be converted into various types of plastic products, depending on the physical properties of the resin used. The first major product was a biodegradable shampoo bottle, which was developed about 5 years ago. However, because BIOPOL resin prices, which range from $3 to $6 per pound, are somewhat higher than prices for other degradable resins, the number of markets for BIOPOL may be limited. According to a Zeneca representative, major target products are likely to be plastic films and coatings. The major markets for BIOPOL currently are in Europe and, to some extent, Japan. Environmental regulations in several European countries, particularly Germany, favor biodegradable products.

Starch-Based Technology Benefits from Corporate Mergers

Recent corporate mergers and technology improvements are helping starch-based polymers to overcome some of the previous difficulties faced by the industry. Moisture sensitivity has been a major concern for starch-based polymers. Developments in various additives have helped many companies create resins that are water resistant. Some of the additives, known as masterbatch additives, incorporate starch, synthetic linear polymers, plasticizers, and other additives that trigger and/or accelerate the degradation process. A careful study of degradability and toxicity must be made when evaluating resins containing these particular additives.

Many starch-based resins can be processed on conventional plastic-molding equipment and, depending on the properties of the specific resin, can be converted into virtually all types of plastic products. These include but are not necessarily limited to: compost bags (lawn and leaf), disposable food-service items (cutlery, plates, cups, etc.), packaging materials (loosefill, films, etc.), coatings (lamination, paper coatings, etc.), and specialty items, such as golf tees, agricultural films, and various medical products. The amounts of starch and other additives used in the polymer generally depends on the desired properties of the end product.

There have been many corporate developments in the starch-based polymer industry since pharmaceutical giant Warner-Lambert closed its Novon division in November 1993. At the time, Novon was the leading U.S. producer of starch-based biopolymers, with a 100-million-pound-per-year capacity. In January 1995, EcoStar International, a company with a background in biodegradable compounds and additives, acquired Novon from Warner-Lambert and formed Novon International, Inc. In February 1995, Novon International was in turn acquired by Churchill Technology, Inc., a British company that owns patents on nonagriculturally based, biodegradable resins. All three corporate entities have been consolidated into the Novon International facilities in Buffalo, New York, and will continue to be known as Novon International, Inc.

The starch-based polymer currently available from Novon International is called Novon, and it is manufactured primarily from corn or potato starch, along with smaller amounts of foodgrade additives (although not intended for human consumption). This resin is suitable for manufacturing nearly all plastic products, and is currently priced around $2.25 to $2.50 per pound. Also available from Novon International is a starch-based masterbatch additive called Novon-Plus. Novon-Plus is intended to be mixed with synthetic polymers to create nearly any plastic product, while making the product more degradable than the traditional synthetic plastic. A typical product may be about 43 percent starch, 50 percent synthetic polymer, and 7 percent proprietary ingredients. Current pricing for Novon-Plus additives are about $1.60 to $1.70 per pound.

Other companies are developing starch-based polymers as well. Founded in February 1995, BioPlastics, Inc., is using technology from Michigan State University, licensed through the Michigan Biotechnology Institute (MBI), to create a resin called ENVAR. A for-profit subsidiary of MBI, Grand River Technologies, Inc., also is entering the starch-based resins market. Grand River has joined with Japan Corn Starch Company, Ltd., to form EverCorn, Inc., to market cornstarch-based EverCorn resin. EverCorn completed a $1.8-million research and development phase in July 1995, and has a pilot-scale operation in place to provide customers with samples in 1,000-pound quantities. The company hopes to have a 10-million-pound, semi-works plant operating by late 1996, and plans for a 250- to 500-million-pound commercial plant in 1998.

Cargill Leads the Way in PLA-Based Resins

The third major biobased polymer technology is based on polylactic acid. PLA polymers are generally derived by fermenting carbohydrate crops, such as corn, wheat, barley, cassava, and sugar cane. Companies such as Archer Daniels Midland and Cargill produce lactic acid (via starch fermentation) as a coproduct of corn wet milling, which can be converted to PLA. PLA-based polymer resins are completely biodegradable under compost conditions. PLA can be hydrolyzed using only water back to lactic acid, and can be repolymerized if desired. PLA-based resin also can be degraded by marine microbes into water and carbon dioxide. However, PLA is not water soluble. PLA-based polymers can be modified to suit nearly all plastic applications from disposable foodservice items to coatings for paper.

The largest producer of PLA-based polymers is Cargill. The company's PLA-based resins, called EcoPLA, are commercially available from its plant in Savage, Minnesota. This plant has an annual capacity of about 10 million pounds of resin, but Cargill plans to open a larger facility with a capacity of 100 to 300 million pounds in Blair, Nebraska, by 1998. Current prices for EcoPLA resins range from $2 to $5 per pound, depending on grade, but, with the larger facility, future prices are expected to be around $1 per pound.

