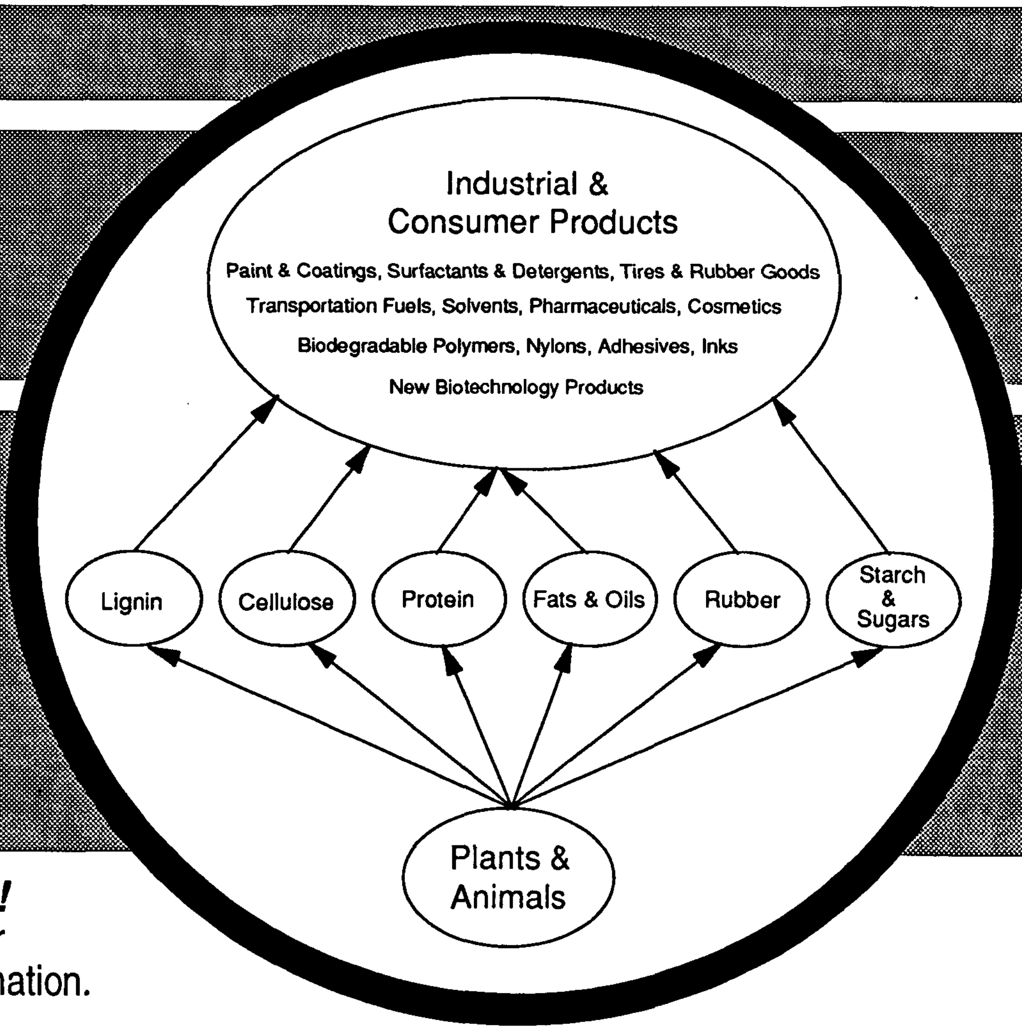
United States
Department of
Agriculture

Economic
Research
Service

IUS-1
June 1993

Industrial Uses Of Agricultural Materials

Situation and Outlook Report



Premier Issue!
See back cover for subscription information.

SUGGESTIONS FOR FUTURE ISSUES

Your responses to the following questions will help make future issues more effective.

1. Please circle your affiliation:

Agribusiness Other business (type ____________________) Academic Government

2. Please rate the usefulness of each section of the report by circling the appropriate number.

	Very Useful			Not Useful		Not Reviewed
a. Industrial Uses: Some Science, Economics, and History	5	4	3	2	1	0
b. Current Macro and Industrial Outlook	5	4	3	2	1	0
c. Starches and Sugars	5	4	3	2	1	0
d. Fats and Oils	5	4	3	2	1	0
e. Natural Fibers	5	4	3	2	1	0
f. Animal Products	5	4	3	2	1	0
g. Specialty Plant Products	5	4	3	2	1	0
Special Articles						
h. The Effects of Expanding Biodegradable Polymer Production on the Farm Sector	5	4	3	2	1	0
i. Ethanol's Evolving Role in the U.S. Automobile Fuel Market	5	4	3	2	1	0
j. Back Tables	5	4	3	2	1	0

3. Which topics would you like to see more of in upcoming Reports? Less?

4. What specific suggestions do you have for making any of the sections of the overall report more helpful to you?

Please clip or copy and mail this to:

Gregory Gajewski
Economic Research Service-USDA
1301 New York Ave. NW, Room 836
Washington, DC 20005-4788

PRINTED WITH SOY INK™

Industrial Uses of Agricultural Materials: Situation and Outlook. Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture, June 1993, IUS-1.

Contents

Coordinators

Lewrene Glaser
Gregory Gajewski
Voice (202) 219-0085, Fax (202) 219-0042

Contributors

Mark Dungan, New Uses Council
Gregory Gajewski
Douglas Beach
Irshad Ahmed, Inst. for Local Self-Reliance
Ralph Monaco
Jennifer Beattie
David Torgerson
Donald Van Dyne, Univ. of Missouri
Lewrene Glaser
David Pace
Maryanne Normile
Ronald Babula
Michael Dicks, Univ. of Oklahoma
Jun Zhang, Univ. of Oklahoma
Chuck Hibbard, Univ. of Oklahoma
Thomas Marcin, USDA, Forest Service
William Moore
Michael Price
Hyunok Lee, USDA, Office of Energy

Statistical Support
William Moore, (202) 219-0883

Graphics and Table Design and Layout
Wynnice P. Napper, (202) 219-0884

Word Processing and Design and Layout
Diana L. Claytor, (202) 219-0085

Approved by the World Agricultural Outlook Board. Summary released June 28, 1993. The next summary of *Industrial Uses of Agricultural Materials* is scheduled for release on December 15, 1993. Summaries and text may be accessed electronically through the USDA CID System; for details, call (202) 720-5505. See back cover for subscription information.

Acknowledgements

This report was made possible only through the active support of many people and organizations. The June and December 1993 issues are primarily funded by contributions from the Department of Energy's Office of Industrial Technologies, USDA's Alternative Agricultural Research and Commercialization Center, and USDA's Cooperative State Research Service, Office of Agricultural Materials. Economists from USDA's Forest Service and Office of Energy have written sections of the report. Harry Parker, Professor of Chemical Engineering at Texas Tech University, and Donald Van Dyne, Professor of Economics at the University of Missouri, both made strong contributions to this report. We are also indebted to Irshad Ahmed, Senior Research Engineer of Biochemical Technologies of the Institute for Local Self-Reliance and coauthor of *The Carbohydrate Economy*, who helped us substantially in preparing this issue.

Summary

U.S. Industrial Uses of Agricultural Materials To Continue Rising

Recent scientific advances are reducing the costs of producing and processing renewable resources into industrial products. These include advances that make agricultural production techniques more environmentally benign. And the advances in process engineering--especially in destructive distillation, steam explosion, ultracentrifuges, and membranes--are making agriculturally based products more competitive. The scientific gains, along with Federal and State environmental regulations, and growing consumer preference for "green" products, are increasing the industrial demand for agricultural materials.

Some analysts expect that over the next 3 years the amount of plant matter used in industrial materials, excluding paper and natural rubber, could increase by over 5 million tons, almost double that of 1990.

