Ethanol Production Down, But Packaging And Adhesive Uses Are Up

Industrial uses of corn are expected to total 622 million bushels in 1995/96, down 18 percent from the previous year, mainly due to lower use for ethanol. Ethanol producers are in the midst of a financial squeeze, resulting from a combination of rapidly rising corn prices, only moderate gains in coproduct prices, and relatively stable ethanol prices. Biodegradable loose-fill packaging materials are being manufactured from corn and wheat starch. Almost one-third of all adhesives produced and used in the United States are of natural or renewable origin.

Industrial uses of corn are expected to total 622 million bushels in 1995/96 (September/August), down 18 percent from the previous year (table 3). Corn use for the production of industrial starch, fuel, and manufacturing alcohol will all be lower than in 1994/95, primarily due to this year's high corn prices. In 1996/97, with a larger corn crop, industrial uses of corn are forecast to rise 6 percent from this year's depressed levels to 661 million bushels.

Corn used for ethanol production in 1995/96 is estimated at 395 million bushels, down 26 percent from last year. Higher corn prices have affected fuel ethanol producers, especially dry-mill operations. With corn prices expected to stay strong and ethanol prices held down because of competitive pressures, as of August 1996, producers are expected to keep production low until new-crop corn is available. In 1996/97, ethanol production is likely to partially rebound and use 425 million bushels of corn, which is still below the 1994/95 peak of 533 million bushels.

Corn used to make starch in the first three quarters of 1995/96 declined 4 percent from a year earlier. Starch prices have been strong and may have encouraged some switching to other feedstocks to reduce use. High reported prices suggest producers have passed along the higher costs of corn. Based on elevator bid prices and values of wet-mill byproducts, the net cost of corn for starch has increased sharply during 1996. In May 1996, net corn costs were 9.64 cents per pound, up from 1995's average of 4.34 cents. Use of corn for starch may be up in June to August from a year ago, leaving use for all of 1995/96 down 3 percent from the 226 million bushels used in 1994/95.

In 1995/96, corn used for denatured manufacturing and industrial alcohol is expected to total 40 million bushels, nearly the same as the 36 million used in 1994/95. Current data are only available from the Bureau of Alcohol, Tobacco, and Firearms (ATF) through December 1995 and showed a doubling in corn use for the September through November period. With high corn prices, use will likely slow, as has occurred in prior high-cost periods. In the last half of the marketing year, use is expected to drop significantly below a year earlier. If corn prices decline as expected in 1996/97, corn use in manufacturing alcohol will likely hold its own against other feedstocks and chemical processes for making ethyl alcohol (ethanol).

Revisions Made in the Data on Food And Industrial Uses

Data on food and industrial uses of corn were revised this month following a review of various use categories. These estimates were changed to reflect the numbers reported in the final 1992 Census of Manufacturers. Changes in beverage and manufacturing alcohol also relied heavily on ATF data.

Estimates of corn used to make starch were lowered slightly to reflect Census Bureau numbers. For beverage and manufacturing alcohol, the new series is much more variable and around 20 million bushels larger than previous estimates for recent years. Although licensed by ATF

Table 3--Industrial and food uses of corn, 1990/91-1996/97

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: Manufacturing	Alcohol: Fuel	Total industrial use 4/
	Million bushels									
1990/91	379	200	114	33	186	219	54	81	349	616
1991/92	392	210	116	34	191	225	58	103	398	692
1992/93	415	214	117	33	185	218	55	80	426	691
1993/94	444	223	118	33	190	223	51	55	458	703
1994/95	465	231	118	34	192	226	64	36	533	761
1995/96 5/	485	235	118	33	187	220	62	40	395	622
1996/97 6/	505	245	120	35	196	230	70	40	425	661

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 manufacturing and fuel alcohol. 5/ Preliminary. 6/ Forecast.

as beverage plants, some ethanol plants also produce fuel or manufacturing alcohol. This necessitated a revision in the data. While the Census of Manufacturers previously published data on beverage industries, the 1992 Census broke out ethyl alcohol production by organic chemical manufactures, including fuel alcohol from wet and dry milling and pure (natural) alcohol. The Census data are within 1 percent of the ATF data, assuming denatured alcohol is 95 percent alcohol and pure alcohol in proof gallons is actually 185 proof. Because alcohol data are reported in proof gallons, tax gallons, and wine gallons, aligning the two sets of data is not always easy. ATF has distinct legal definitions of proof and tax gallons, but in practice a proof gallon and a tax gallon are about the same, both 100 proof, 50 percent ethyl alcohol.