Two other U.S. firms and several Japanese firms also have been developing PLA-based polymers for the past few years. The U.S. firms are Ecochem, a joint venture between DuPont and ConAgra, and the Chronopol Company, a subsidiary of ACX Technologies, which is headquartered in Golden, Colorado. Ecochem and Chronopol have formed a patent-holding venture called EcoPol L.L.C., but the companies will continue to operate independently. Chronopol is currently at the pilot-plant stage and does not have commercial quantities of resin available, and Ecochem is not pursuing resin production at this time. According to industry sources, three Japanese firms—Dainipon Ink and Chemicals, Inc.; Mitsui Toatsu Chemicals, Inc.; and Shimadzu Corporation—are planning pilot plants.

ILSR estimates that only 1.1 percent of the plastics produced in 1996 will be partly or wholly derived from plant matter. This means that, for the near future, companies making PHB/V-, starch-, and PLA-based polymers will continue to focus on niche markets. These markets will serve customers who are willing to pay a higher price for products that are environmentally friendly, or specialty uses where a higher price is not a limiting factor. PLA technology, for example, has been used for years in specialty medical applications, such as bioabsorbable sutures and bone implants. However, PLA's high price compared with petroleum-based resins has prevented its use in vast commercial applications.

Though recent advances in production technology have helped lower some resin prices and make biobased polymers function more like traditional petroleum-based products, prices of biodegradable resins are still significantly higher than those for petroleum-based plastics. In addition, companies and communities must be willing to provide the proper composting facilities for biodegradable polymers. Otherwise, they will end up in the solid waste stream with other trash and will not degrade as designed. The long-term outlook for biobased polymers is still uncertain, but is likely dependent on future worldwide regulatory developments and continued improvements in cost-lowering technologies.

Xanthan Gum Popular in Food and Industrial Applications

Discovered in 1963 at USDA's Northern Regional Research Center (now called the National Center for Agricultural Utilization Research), xanthan is now one of the most popular commercially produced gums. It was first derived from the bacterial action of *Xanthomonas campestris* on plants, primarily those in the cabbage family. With the advent of viscous fermentation technology in the early 1970's, this high-molecular-weight polysaccharide is now produced from cornstarch.

Gums is the common term for hydrocolloidal gels—polysaccharides that have an affinity for water and exhibit binding properties with water and other organic/inorganic materials. Traditionally, gums have been derived from a wide variety of plants. More recently, however, other valuable polysaccharides have been identified that are produced from microbial sources (table 3). Hydrocolloidal gums also can be produced from marine plants and cellulosic materials.

Kelco (San Diego, California), a division of Monsanto Company, and Archer Daniels Midland Company (Decatur, Illinois) are the two U.S. producers of xanthan gum. U.S. capacity in 1994 was estimated at 57 million pounds. Based on trade data and new-plant construction information, U.S. production capacity in 1995 is estimated at 77 million pounds. (Producers will not verify actual capacities; plant capacity and production volumes are considered proprietary.) If the companies' four plants are operating at full capacity, an estimated 5 million bushels of corn will be used to produce xanthan gum in 1995.

Xanthan gum also is imported from a Kelco plant in the United Kingdom, a Jungbunzlauer plant in Austria, and several French plants operated by Rhone-Poulenc and Sandfi Bio-Industries. Both Jungbunzlauer and Rhone-Poulenc have expressed interest in producing xanthan gum in the United States.

Xanthan gum is used in a variety of industrial and oil-field applications, pharmaceutical and personal care items, and processed foods (table 4). Its broad usefulness as a thickening and stabilizing agent makes xanthan gum one of the most attractive products of the over $2.5-billion hydrocolloid mar-

Table 3--Commercial gums produced in the United States, by type of source material

Microbial fermentation	Marine plants	Terrestrial plants	Cellulose sources
Dextran	Agar	Guar gum	Carboxymethyl cellulose
Gellan gum	Alginates	Gum arabic	Hydroxypropyl cellulose
Rhamsan gum	Carrageenan	Gum tragacanth	Hydroxyethyl cellulose
Welan gum	Furcellaran	Karaya gum	
Xanthan gum		Locust bean gum	
		Pectin	

Source: Irshad Ahmed, Booz, Allen & Hamilton, Inc., McLean, VA, July 1995.

Table 4--Xanthan gum's properties and end-product applications

Property	Industrial applications	Oil-field applications	Pharmaceutical and personal-care applications	Food applications
Emulsifying	Abrasives, agricultural products, pulp, and paper	Improves drilling-hole cleaning and penetration rates	Medicated syrups (e.g., dextromethorphan) and shampoos	Batters and beverages
Stabilizing	Ceramics	--	Liquid soaps and toothpastes	Pie fillings, dairy products, frozen foods, sauces, and gravies
Thickening	Cleaners, polishes, paints, and textile inks	Debris suspension	Shampoos and liquid soaps	Batters and sauces
Gelling	Coatings and adhesives	--	Toothpastes	Confectionery
Film forming	--	--	--	Barrier coatings

-- = Not applicable.
Source: Irshad Ahmed, Booz, Allen & Hamilton Inc., McLean, VA, July 1995.

ket. The outlook for xanthan gum is bright in both food and industrial applications. However, industrial uses are increasing at a faster rate than food uses. Between 1983 and 1993, gums derived from microbial fermentation of starch have enjoyed strong market success, with average growth rates of 9 percent annually.