Given the national economic outlook, housing, textiles, and metal fabricating--key users of agricultural materials--are likely to show above-average growth, while printing and publishing--also key users--probably will show more sluggish growth. Petroleum prices are forecast to rise slightly.

Over the next 4 years, production increases in ethanol, adhesives, and biopolymers will pull up the industrial uses of starches and sugars. Cornstarch is now relatively less expensive than starch from other sources, and has captured most of the market. Translating the demand for starch into corn-equivalents, industrial uses of corn are expected to increase about 140 million bushels to 795 million bushels by 1995/96--up roughly 8 percent per year.

Industrial rapeseed acreage is down, while crambe acreage has risen 150 percent from last year. Derivatives made from these oilseeds are used in slip agents for plastic films, lubricants, and automatic transmission fluids.

Jojoba prices are down, and growers and processors are working to find new uses for the oil. Animal- and plant-based oils are making inroads into surfactant markets. Plus soy ink use continues to grow.

Biodiesel, which can be made from almost any animal or plant fat or oil, is being commercially produced in Europe, and is being tested in the United States as a possible means of meeting Clean Air Act Amendments' emission standards. More testing is needed, but the results so far are favorable.

This year, over 4,300 acres of kenaf, a tropical fiber crop, are being commercially grown in the United States. Kenaf is used for packing materials, bond paper, horticultural mulches, potting mixes, seeding mats, animal litter and bedding, and oil absorbents. Potentially, it could move into newsprint and paperboard markets. Erosion-control products are promising to increase the demand for natural fibers.

According to industry estimates, U.S. beef byproducts are worth $3 billion a year, with most going for industrial uses. In 1992, almost 5.8 billion pounds of inedible tallow was produced, and half was exported. During 1990-92, U.S. production of inedible rendered products rose very slightly. Domestic use slipped over 12 percent while exports rose nearly 13 percent. That partly reflects a switch by U.S. consumers to liquid soap from bar soap.

New products that conserve forest resources are on the rise. Biopulping and other advances in making paper are more efficient and generate less chemical waste. New lumber composites, often made with recycled wood wastes, are reducing the demand for old-growth wood and offer improved performance and design characteristics.

Developing alternative sources of the drug taxol is limiting the long-term opportunities to commercially farm the Pacific yew tree, but there may be some opportunities for growing other species of yews. Some experts predict that in 3 years, taxol will be made from trees on commercially developed plantations, laboratory semisynthesis, cell tissue culture, and fungal metabolites.

Guayule, a desert shrub native to the southwestern United States, is a high-cost source of natural rubber. But a new market may open up for medical gloves, condoms, and other consumer items made from guayule-derived latex for people allergic to hevea-based natural latex products.

Using two probable growth scenarios for starch-based biodegradable polymer output to the year 2000, net farm income will increase slightly and total government deficiency payments will decrease slightly as a result. However, farm output will be largely unaffected. The analysis suggests that increased support for biodegradable polymer research, development, and commercialization would decrease government outlays and increase net farm income.

U.S. ethanol is now mostly made from corn. Future sources may include cellulosic materials, such as short-rotation woody and grass crops. Provisions of the 1990 Clean Air Act Amendments, aimed at controlling carbon monoxide and ozone, are opening up new markets for ethanol along with its main oxygenate competitor, MTBE. Ethanol's near-term demand growth as an oxygenate will depend on regulations expected to be finalized this fall. Over the long term, ethanol has the potential to be a cost-competitive feedstock for oxygenating ethers (ETBE), as well as an alternative fuel.

Introduction

When most people think of agriculture or farming they think of food. Few are aware that what farmers grow can also be used to produce a vast array of nonfood industrial and consumer products.

This lack of knowledge is undertandable. For the past several decades, nonrenewable industrial feedstocks have been considered cheaper than renewable feedstocks and were domestically plentiful. And periodically there have been concerns about whether agricultural resources were adequate to feed the world. During this time, agricultural research and development dollars were primarily spent to improve yields of traditional crops and to develop new food products. The promise of ever-growing international markets kept the focus of the farm sector and public policymakers on traditional products.

Times have changed. Worldwide, the fantastic growth in farm productivity over the last 20 years has caused inflation-adjusted U.S. farm income to decline, a trend that most forecasters see continuing over the next decade. Ever-increasing yields and production efficiencies are outstripping the demand for traditional farm products and reducing job opportunities in rural areas. International commodity markets, once considered easy pickings for U.S. farmers, grow more competitive each day. And it is anyone's guess what will happen to yields of traditional crops--such as corn, soybeans, and wheat--when new advances in biotechnology are brought to bear.

More and more questions are being asked about the true costs of nonrenewable resources. There is mounting evidence of the high environmental costs of recovering, transporting, and using nonrenewable resources. Shrinking U.S. oil production and the Nation's growing dependence on oil imports have added to the debate over the wisdom and cost of an industrial economy that relies so heavily on nonrenewable resources.

This is not to say that agriculturally based industrial products are without environmental costs. Much work remains to be done by government, business, and academia to more accurately measure and account for the full social costs of producing and selling all goods--whether from renewable or nonrenewable resources.

However, changes in the materials and biological sciences are reducing the costs of producing and processing renewable resources into industrial products. These include a number of advances that make agricultural production techniques more environmentally benign. And advances in process engineering--especially in destructive distillation (fast pyrolysis), steam explosion, ultracentrifuges, and membranes--are making agriculturally based products more competitive in the marketplace. The scientific gains, along with environmental regulations at the national and State levels, and growing consumer preference for "green" products are beginning to increase the volume of renewable agricultural resources used by industry.

Many experts believe that the industrial demand for agricultural materials will substantially increase over the next few years. A 1992 report by the Institute for Local Self-Reliance states that, "In the next 3 years, the amount of plant matter used in industrial materials, excluding paper and natural rubber, could increase by over 5 million tons ... almost double ... their 1990 level." The Institute has updated its analysis and the key results are in table 13.

Industrial uses provide U.S. farmers with one of the greatest potential market opportunities in history. Approximately 60 million acres of cropland were idled last year. U.S. farmers have the capacity to produce ample supplies of food and to supply industry with renewable raw materials. Expanding industrial demand for farm products can also help restore economic opportunity in rural communities.

This report is meant to help team up agriculture, industry, government, and academia to produce a new generation of plant- and animal-based industrial products that create jobs and economic activity in rural areas while helping to preserve our environment.

The authors of this report are eager to make it as useful as possible. Suggestions on how it can be made more useful will be enthusiastically received. After you have gone through the report, please fill out the evaluation on the inside front cover, copy it or clip it out, and mail it in.

Mark Dungan
Chief Executive Officer, New Uses Council

Gregory Gajewski
Leader, Aquaculture and Alternative Products Section
Economic Research Service, USDA

Industrial Uses: Some Science, Economics, and History

This new Situation and Outlook (S&O) Report covers industrial uses of agricultural materials. New uses and their impacts are highlighted. The report will supply economic intelligence to people involved in all aspects of taking agricultural materials from the farmgate through the industrial marketplace.

Current trends and new projects are covered, but the goal is to provide analysis and forecasts useful to people developing new industrial uses. In this first issue, we focus on defining the subject matter and markets involved, as well as assembling the beginnings of a useful database. We have also made some initial short-term forecasts and longer term assessments.

Each issue will begin with the national and international economic outlook, and how these broad economic forces are expected to affect key industrial sectors that buy or potentially buy agricultural materials. Next come Sections for six categories of agricultural materials: Starches and Sugars, Fats and Oils, Fibers, Animal Products, Forest Products, and Specialty Plant Products. Each of these Sections covers traditional uses, new uses currently in the marketplace, and uses on the horizon. Each has a flow chart that depicts how the materials move from the farm through various processing stages and intermediate products to end uses.