While the ATF and Census data on alcohol production agree, Census numbers on grains used in alcohol production are not available for the organic chemical category to compare with ATF numbers. The ATF data give production of various types of alcohol and total grains used. For alcohol and spirits 190 proof and over, there is a breakout of production by kind of materials used, such as grain, fruit, or ethylene gas. Some simplifying assumptions were used to calculate use. Estimated corn used for beverage and manufacturing alcohol was calculated by taking grain needed and multiplying it by corn's share of total grains as reported by ATF. Grain needed was the sum of estimated grain spirits over 190 proof, less net withdrawals for fuel, grain spirits less than 190 proof, and whiskey production converted to grain at 5.1 proof gallons per 56 pounds of grain. Finally, corn used to produce beer, as reported by ATF, continues to be included in the beverage category.

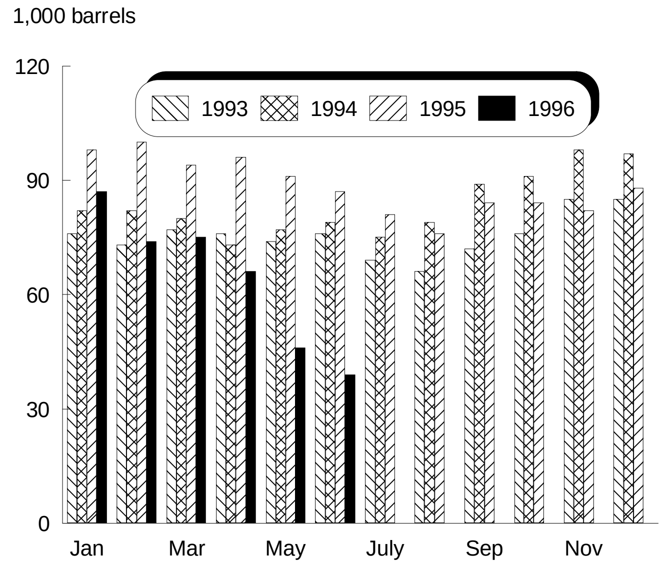
Prices Squeeze Ethanol Producers

Ethanol producers are in the midst of a financial squeeze, resulting from rapidly rising corn prices, only moderate gains in coproduct prices, and relatively stable ethanol prices. The result has been a 30-percent reduction in ethanol production from a year ago, and production is expected to continue falling over the next several months.

Ethanol production is seasonal, picking up in September and October in anticipation of the oxygenated-fuel season that runs from November through February in about 30 cities. Production begins to decline in March and April, as wet millers shift to making sweeteners used in beverages that are in higher demand during the summer (figure 1). Producers also tend to upgrade and perform maintenance on their facilities during the summer, when seasonal demand for ethanol is lower.

Several factors have affected the profitability of ethanol producers in the first 6 months of 1996. First, corn prices have been historically high, exceeding $5 per bushel in Chicago spot markets at one point. Second, while soybean prices have also increased, they have not risen as much as corn prices. Thus, corn prices are higher relative to soybean prices on an historical basis. Prices of coproduct feeds from ethanol production are closely linked to soybean meal prices and, therefore, have not increased as much as corn prices have. Third, until the sharp rise in gasoline prices in February and March, gasoline prices re-

Figure 1
Monthly Ethanol Production



mained steady. Ethanol prices are strongly influenced by gasoline prices, because a large proportion of the ethanol produced in the Corn Belt is blended into regular gasoline as an octane enhancer and fuel extender. Stable gasoline prices have tended to keep ethanol prices from climbing.