List prices for both food-grade and industrial-grade xanthan gum were stable between 1989 and 1992. Prices increased in 1993 for both categories by approximately 10 percent. Food-grade prices rose from $5.50 per pound to a current price of over $6.20 per pound. The price of xanthan for industrial applications varies considerably, depending upon the grade. On average, industrial-grade xanthan sells for $5 per pound, while refined grades for special applications command over $8 per pound.

Xanthan Gum Has Many Industrial Uses

Although food and beverages account for the largest end-use category, xanthan gum also is used in a wide variety of industrial applications (figure 1). Industrial xanthan gum products are manufactured to meet formulation criteria, such as long-term suspension and emulsion stability in alkaline, acid, and salt solutions; temperature resistance; and pseudoplasticity. In addition, a range of differentiated xanthan gum products are designed to meet specific applications requirements. These include a transparent grade to improve solution clarity and a dispersible grade for low-shear mixing conditions. Examples of xanthan gum's many industrial uses include:

Agricultural products. Xanthan gum is an excellent suspension agent for pesticides, fertilizers, and liquid-feed supplements. It helps control spray drift and cling, which increase the contact time between the pesticide and the crop.

Ceramics. Xanthan gum is used as a suspending agent in electrode coatings, as well as in glazes and binding agents for tiles and sanitary ware. It also prevents sagging and pinholing in these products.

Cleaners. Xanthan gum's flow properties and broad pH stability make it the thickener of choice in products such as highly alkaline drain, tile, and grout cleaners; acidic solutions for removing rust and metal oxide; graffiti removers; aerosol oven cleaners; toilet-bowl cleaners; and metal-cleaning compounds. Xanthan gum provides cling to vertical surfaces, as well as easy removal.

Coatings. The pseudoplastic properties of xanthan gum provide excellent texturing in ceiling-tile coatings and paints with a high-solids content, ensuring in-can stability, ease of application to the wall, and retention of the textured finish. Xanthan gum thickens latex paints and coatings, and uniformly suspends zinc, copper, and other metal additives in corrosion coatings.

Oil-drilling aids and fluids. Xanthan gum is used as a thickener in conventional drilling aids that flush pieces of rock away from the drill bit. Xanthan-formulated systems provide optimum hydraulic efficiency of drilling fluids. It reduces pressure losses within the drill string, allowing maximum hydraulic power to be delivered to the bit. As a result, penetration rates can be increased. Historically, secondary and tertiary oil-well drilling have been significant users of xanthan gum.

Paper. Xanthan gum is used as a suspension aid or stabilizer in the manufacture of paper and paperboard, particularly when intended for contact with food.

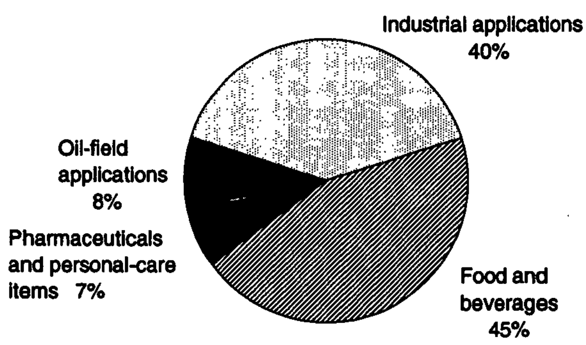
Personal care applications. Xanthan gum improves the flow properties of shampoos and liquid soaps and promotes a stable, rich, and creamy lather. It is an excellent binder for all toothpastes, including gel and pumpable types. Ribbon quality and ease of extrusion are improved as well.

Pharmaceutical applications. Xanthan gum stabilizes suspensions of a variety of insoluble materials such as barium sulfate (for x-ray diagnoses), complexed dextromethorphan (for cough preparations), and thiabendazole. It is playing an increasingly important role in controlled-release applications, where disintegration of the tablet is the primary mechanism of release.

Polishes. Xanthan gum suspends solids in leather and silver polishes, provides lubricity to lotions and heavy creams, and stabilizes polish emulsions.

Textiles. Xanthan gum forms temperature-stable foams for printing and finishing, and acts as a flow modifier for dyeing heavy fabrics. Its flow properties and temperature stability make it ideal for carpet jet printing, where it ensures sharp print definition, absence of frosting, and trouble-free operation. [Irshad Ahmed, (703) 917-2060; Charles Plummer, (202) 219-0717; Allen Baker, (202) 219-0360; and John McClelland, (202) 501-6631]

Figure 1
End Uses of Xanthan Gum in 1994[1/]



1/ U.S. capacity in 1994 for xanthan gum is estimated at 57 million pounds.
Source: Irshad Ahmed, Booz, Allen & Hamilton, Inc., Mclean, VA, July 1995.