Special (i.e., feature) articles in this issue focus on the prospects, and likely effects, of increasing production of starch-based polymers, and the role of ethanol in the U.S. automobile fuel market. Future special articles will look at the implications of growing more industrial oilseeds; the prospects for, and likely economic effects of, biofuels; the role of government in developing industrial uses; methods for evaluating proposed projects for public funding; and case studies of developing and commercializing new uses.

Data published here come from many government agencies, private publications, trade associations, producer and processor groups, and industry sources. We asked for information from a wide range of individuals and organizations. Many thanks to those who took the time to send us their material. Please send us information you think we can use and we will try to include it in upcoming issues.

Chemical Building Blocks Are the Foundation

To explain how materials move from farms and forests to become industrial and nonfood consumer products, some chemistry background is necessary. Plant and animal materials are made up of different combinations of carbon, oxygen, hydrogen, and nitrogen. The categories used here are different groups of organic compounds suited to different applications. Plant and animal matter can be further grouped into several key components: carbohydrates, oils (almost all are triglycerides), proteins, and lignin (a component of woody plants).

Carbohydrates are made up of carbon, hydrogen, and oxygen and are the most plentiful organic compounds. Over three-fourths of the dry weight of all vegetation is carbohydrates. Carbohydrates are divided into sugars, starch, cellulose, and natural gums. Starch is similar to cellulose but can be more easily broken down into sugars through hydrolysis, and then into alcohol by the action of microbes in a process called fermentation. Cellulose is harder to break down with traditional fermentation processes because it will not dissolve in water and is partially crystalline. In addition, cellulose is often bound together with lignin, a resinous chemical that provides rigidity to wood, which also makes it difficult to ferment. Woody crops are often called lignocellulosics because lignin is a significant component, which has industrial applications.

Fats and oils come from a wide range of plants and animals. The only distinction between fats and oils is that fats are solid at room temperature, while oils are liquids. They can be grouped according to their various chemical properties: drying (linseed, tung), nondrying (castor, coconut, lard), edible (corn, soybean, canola, olive), and inedible (industrial rapeseed, castor, crambe, and inedible tallow). Essential oils are volatile liquids from plants used in perfumes and flavorings, and are not triglycerides.

Proteins are chains of amino acids connected by peptide linkages. They are in the cells of all living things, but are generally more concentrated in animal products. They come as enzymes, hemoglobin, hormones, viruses, genes, and nucleic acids, and are the basic components of connective tissues. Leather, silk, and wool are the protein materials most familiar to the public.

Enzymes are biological catalysts for numerous chemical reactions, and are of growing importance in industrial applications. Catalysts increase the rate of a chemical reaction without themselves being consumed by the reaction. Using enzymes as catalysts can cause complex chemical reactions at low temperatures and pressures. That is an advantage over most inorganic catalysts that require high temperatures and pressures to cause simple reactions.

Manufacturing industrial and nonfood consumer products from agricultural materials requires initial processing of the materials into their more basic components. This involves milling, rendering, crushing, chopping, refining, and so on. The results include the building blocks of our categories: starches and sugars, fibers, fats and oils, various protein meals, and other higher value compounds. These are then put through different chemical, biochemical, or thermochemical processes. Outputs are second-generation products including polymers, fatty alcohols, gelatin, fiber pulps, and other intermediate chemicals. These go through additional conversion and manufacturing stages to become the products used by industry and consumers.

Fossil fuels (petroleum, coal, natural gas, and lignite) go through similar stages from raw material to end product. Initial processing of petroleum involves desalting and dewatering. Petroleum then flows into distillation and different "cracking" processes where heat and metal catalysts are applied to separate different grades of fuels, oils, and residual tars. Many of these second-generation products then go through further processing to be turned into plastics and specialty chemicals before they are sold to industry and consumers. Coal has to go through even more extensive processing stages to be converted into coke, coal tars, and other products.

Natural gas is processed by first removing nonhydrocarbon gasses, and then it is distilled into processed natural gas--methane, ethane, propane and others--for fuel and chemical use. Natural gas also supplies ammonia, methanol, and other compounds. Ethylene, a widely used petrochemical feedstock, is made by cracking ethane and propane. Ethylene, benzene, and other refined petrochemicals must go through further processing to become industrial and consumer products.

Hydrocarbons are exclusively compounds of hydrogen and carbon. They are primarily from petroleum, coal tar, and some plants. Plants containing hydrocarbons include hevea rubber and guayule, which are covered in the Specialty Plant Products Section. The distinction between hydrocarbons and carbohydrates is that carbohydrates contain oxygen. Because of the oxygen, plant-matter feedstocks are typically more bulky and require less energy to break down into refined products. In addition, they generally result in fewer chemical byproducts that are harmful to the environment. However, carbohydrates are mechanically more difficult to process on a large scale than hydrocarbon liquids and gasses.

Why Industrial Products From Agricultural Materials?

Industrial uses of farm products are making a comeback because public concern about pollution and the environment has intensified and new, less costly technologies for processing agricultural materials have become available. In addition, farmers need more market opportunities beyond traditional food, feed, and fiber products. Partly because of the environmental and social implications, a unique coalition of people from industry, government, the research community, environmental interest groups, and farmers' associations are working together to increase the use of farm and forest materials by industry.

Early in the industrial revolution, virtually all industrial inputs were based on plant and animal products. Vegetable oils were used to make paints, varnishes, linoleum, and soaps. In the 1840's, mechanical processes for pulping wood were developed, and with new chemical processes beginning in the 1850's, the modern paper industry was born. Wood was also used to make charcoal for smelting iron. Methanol, a byproduct, was used as an industrial solvent and later to produce the first generation of plastics. And grain alcohol (ethanol) was a key industrial solvent and fuel prior to an 1862 tax on both beverage- and industrial-grade alcohol.

Around the turn of the century--when environmental pollution was not a major public concern--new technologies began making less expensive and high-quality products available from nonrenewable fossil fuels. By the mid-1920's and 1930's, coal and petroleum and their derivatives were squeezing out many agricultural materials, and much of the Nation's research funding focused on developing products from fossil fuels. The Institute for Local Self-Reliance estimates that plant-based materials still accounted for about 35 percent of industrial inputs in 1925, but by 1989 that share had dropped to less than 16 percent, mostly for producing paper.

Plastics are a case in point. In the last half of the 19th century, several plastics derived from plant products were developed, such as celluloid. Commercial successes came in the early 1900's when moldable plastics from plants became useful to manufacturers of cars and other consumer goods. But petroleum-based plastics, led by the invention of vinyl chloride in 1913, outperformed plant-based polymers in quality and price. By the end of World War II, petroleum ruled the plastics market.

What Is Government's Role?

Why is government helping to develop new uses from plant and animal products? Because market incentives for private research and development of new industrial uses are often limited, resulting in underinvestment. The private sector underinvests because:

- Firms cannot capture all the profits from their research,
- The environmental costs of competing products are not reflected in their prices,
- Farm price- and income-support programs dilute producers' incentive for demand-creating research, and
- Firms may value near-term payoffs more highly than does society.

Looking at each of these in turn:

Research appropriability becomes an issue when research and development lead to knowledge with wide-ranging applications, and result in products that benefit society more than individual businesses. Goods with such properties cannot be as profitably merchandised, even though the gains to society may be significant. Firms cannot capture all the profits from goods with collective properties. Private goods, on the other hand, allow the owners of the associated property rights or patents to collect all the profits.

Some analysts argue that small producers serving a single market are less likely to undertake wide-ranging research and development projects than large firms that are vertically integrated--owning companies that control production from the extraction of the raw material to the end product. So, for example, appropriability could be more of an issue for agriculturally based materials than for petrochemically based materials.