The result of these market forces has been an increase in the net cost of corn per gallon of ethanol produced from about 50 cents a year ago to more than $1 now, based on cash prices for corn of $4.80 to $5 per bushel. (Net corn costs include the cost of corn per bushel minus revenue for coproduct feed.) With these costs doubling, producers needed similar increases in ethanol prices to maintain profit margins. Instead, ethanol prices were held in the $1.10 to $1.20 range through April 1996. This combination of rising net corn costs and flat ethanol prices created financial conditions that could not sustain ethanol production in the long run. Not until the effects of the February and March gasoline price spikes had worked their way into the market were ethanol producers able to raise prices and ease tight margins.

Because some ethanol producers engage in hedging and other strategies to limit price risk, they probably have been affected less severely than an analysis using cash prices would indicate. However, some producers found their most profitable course of action was selling their futures positions that had nearly doubled in value and temporarily suspending production, instead of buying corn to produce ethanol. This action on the part of several firms will exacerbate the seasonal reduction in ethanol production and could result in the lowest monthly ethanol production in 10 years.

The outlook for the next 6 months is for lower production and poor margins for producers. As production drops, prices may get a boost because a greater share of ethanol demand will be as an oxygenate in reformulated gasoline markets instead of a fuel extender in conventional gasoline blending. If profit margins for ethanol producers remain tight, ethanol blending in the conventional gasoline octane/extender market could come to a virtual halt. However, mandated markets for oxygenated fuel and reformulated gasoline will continue to provide a market for ethanol, which remains competitive with other oxygenates in many mandated market areas.

States are continuing their financial support for ethanol producers. While some ethanol plants have been temporarily closed, others in Minnesota have just begun production. These farmer-owned cooperatives are backed by the commitments of their members and a 20-cents-per-gallon State payment.

A good corn crop this year is likely to bring ethanol prices down. August USDA estimates for the 1996/97 marketing year of $3.15 to $3.55 per bushel might be high enough to keep some plants from returning to full production at current gasoline prices. However, the real key to producer profitability is net corn costs per gallon. A more normal alignment between corn and soybean prices should help net corn costs decline after the harvest. If they do, many ethanol producers will begin producing at much higher utilization rates.

Starch-Based Loose Fill Used For Product Packaging

Protective packing materials are used to cushion, protect, and stabilize articles in boxes, cartons, and other containers for shipping and storage. Manufacturers, mail-order firms, and other industries are big users of protective packing materials. The most common materials used to make protective packing are expanded polystyrene (EPS), shredded newsprint, cardboard, excelsior (fine wood shavings), popcorn, and starch. EPS-based, loose-fill foams have enjoyed a steady growth in packaging applications over the last two decades, but are now a target in the solid waste disposal debate because of their nondegradability. Consumers are demanding and legislators are mandating the use of environmentally benign packing materials.

To address the public's concern regarding disposability, biodegradable loose-fill packaging products are being developed and manufactured from corn and wheat starch, and are a growing portion of the loose-fill packaging market. In most cases, starch-based, loose-fill products are 100-percent biodegradable, with the exception of products that contain nondegradable additives. Most starch-based, loose-fill products can be dissolved in water. Smaller quantities could be disposed of in flowerbeds and gardens or simply flushed down the drain to a municipal wastewater treatment facility. Large quantities, which could have detrimental effects on a wastewater treatment facility simply due to the sheer volume of product, would need to be composted; for example, with municipal lawn and garden waste. A 1993 comparative study by the Minnesota Office of Waste Management claims that starch-based loose fill is a reasonable alternative to EPS-based loose fill if composting infrastructures exist and EPS foam recycling is impractical.

Satisfactory performance, good properties, and low cost have enabled EPS-based loose fill to grow over the last 20 years into a successful 90-million-pound-per-year packaging product (*1*). EPS market growth was particularly strong in the 1980's, at more than 20 percent per year. However, many external-market and economic forces, such as the Persian Gulf War, recession, and the switch to alternative packing materials and methods, slowed this growth rate to less than 2 percent during the 1990's. In addition to using alternative loose-fill products, manufacturers have redesigned packages and packing products to use less material. Suppliers conservatively estimate the starch loose-fill market, as of June 1996, at approximately 15 to 20 percent of the EPS loose-fill market. This means that packagers are using 13.5 to 18.0 million pounds of starch loose fill in addition to the 90 million pounds of EPS loose fill.