Environmental externalities of products involve environmental costs and benefits that affect society but do not enter the profit calculations of firms. Without collective action, markets simply do not take into account environmental costs when allocating resources among productive uses. For petroleum-based plastics and other products having negative externalities, the price consumers pay does not include environmental impacts, waste disposal costs, and other costs associated with these products.

One approach to government intervention would be to impose a tax on plastics to cover disposal, recycling, and environmental costs. Without such a tax, environmental externalities act as a barrier to entry of more "environmentally friendly" alternatives, like starch-based polymers. Starch-based polymers can be fully degradable, but their cost is currently greater than the cost of petroleum-based plastics.

Another intervention route is for government to support research and development activities to reduce the private costs of starch-based polymer production. See the Starches and Sugars Section and the first special article for specifics.

A broader approach would involve the creation and implementation of full-cost accounting. Economists at numerous organizations--including the United Nations, the World Resources Institute, and ERS--are developing national income and product accounts that incorporate the value of the natural and environmental resources consumed. Some in industry and government are developing a system called "Life Cycle Analysis" that tracks a product's full costs, from raw materials through disposal. However, moving to such a system will require strong public intervention, because any single company that prices products to include the social environmental costs cannot long survive in a competitive market. And a competitive market is the least-cost system for allocating scarce resources that are privately owned.

The structure of Federal farm price- and income-support programs means that deficiency payments decline when market prices rise. So, the government has an incentive to fund projects developing new uses because demand-creating innovations can cut the costs of farm-income-support programs. A technological breakthrough, for example, in the production of starch-based polymers would increase market demand for corn or wheat and reduce program payments. See the Starches and Sugars Section and the first special article for more on this.

Similarly, innovations in the development and use of new crops that are economically viable alternatives to program crops could also reduce the costs of farm-income-support programs. For example, if the demand for kenaf increased sharply, its price would rise relative to the prices of program crops. Some farmers would then shift acres away from program crops to grow kenaf. With less acreage in the programs, Federal payments would decline.

Short planning horizons lead some private firms to underinvest in research and development because they value near-term profits more highly than does society. Also, risk-averse firms may reduce research and development below what is socially optimal. Studies differ on whether these risk- and time-preference differences exist and whether they justify government intervention.

"Short-termism" in business planning has many dimensions. U.S. industrial structure and corporate ownership patterns tend to support investments with higher short-term payoffs compared with the economies of Japan and Germany. The funding rate of precommercial research and development in Japan and the European Community (EC) is higher than in the United States. Through efforts like the MITI and Key Technologies programs, Japan has promoted partnerships downstream from basic research--between business, universities, and government. Similarly, the EC has promoted collaborative research and development under the Framework Program.

Government-induced structural barriers, as well as standard business practices, may be factors limiting investment in precommercial research and development in the United States. For example, U.S. laws keep ownership of banks and nonfinancial corporations separate, creating pressure for higher short-run payoffs to repay loans. This is not the case in many other countries.

However, public efforts to boost technology transfer in Europe and Japan have had mixed results. There is broad agreement among economists that the United States must develop programs in which government does not try to pick technological winners, but rather promotes financial support of research, development, and demonstration activities that are economically efficient--stepping in only where there is a market failure.

New Institutions Promote Adoption

Since the 1940's, agricultural research and development have helped boost productivity by 230 percent. However, the government's share of research funding, has trended downward, from about 50 percent in the 1960's and 1970's to less than 45 percent in the 1980's, and likely will continue to drop. Many analysts believe that to get the biggest bang for each research dollar, more Federal support is needed at the applied, development, and demonstration (precommercial) stages to move basic research advances into the marketplace.

Congress set up the Alternative Agricultural Research and Commercialization (AARC) Center under the 1990 Farm Bill, which supports precommercial development of nonfood, nonfeed uses of agricultural materials. Through the AARC Center, Congress is trying to bridge a funding gap and an institutional gap. The institutional gap arises because the link is weak between scientists making discoveries and the firms marketing new products. The funding gap arises in part because risk remains high and costs tend to increase sharply at the precommercial stage. So capital is often lacking to develop technologies emerging from the laboratory but not yet ready for commercial prototyping.

According to estimates from the Department of Commerce, for each dollar spent on research, $10 is spent on development and $100 on precommercial activities before a new product reaches the market. The point between development and commercial production is where technology transfer often fails. The AARC Center is especially situated to help private industry bridge the funding gap and bring new-use commercial technologies to the marketplace. The Center and private firms share funding risks and the returns from the marketplace. The Center funds projects on a competitive basis and only when there is a strong financial commitment from a private partner. Specific projects the AARC Center is funding this year are in the final stages of negotiations and will be covered in the next issue.

The AARC Center is also establishing two regional centers this year to enhance grass roots participation in developing new uses for agricultural materials. The host institutions, chosen through a competitive process, will be the Kansas Industrial Agricultural Consortium and the Northern Regional Agricultural Utilization Consortium, which currently includes Minnesota, North Dakota, and South Dakota.

Through public-private partnerships, USDA's Cooperative State Research Service, Office of Agricultural Materials is also helping to bridge the gap through joint ventures with industry, universities, and other government agencies. They are supporting the development of products ranging from vegetable-oil-based lubricants and polymers to kenaf newsprint and bond paper, to guayule rubber tires.

The Technology Transfer Act of 1986 promotes technology transfer by authorizing Cooperative Research and Development Agreements (CRADA's) between government scientists and private companies to develop particular discoveries. These agreements give private companies exclusive rights to develop government discoveries for a given time period, but no transfer of public funds is involved.

Since 1986, scientists at USDA's Agricultural Research Service (ARS) have established over 300 such agreements with companies to commercialize technology arising from their research, while USDA's Forest Service has established 50 agreements. USDA and the Department of Energy (DOE) are the lead Federal departments in setting up CRADA's.

DOE's Office of Industrial Technologies runs an Alternative Feedstocks Program. The goal is to develop precompetitive and environmentally acceptable technologies for producing high-volume chemicals and materials from renewable resources, namely agricultural and forestry materials.

The program has recently examined opportunities for about 70 chemical and material products from renewables. The evaluation was done by a National Laboratory Team with input from industry. The Team includes the National Renewable Energy Laboratory (Golden, CO), Argonne National Laboratory (Argonne, IL), Idaho National Engineering Laboratory (Idaho Falls, ID), Oak Ridge National Laboratory (Oak Ridge, TN), and the Pacific Northwest Laboratory (Richland, WA).

Based on this study, the program is evaluating opportunities to use biomass to produce succinic acid and butanol. More generally, the program is looking at the use of clean fractionation to convert lignocellulosic biomass into cellulose, hemicellulose, and lignin as future chemical building blocks. The program will form partnerships with industry to develop and commercialize these uses of agricultural and forestry materials.

Among the nonprofit groups working to develop industrial uses of agricultural materials is the New Uses Council. Incorporated in Kansas, its mission is to seek commercial development of new nonfood, nonfeed products made from renewable farm-based commodities through education, advocacy, information dissemination, and public-and-private-sector partnerships.

The Institute for Local Self-Reliance (Washington, DC) is another nonprofit private group interested in developing industrial uses of plant and animal products. The Institute works to achieve a dramatic reduction in U.S. per capita consumption of raw materials, and to help the economy shift from fossil fuels to renewable resources. While some of the estimates from the Institute tend to be more optimistic than the estimates elsewhere in this report, see table 13 for a comprehensive assessment of the potential for industrial uses of plant matter. Their estimates are based on several years of research and close contact with industry and academia.

While these organizations are playing leading roles in advancing industrial uses of agricultural materials, support does not end with them. Many other State and local groups and commodity associations are also advancing these concepts. [Gregory Gajewski, Douglas Beach (202) 219-0085, and Irshad Ahmed (202) 232-4108]

Current Macro and Industrial Outlook

Moderate increases in demand and modest increases in costs expected for the rest of 1993 and 1994 will provide a supportive environment for agricultural producers selling to the industrial sector. Inflation and interest rates are expected to remain low. Business spending on plant and equipment is likely to lead the expansion. Petroleum prices are forecast to rise slightly. Housing, textiles, and metal fabricating--key users of agricultural materials--are likely to show above-average growth, while printing and publishing--also key users--probably will show more sluggish growth.

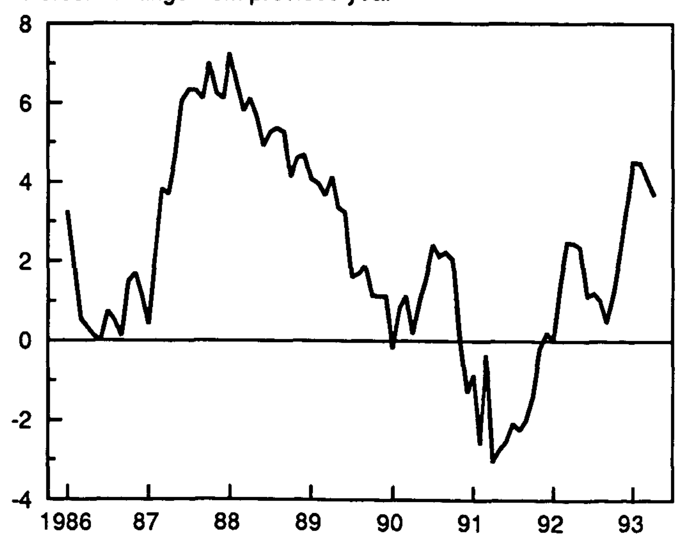
Modest U.S. Economic Growth Ahead

Most analysts expect that inflation-adjusted Gross Domestic Product (GDP) will grow at a 3-percent annual rate through the end of 1994. This is consistent with 3.5- to 4-percent annual growth in industrial production (figure 1). Although this faster growth should push down unemployment, the unemployment rate is likely to remain relatively high. Unemployment rates in rural areas, which fell below the overall rate in 1992, are likely to remain close to rates in urban areas.

Figure 1

Industrial Production

Percent change from previous year



Coupled with this relatively high unemployment rate, low industrial-capacity use should help keep inflation around where it is now: about 2 percent for overall producer prices. Interest rates are expected to rise slightly as the economy gathers strength, but still remain very low by historical standards.

Business spending on plant and equipment and residential building are the two areas most likely to lead overall GDP growth. A Census Bureau survey suggests that businesses plan to increase inflation-adjusted (i.e., real) spending on new plant and equipment by 6.4 percent in 1993. Further, housing starts are generally expected to be up 10 percent in 1993 and then rise another 4 percent in 1994.

Growth in consumer spending is likely to be slightly slower than the growth in GDP, as consumers attempt to rebuild their low savings and reduce debt levels. This suggests less growth in industries that supply primarily to consumers in 1993 and 1994. Government purchases at all levels are expected to decline slightly over the next 18 months, signaling continued contraction in industrial demand from those sources.

Cost pressures should be minimal over the next 12 to 18 months. Low interest rates should keep interest expenses down, and provide an opportunity to expand production or processing lines. Wages have been declining recently, and with a relatively high unemployment rate, are not likely to accelerate soon. Unit labor costs in manufacturing fell 0.5 percent in 1992, the largest decline since 1987.

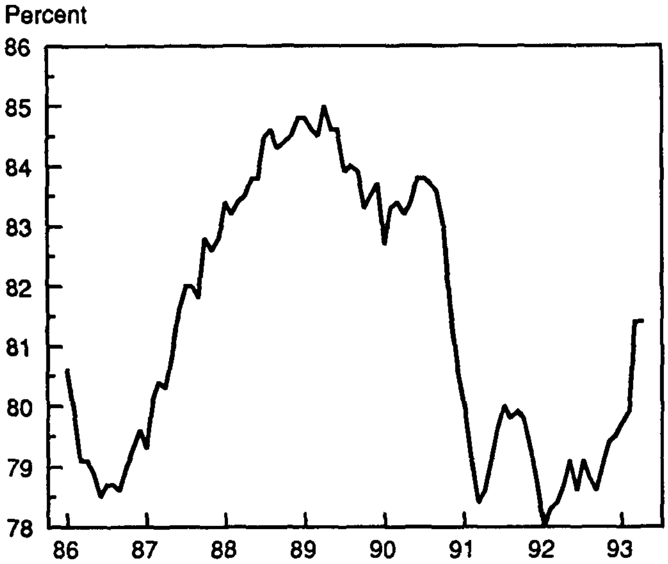
Although the latest recession brought about average declines in industrial production and capacity use, the subsequent recovery has been much slower than average. Twenty-five months after the trough of the 1991-92 recession, overall production has risen by only about 8 percent, less than half of the increases achieved at the same point in previous recoveries. Factory output has shown a similar sluggishness, although it has risen slightly faster than total output. Between the recession's end and April 1993, manufacturing production grew just over 9 percent. Capacity utilization has also inched up slowly (figure 2). The utilization rate rose only 4 percent since the March 1991 trough, compared with increases of nearly 8 percent and more than 10 percent during the last two recoveries.

Defense Cuts Slow Industrial Growth

Many analysts suggest that reduced defense spending has contributed substantially to slow growth in overall industrial production since the recession's end. From the first quarter of 1991 through the first quarter of 1993, Federal purchases of defense goods and services fell more than 4 percent (figure 3).

The defense-spending decline has affected manufacturing by directly reducing production in some industries, such as aerospace manufacturing and shipyard work. The decline has had large indirect effects on many other manufacturing

Figure 2
Capacity Utilization Rate



industries that supply defense-related manufacturers with inputs, such as metalworking machinery.

The defense-spending decline projected over the next few years points to continued restructuring for some industries, perhaps leading to continued sub-par industrial production growth. However, if defense-spending cuts are used to reduce the Federal deficit, the Federal demand for credit will fall and interest rates would likely decline, increasing demand for most industries.

Falling Interest Rates Help Lift Investment

Because financial markets have already incorporated some degree of lower Federal spending into their expectations, some of the interest-rate decline has already occurred. For example, yields on long-term bonds fell about 50 basis points (100 basis points equal a percentage point) in the early part of 1993, which most analysts attribute to the expectation of reduced Federal credit demand.

Short-term rates declined less than long-term rates. Yields on 3-month Treasury bills fell below 3 percent in February and have remained there since. Overall, short-term rates are the lowest in about 30 years. At about 6.7 percent in April 1993, yields on long-term Treasury bonds are the lowest they have been in about 17 years. Low long-term interest rates keep down the costs of financing new plant and equipment and more generally lead to expanding consumer and business spending.

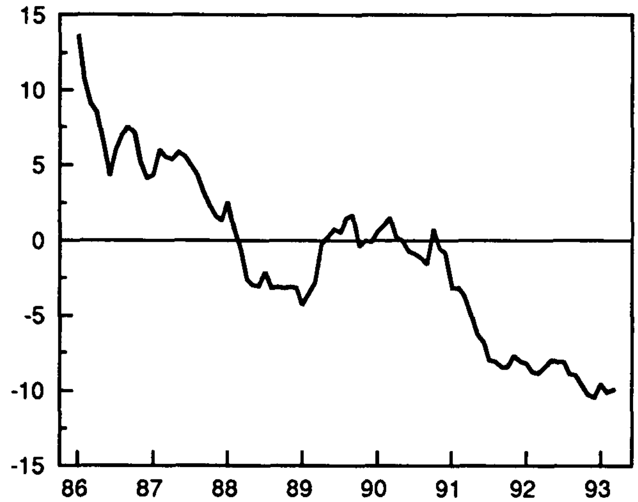
Foreign Developments Point to Modest Export Growth

U.S. export growth slowed in 1992 and is not likely to accelerate in 1993. Although the foreign-exchange value of the dollar remains low and fell slightly through the first 5 months of 1993--keeping U.S. exports competitive in foreign markets--economic growth abroad has slowed substantially.