For starch-based products to have captured some of the loose-fill market means they have had to compete with EPS's performance characteristics. For example, mechanical integrity is important because the function of loose fill is to adequately protect shipped or stored goods. Compression and resiliency tests, conducted by USDA's National Center for Agricultural Utilization Research (NCAUR) in Peoria, Illinois, demonstrated that both starch-based and EPS-based loose fill have similar mechanical integrity. Starch loose fill is more sensitive to changes in relative humidity and temperature than EPS loose fill, but the higher amount of absorbed moisture does not compromise its mechanical properties. A beneficial property that starch loose fill has, which EPS does not, is the ability to resist static cling.

Starch-Based Loose Fill Produced by Several Companies

In general, starch-based packaging products are manufactured using extrusion technology, a process in which the starch is cooked, worked into a plastic-like dough, forced through a die, expanded by loss of moisture and a decrease in pressure, and cooled into a rigid structure with a porous texture. Modified or unmodified starches may be used, depending on the producer and the product. In addition, manufacturers add proprietary additives and other ingredients to develop specific products. Technology typical of the plastics industry molds the starch-based material into final shapes, such as loose fill, sheets, and other forms.

Several companies actively develop, produce, and/or market starch-based loose fill. The products and producing companies are:

- CLEAN GREEN by Clean Green Packing Company of Minneapolis, Minnesota, a wholly owned subsidiary of Environmental Technologies USA, Inc.;
- ENVIROFIL by EnPac, a DuPont/ConAgra Company, of Wilmington, Delaware;
- ECO-FOAM by American Excelsior Company of Arlington, Texas;
- FLO-PAK BIO 8 by Free-Flow Packaging Corporation of Redwood City, California;
- RENATURE by Storopack, Inc., of Cincinnati, Ohio; and

- STAR-KORE by Star-Kore Industries of Memphis, Tennessee, formerly Unistar Industries, Ltd.

Some of these companies produce or distribute other non-starch-based packaging products as well. For example, Free-Flow Packaging manufactures 100-percent, recycled EPS loose fill and American Excelsior manufactures virgin EPS loose fill.

Warner Lambert of Morris Plains, New Jersey, no longer manufactures starch-based resin for loose fill, but licenses the technology to EnPac. National Starch of Bridgewater, New Jersey, licenses its high-amylose starch technology exclusively to American Excelsior Company. Norel Company of Little Ferry, New Jersey, and Storopack, Inc., manufacture and distribute starch loose fill for EnPac under the ENVIROFIL trademark. EnPac sublicenses the Warner-Lambert technology to other companies including Clean Green Packing and Free-Flow Packaging Corporation.

Many companies have recently introduced new-product applications. EnPac has introduced ENVIROMOLD, a wheat-starch, loose-fill material that is dampened with water so the foamed pieces can stick together to form a continuous protective cushion. This product is targeting packagers that use foamed-in polyurethane (liquid chemicals that are combined to form a resilient foam structure) and polyethylene. This market is estimated at about 300 million cubic feet (*2*). American Excelsior manufactures starch-based extruded shapes and rigid-sheet products for a variety of applications, including end caps, pouches, rolls, and die-cut forms. Other applications recently announced by American Excelsior at the International Agricultural Summit in Kansas City, Missouri, include toys such as foamed logs and blocks, confetti, furniture guards, and potty training aids. Star-Kore Industries has developed flexible- and rigid-sheet products from modified-starch technology.

Starch Loose-Fill Prices Dependent On Corn Prices

Though comparable in function to EPS loose fill, starch-based loose fill is still about 30 percent more expensive. Excluding shipping costs, the average price of commercial starch-based loose fill is 54 cents per cubic foot, while EPS loose-fill prices average about 41 cents per cubic foot from the manufacturer. In addition to being higher priced than EPS loose fill, starch loose fill also has a higher bulk density (weight per cubic foot) than EPS loose fill. This means that an equal volume of starch loose fill in a package will weigh more than an equivalent volume of EPS loose fill. Thus, end users of starch loose fill are hit twice, first by higher purchase prices and then by higher shipping costs due to more weight. However, over the past year, manufacturers of starch-based loose fill have been able to narrow the cost differential between starch and EPS-based foam products due to improvements in manufacturing methods.