Figure 3

Production of Defense and Space Equipment

Percent change from previous year



Agricultural exports in 1992/93 are forecast at $42.5 billion, virtually unchanged from a year earlier.

Growth in Germany and other parts of Europe was held down by high German interest rates, where tight monetary policy was imposed to ward off the inflation prompted by reunification. Growth in Japan slid as the economy retreated from its unsustainably rapid growth of the late 1980's. Neither country is expected to recover substantially in 1993; German GDP is expected to decline close to 2 percent and Japan's economy is expected to grow only 1 percent.

Both countries are expected to recover somewhat in 1994. Faster growth in those countries is likely to help support growth in the U.S. industrial sector in 1994. Although the value of the dollar is expected to rise as foreign interest rates decline relative to U.S. rates, the increase is not expected to be a serious drag on U.S. export performance in either 1993 or 1994.

Textiles, Metal Fabricating Show Strongest Potentials

Although some industrial uses of agricultural products depend more on the general economy--for example, using various plant extracts and oils as lubricants or using ethanol or biodiesel as a fuel--others are tied more closely to specific industries--such as fibers, inks, and paper.

Textile production fell at about a 2-percent annual rate for the 6 months ending April 1993, compared to 9.2-percent growth during 1991 and 4.5-percent growth during 1992. Recently, some specific textile industries have been sluggish. Since October, fabric production has remained flat and production of overall knit goods has fallen about 1.4 percent. Production of carpeting dropped 14.2 percent. However, output of yarns and miscellaneous textiles rose by 1.4 percent. Textile output is one barometer of the likely demand for kenaf, jute, hemp, sisal, and milkweed fibers. For example, kenaf fibers are now being used in degradable mats for seeding grass. If overall housing activity and consumer spending is spurred by the relatively low interest rates, then some of these industries may experience better than average production increases over the next year or so.

Printing and publishing production has risen more slowly than overall industrial production recently, rising only 1.5 percent during the last 6 months. Industry output fell 4.5 percent during 1991, and another 0.8 percent during 1992. By the end of 1992, output was down 1.8 percent from the end of 1989. The growth of the printing and publishing industry--which includes newspapers, books, periodicals, and other printing--gives some indication of the health of the market for soy and other vegetable inks and many fibers that rely on paper demand. A more robust outlook for this sector would help the commercialization of kenaf as a material for newsprint and other types of paper.

Production of fabricated-metal products has climbed 6.2 percent in the last 6 months, well above the pace of overall production. Production fell 1.1 percent during 1991, but rose close to 3 percent during 1992. However, by the end of 1992, it was still 1.1-percent below the level at the end of 1989. This industry is important to industrial rapeseed and crambe oils, which are used as raw materials for lubricants in the rolling and stamping of metal products.

Construction governs the demand for many forestry products, particularly lumber. The housing market was hit significantly during the recession. Housing starts fell 13 percent in 1990 and 15 percent in 1991. But in 1992, starts rose 18 percent, and in April 1993 were about 11 percent above a year earlier. Other indicators suggest a continued rebound in construction activity: building permits, an indicator of future construction activity, rose 6 percent for the 12 months ending in April. Continued relatively low long-term interest rates should prove beneficial for further growth in the housing market, which will boost the demand for lumber and related forestry products.

Petroleum Prices To Increase Slightly

Developments in energy markets have major implications for overall industrial markets as well as for industrial uses of agricultural materials. A sharp increase in the price of oil, for example, would tend to reduce overall economic activity and raise costs, but would also stimulate production of alternatives to petroleum-based fuels and lubricants, including those derived from agricultural materials.

The major factor which determines the price of petroleum-based products is the price of crude oil, with weather and domestic and foreign macroeconomic growth as important secondary factors. Politics, OPEC, and foreign affairs also play a key role as the United States imports about 45 percent of its petroleum. A good proxy for a single market price of crude oil is the weighted-by-sales cost of crude oil imported into the United States--known as the refiner acquisition cost (RAC).

The commonly reported price of West Texas Intermediate crude oil will be between $2 or $3 per barrel (42 U.S. gallons) more than the RAC. The Energy Information Administration's (EIA) short-term forecast has the RAC averaging $18.34 in 1993 and $19.51 in 1994. The RAC was $18.22 in 1992 and, in the first quarter 1993, it was down to $17.27. EIA projections are consistent with moderate economic growth both for the United States and other industrialized countries. Some analysts see an even slower crude price growth in the near-term, pointing to possibly more sluggish growth in industrialized countries in 1993 and 1994.

The EIA estimates a current global excess capacity in crude oil production of 1 million barrels per day. Over time, world economic growth will tend to raise fuel demand, while the former Soviet Union's oil production is likely to decline further. As excess capacity is eliminated, the RAC is likely to rise in real terms. Only an expectation of severe future market tightness, as during the Gulf war, or abnormally bad weather could induce the RAC to rise sharply before the above balance is restored.

EIA forecasts that the real price of oil will rise in the second half of 1994 as lower crude oil capacity balances increased demand. Other analysts suggest that real oil prices will not rise substantially until well into 1995, due to weak world growth. In their opinion, the RAC would stay below $19 until 1995. Gasoline prices are expected to peak at about $1.29 per gallon in late 1994. Diesel prices should peak at $1.26 per gallon about the same time. [Ralph Monaco, Jennifer Beattie, and David Torgerson (202) 219-0782]

Starches and Sugars

Over the next 4 years, increases in the production of ethanol, adhesives, and biopolymers will pull up the industrial uses of starch and sugar (figure 4). The degree of market penetration in these markets is closely tied to environmental developments. In most of these markets, biobased products have a clear advantage environmentally, compared to synthetic substitutes.

The analysis here assumes that corn is the feedstock. Other sources of starch and sugars include barley, potatoes, sorghum, wheat, and woody crops. Cornstarch is now relatively less expensive than the starch from these other sources, and has captured most of the market. With that and other assumptions, industrial uses of corn are expected to increase by about 140 million bushels to 795 million bushels by 1995/96. This translates into an annual increase of roughly 8 percent per year (table 1). Over the long term, increases in the demand for ethanol will improve opportunities for short-rotation woody and grass crops.

Table 1--Industrial use of corn, 1990/91-1995/96

Marketing year 1/	Starch	Fuel alcohol	Total industrial demand
		--Million bushels--	
1990/91	197	349	546
1991/92	201	398	599
1992/93	204	410	614
1993/94	208	445	654
1994/95	217	503	720
1995/96	226	568	795

1/ Marketing year beginning September 1. 1992/93-1995/96 are forecast.

Fuel Ethanol Use To Accelerate

Industry estimates place the combined demand for fuel-oxygenate additives--as a result of the 1990 Clean Air Act Amendments (CAAA)--at 3.7 billion gallons of ethanol equivalent by 1995/96, or more than 3 times current ethanol production. Market analysts project that corn-based ethanol will capture approximately 35 percent of the oxygenated fuels market by 1993. This implies a demand for ethanol of 1.3 billion gallons by 1995/96. As a result, an additional 123 million bushels of corn could be needed during 1992/93-1995/96 for the fuel-ethanol market. This would raise total use of corn for fuel-ethanol production to approximately 568 million bushels by 1995/96. See the second special article for more on ethanol.

Since the late 1970's, ethanol has been used as a gasoline extender by blending one part of ethanol with nine parts of gasoline to produce "gasohol." This 1/10 ratio is the technical definition of gasohol. Ethanol production has grown from 20 million gallons in 1979 to almost 1 billion in 1991. From September 1992 through February 1993, corn used to make fuel rose 6 percent.

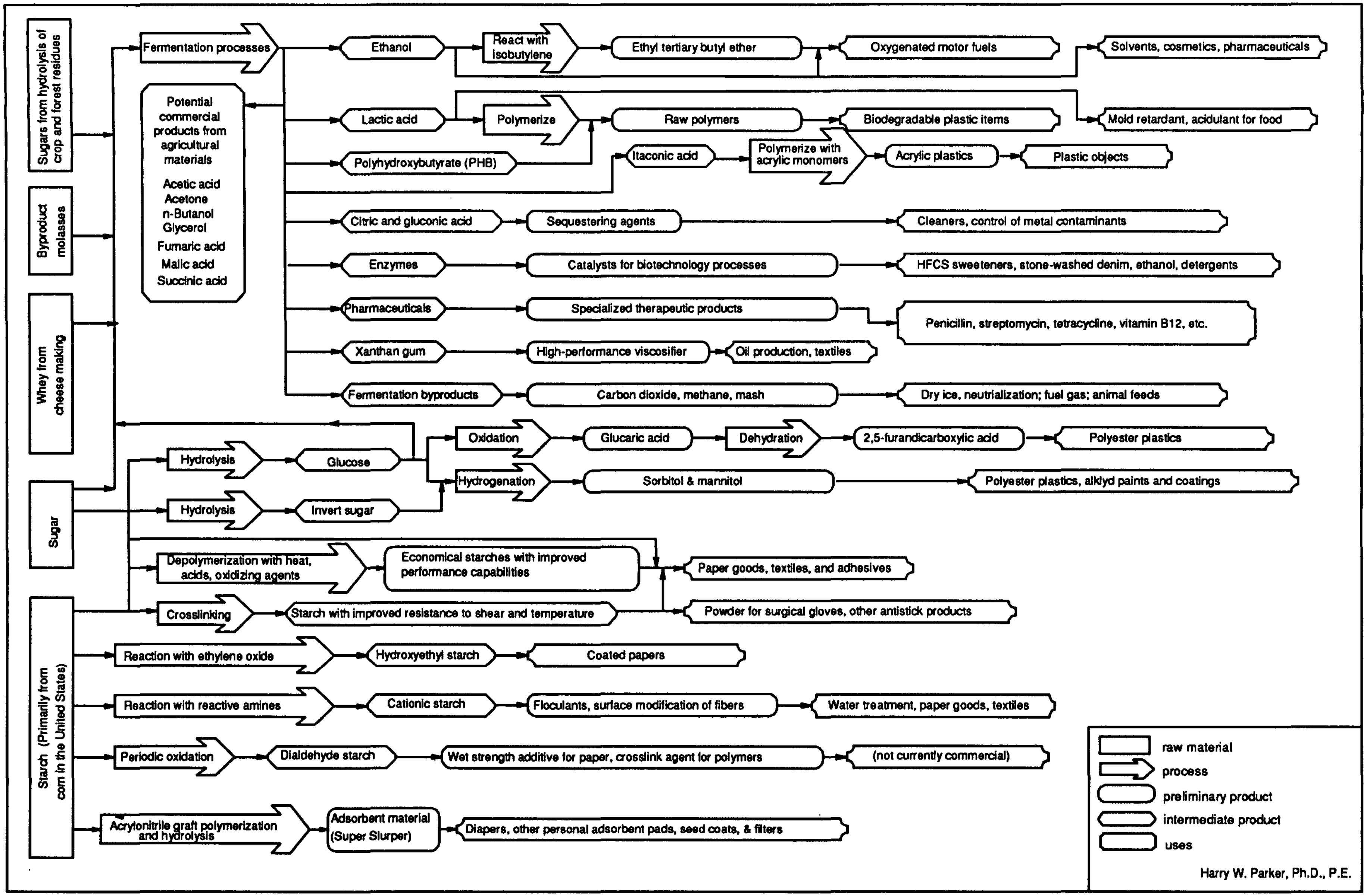
To achieve this expansion, corn-based ethanol has been and is highly subsidized. These subsidies have elements of both research and development funding (e.g., Federal loan subsidies by USDA and DOE for physical plant) and direct production support.

Private and public research and development have helped transform corn-based ethanol production from a negative energy balance to a positive energy balance. The energy value of one gallon of ethanol is 76,000 Btu (British thermal units). As late as the mid-1980's, the total energy necessary to produce one gallon of ethanol was 120,000 Btu and the energy credit for the coproducts (corn oil, gluten feed, gluten meal, and carbon dioxide) was 32,000 Btu [3]. This gave a net energy loss of 12,000 Btu.

Currently, the total energy requirement for an average-efficiency corn farm and an average-efficiency ethanol plant is 75,811 Btu. The coproduct energy credit is 24,950 Btu--resulting in a net energy gain of 25,139 Btu. So, corn-ethanol production has gone from a net energy sink, requiring

Figure 4

Processing Starches and Sugars into Industrial and Consumer Products



16 percent more energy than it produced, to a net energy producer, yielding a 33-percent energy surplus [2].

Increases in ethanol production can decrease farm program costs by raising grain prices. Moreover, an increase in the price of corn generally lifts all other feed-grain prices, thus lowering the cost for all feed-grain programs. A recent USDA study projected that annual U.S. corn-based ethanol consumption would increase gradually from 800 million gallons in 1987 to 2.7 billion gallons in 1995. Lost government revenues due to the 5.4 cent-per-gallon subsidy of ethanol-blended fuels would cost the Federal government an estimated $5 billion. This was offset by a $9-billion decrease in Federal-farm-program payments, resulting in net Federal savings of $4 billion [1].

A second, possibly more significant advantage of the corn-ethanol program may come from the CAAA. The Environmental Protection Agency (EPA) estimates that nationally, cars and trucks contribute 56 percent of carbon monoxide emissions, 43 percent of volatile organic compounds (VOC) emissions, and 57 percent of nitrogen oxide (NOx) emissions. Carbon monoxide can be lethal in high concentrations. VOC's and NOx contribute to ground-level ozone formation, which can lead to various respiratory problems.

In response to these health hazards, Congress enacted the CAAA in 1990. This legislation amended existing Federal clean air laws by defining standards for nonattainment areas where air quality goals are not met. The CAAA also mandated the sale of reformulated or oxygenated gasolines in nonattainment areas.

The first stage of the CAAA was implemented last November. The Act required a 2.7-percent oxygen content by weight for fuels sold in 39 metropolitan areas not meeting carbon monoxide goals for at least 4 winter months. The addition of 10-percent alcohol to gasoline gives an oxygen percentage of 3.5 by weight, well above the amount necessary to meet the requirements.

Use of alcohol might have been even higher in 1992/93 if California had kept its 2.7-percent oxygen requirement rather than reducing it to 2.2 percent, and if New York had not delayed the start of its program. Supplies of a petroleum-based oxygenate, methyl tertiary butyl ether (MTBE), were built up for the program. Petroleum producers added manufacturing capabilities for MTBE. Spot prices of all oxygenates declined during the November 1992-February 1993 program period because of plentiful supplies.