Because commercial starch-based loose fill generally contains more than 90 percent starch, the price of a specific loose-fill product is highly dependent on starch prices. (The remaining 10 percent or less consists of additives that facilitate production and improve performance.) Because cornstarch is the cheapest, most widely used industrial starch in the United States, most starch-based loose fill likely is manufactured from cornstarch, although some products may use wheat and/or potato starch.

Good mechanical performance and biodegradability have enabled starch-based loose fill to successfully compete with EPS-based products. Industry sources anticipate continued market growth for starch-based products, as research efforts continue to reduce cost, improve performance, and develop new applications for loose fill and other starch-based foam products. This research is being conducted by starch producers, packaging manufacturers, and USDA laboratories such as NCAUR.

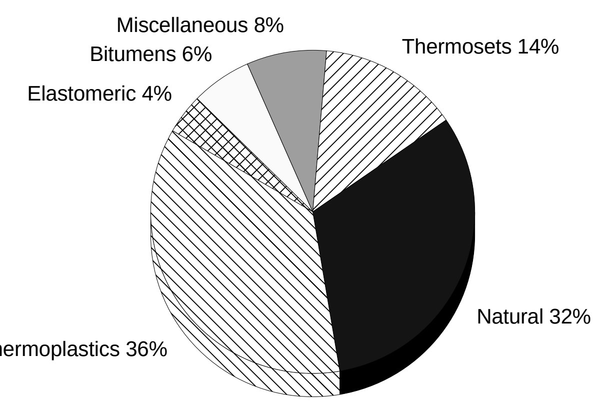
Natural Adhesives Respond to Changing Market Influences

Adhesives are used in a wide variety of applications. Over 1,000 different types of natural and synthetic adhesives are used in the manufacture of textiles, plastics, wood products, ceramics, electronics, glass items, cosmetics, pharmaceuticals, and metals.

Adhesives are one of the leading industrial-product categories that use a large amount of natural raw materials. Almost one-third of all adhesives produced and used in the United States is of natural or renewable origin (figure 2). Natural adhesives are derived from a wide variety of raw materials, including agricultural, animal, and forestry components. Leading feedstocks are corn and wheat starches, vegetable oils, rubber, animal-based proteins, gelatin, lignin, and mussels. Specialty natural adhesives are derived from highly refined starches. Synthetic adhesives are primarily derived from petrochemicals and include thermoplastics, thermosets, bitumens, and elastomeric adhesives. The thermoplastics sector is the largest sector by volume, while the elastomerics sector is highest in value of the synthetic adhesives.

The 12.8-billion-pound U.S. adhesives market was valued at $6.5 billion in 1995. In the last decade, overall adhesive

Figure 2
Adhesives Production by Major Class in 1995 1/



1/ In 1995, the estimated production and use of natural and synthetic adhesives was 12.8 billion pounds.
Source: Irshad Ahmed, Booz-Allen and Hamilton, Inc., McLean, Virginia, July 1996.

growth averaged 2 percent per year, by volume. The recession of 1990 dampened adhesive use, but the demand for natural adhesives has been growing steadily since late 1992. In 1995, the overall demand for adhesives grew 3.1 percent, and is projected to grow at 3.3 percent annually through 2000. Natural adhesives are expected to exceed this average and grow over 3.8 percent annually through 2000, higher than the rates projected for bitumens and elastomerics. Certain synthetic subcategories, catering to niche markets, may also see above average growth.

During late 1980's, certain synthetic subcategories saw growth several times the average, notably hot melt, hot melt pressure-sensitive, acrylic pressure-sensitive, polyvinyl acetate, cyanoacrylate, anaerobic, and radiation-curable adhesives. However, their growth rates have suffered in the 1990's. Environmental regulations restricting the use of certain synthetic adhesives, product-quality improvements, green-product reformulation, and identification of new applications, combined with overall growth in the U.S. economy in recent years, are some of the key factors responsible for the recent and projected growth for natural adhesives. This year's high corn prices, however, have dampened the demand for many starch-based adhesives. High-volume, low-value grades may see no or slight market growth until prices become competitive with other substitutes. High-value, refined, starch-based naturals may not be affected by higher corn prices.

Certain important categories of synthetics, particularly thermoplastics, are expected to shrink over the next 5 years, while some specific naturals, especially protein-based adhesives, will probably grow at twice the average. Part of this change is based on the industry's response to environmental regulations. For example, because of Clean Air Act regulations limiting emissions of volatile organic compounds, solvent-based adhesives are being displaced with refined naturals and other specialized synthetic elastomerics in such fields as pressure sensitive, construction, and automotive applications.

Robotics are an increasingly popular means of applying adhesives in assembly line production. These automated systems exhibit a technical preference for natural adhesives due to easy equipment cleaning and flow characteristics. Higher engineered applications, such as the replacement of mechanical fasteners, will also contribute to the overall growth of adhesive markets. In foundry applications, demand for natural adhesives (binders) is expected to grow at 2.8 percent annually to 134 million pounds in 1997.

Environmental concerns have spurred the use of natural adhesives that have better biodegradability profiles than their synthetic counterparts. The success of starch-based adhesives in the packaging industry is directly associated with the solid-waste disposal problems faced by petroleum-based films. Recycling operations have spurred the use of starch-based adhesives in paper cartons, bottle labels, stationery, and some interior plywood fabrications.

Starch-based adhesives are the largest segment of the natural-adhesives market. In 1995, approximately 60 percent of the 4 billion pounds of natural adhesives produced and consumed in the United States were derived from starch, primarily corn and wheat starch. These 2.4 billion pounds of starch required roughly 73 million bushels of corn equivalent. National Starch & Chemical Company is one of the leading starch-based adhesives companies in the United States. It has led the way in developing and introducing a number of starch-based adhesives, including the Kor-Lok and Duro-Lok lines of adhesives. It is estimated that there are over 100 different formulations of starch-based adhesives currently on the market. Starch-based adhesives are less expensive then other natural and synthetic adhesives and range in price between 50 cents and $2.50 per pound. Almost all natural adhesives are priced under $8.00 per pound.

Another type of natural adhesive is animal glue. It is produced by the hydrolysis of the protein collagen from the skins, hides, and bones gathered from slaughterhouses. The glue's diverse applications in paper, glass, abrasives, matches, and metal refining maintain its commercial position in the face of highly competitive synthetic materials. Besides being used directly as an adhesive, animal glue is also an additive in a wide range of adhesive and flocculating formulations.

New Research and Development May Lead to Future Growth

Significant research and development have been underway since the early 1980's to design and develop natural adhesives with specific functional properties. For example, at least three USDA laboratories are engaged in developing natural adhesives with better water resistance properties. Some of the latest natural adhesives under investigation are based on protein, fiber, and oil from corn, wheat, soybeans, and mussels.

Although soy proteins have been used in paints and coatings for many years for their coagulation properties, only recently have commercially viable adhesives with superior application properties been developed. Soy-based wood adhesives are the first alternative adhesives likely to capture significant market share. Mussel protein-based adhesives are already reaching commercial significance, with great potential in medical and industrial applications.

While new categories of natural adhesives are being developed, existing products are being improved. The outlook for natural adhesives in most application areas is bright through the turn of the century as environmental laws continue to regulate the use of synthetics. Efforts by private industry and USDA laboratories promise to further expand the number of natural adhesives and their market share. [*Industrial uses of corn*: Allen Baker, ERS, (202) 219-0360, albaker@econ.ag.gov. *Ethanol*: John McClelland, ERS/OENU, (202) 501-6631, jmcclell@econ.ag.gov. *Starch-based loose fill*: Paul Tatarka, ARS, (309) 681-6428, tatarkpd@ncaur1.ncaur.gov, and Charles Plummer, ERS, (202) 219-0717, cplummer@econ.ag.gov. *Adhesives*: Irshad Ahmed, Booz-Allen & Hamilton, (703) 917-2060, 71332.3160@compuserve.com.]

1. *Modern Plastics,* Vol. 73, No. 1, January 1996.

2. *Plastics News*, Vol. 8, March 25, 1996.