The second stage of the CAAA is to be implemented in 1995. It requires reformulated gasoline in the nine worst ground-level ozone areas. According to the legislation, reformulated gasolines must reduce VOC's and toxic emissions by at least 15 percent, and generate NOx emissions no higher than those of 1990 baseline gasolines. Because splash-blended gasohol may increase evaporative VOC emissions and MTBE does not, ethanol-gasoline mixtures will require lower evaporative emissions from the gasoline component than MTBE-gasoline mixtures. Depending on the cost of decreasing gasoline's evaporative emissions, this could drive up the relative price of gasohol as compared to MTBE-gasoline blends. However, the rules are not yet final and there are several proposals that provide incentives for renewable oxygenates. See the second special article for more on ethanol.

Starch To Continue Dominating Adhesives Market

In 1990, U.S. adhesive consumption was about 5 million short tons with an estimated market value of over $2 billion annually. Natural adhesives accounted for over 40 percent of the market then, and have continued to hold on to that share. Domestic demand for adhesives is projected to exceed 5.5 million tons by 1995/96—an increase of 2.4 percent annually. This translates to an additional 600 million pounds of cornstarch, or an 18-million-bushel increase in corn demand by 1995/96.

Starch dominates the natural adhesives market. Currently, nearly 3.5 billion pounds of corn-starch equivalent is used annually to make adhesives, primarily for the paper and paperboard industry. While the majority comes from corn, starch from wheat and potatoes is also used to make adhesives.

The binding substances in adhesives and glues come from resins, rubber, inorganic and organic compounds, vegetable oils and milk proteins, gelatin (derived from both animal fat and synthetic routes), and even eggs. Synthetic adhesives are tougher and generally more water resistant than the natural adhesives. However, environmental concerns over synthetic adhesives have spurred new technologies using plant-derived starch. Many of these new systems are intended for the packaging market. The success of marketing natural starch-based adhesives in the packaging industry is directly associated with the solid waste disposal problems faced by petroleum-based plastic films. Adhesives, both natural and synthetic, generally cost from 15 cents per pound to $50 per pound or more for specialty products.

Starch adhesives are usually less expensive than synthetic adhesives and are free from the unpleasant odors of some animal glues. Uses include paper carton and bottle labeling, stationery, and some interior plywood fabrications. Perhaps the most well-known use of starch glue is to attach postage stamps.

Biodegradable Polymers To Gain Market Share Slowly

In 1992, biodegradable-polymer resins captured less than 5 million pounds or roughly .08 percent of the plastics resin market. Provided that Congress does not mandate increased biodegradable-polymer use, market penetration into the 8-billion-pound nonfood packaging market will likely be quite slow. The most conservative estimate of biopolymer consumption puts total demand at roughly 8.4 million pounds of resin in 1995/96.

Starting from a base of 5 million pounds in 1992/93 and assuming an average starch-loading technology of 50 percent, biopolymer demand for corn would equal approximately 124,000 bushels in 1995/96. See the first special article for details.

Four markets have been targeted for biodegradable-polymer applications: food packaging, nonfood packaging, personal and health care, and other disposables. Degradable food packaging is not addressed here because the Food and Drug Administration (FDA) has not yet established guidelines for its use. So, nonfood packaging is the key market for the near future.

The MARPOL Treaty, signed in 1987 by 29 countries including the United States, prohibits the discharge of all plastic wastes at sea beginning in 1988 for commercial vessels and in 1994 for government ships. EPA estimates that 4,205 metric tons of plastic wastes are produced each year aboard government ships. Adding merchant ships, navies of other nations, and recreational boaters increases the volume of these wastes by at least tenfold.

The Department of Defense (DOD) has said that there is no suitable alternative to plastic packaging of military rations. Consequently, DOD is under a tight deadline to find a suitable biodegradable alternative. The U.S. Army--in conjunction with USDA and private companies--has implemented a large-scale effort to develop biodegradable polymers to replace petroleum-based plastics for most packaging uses. Many of these polymers are being made from corn, wheat, and potato starch, as well as other biodegradable materials. They are fully degradable but generally cost 2 to 10 times more than petroleum-based plastics. [Douglas Beach (202) 219-0085 and Irshad Ahmed (202) 232-4108]

References

1. LeBlanc, M. and J. Reilly. *Ethanol: Economic and Policy Tradeoffs.* USDA, ERS, Agricultural Economic Report No. 585, April 1988.

2. Morris, D. and I. Ahmed. *How Much Energy Does It Take to Make a Gallon of Ethanol?* Washington, DC; The Institute for Local Self-Reliance, December 1992.

3. Pimental, D. "Energy Security, Economics, and the Environment." *Journal of Agricultural and Environmental Ethics,* 4(1991):1-13.

Fats and Oils

Industrial rapeseed acreage is down, while crambe acreage has risen 150 percent from last year. Industrial rapeseed and crambe oil derivatives are used in slip agents for plastic films, lubricants, and automatic transmission fluids. A major corporation now markets a biodegradable hydraulic fluid made from canola oil.

Jojoba prices are down, and growers and processors are working to find new uses for the oil. Animal- and plant-based oils are making inroads into surfactant markets. Plus use of soy inks continues to grow.

Biodiesel, which can be made from just about any animal or plant fat or oil, is being commercially produced in Europe, and is being tested by several bus fleets in major cities in the United States as a means of meeting CAAA emission standards. Further testing and certification are needed, but results so far are favorable.

Fats and oils can be used directly in the manufacture of products. For example, soy oil is employed in printing inks as a carrier for pigments and other components. Through a process called saponification, coconut oil and tallow are made into soap. However, for industrial purposes, many fats and oils are broken down into their component fatty acids and further chemically modified (figure 5). (Chemicals made from fats and oils are often called oleochemicals to distinguish them from petrochemicals.)

In 1992, 5.9 billion pounds of fats and oils were used for fatty acids, animal feeds, soaps, resins and plastics, paints and varnishes, lubricants, and other inedible uses. During the last 7 years, these applications have accounted for 27 to 30 percent of total use (table 20).

New Uses Emerging for Industrial Rapeseed and Crambe

Two types of rapeseed are being grown in the United States. Canola is the name of rapeseed varieties that have less than 2 percent erucic acid in their oil, making them suitable for human consumption. Industrial rapeseed, on the other hand, must contain at least 45 percent erucic acid in its oil to meet industrial standards.

Industrial rapeseed has been grown in the Pacific Northwest for over 40 years. Since the mid-1980's, it also has been produced in the Mid-South. Harvested acreage of industrial rapeseed has varied over the last few years, from a high of 19,400 acres in 1987/88 to 9,800 acres in 1992/93 (table 2).

Small amounts of crambe acreage were grown in the United States for research and commercial purposes 20 years ago. In recent years, however, crambe has dramatically resurfaced. In 1990, 2,200 acres were harvested in North Dakota, and planted acreage this year is estimated at 60,000 (table 3). Farmers were paid about 9.5 cents per pound for their 1992 crop, and contracts have been issued this year at 10 cents per pound. A potential area of production is northeastern Colorado, southwestern Nebraska, and northwestern Kansas

Table 2--Rapeseed, acreage planted, harvested, yield, production, and value, 1987-92

Year	Planted	Harvested	Yield	Production	Value
	--1,000 acres--		Bushels per acre	1,000 pounds	Million dollars
1987	20.0	19.4	22.7	21,981	N.A.
1988	13.5	13.1	24.1	15,822	N.A.
1989	14.0	13.6	28.2	19,143	2.01
1990	15.0	14.5	31.2	22,717	2.33
1991 1/	18.2	15.6	20.7	16,146	1.63
1992 2/	12.0	9.8	29.5	14,455	1.45

N.A.= Not available.
1/ Preliminary. 2/ Forecast.

Figure 5

Processing Fats and Oils into Industrial and Consumer Products

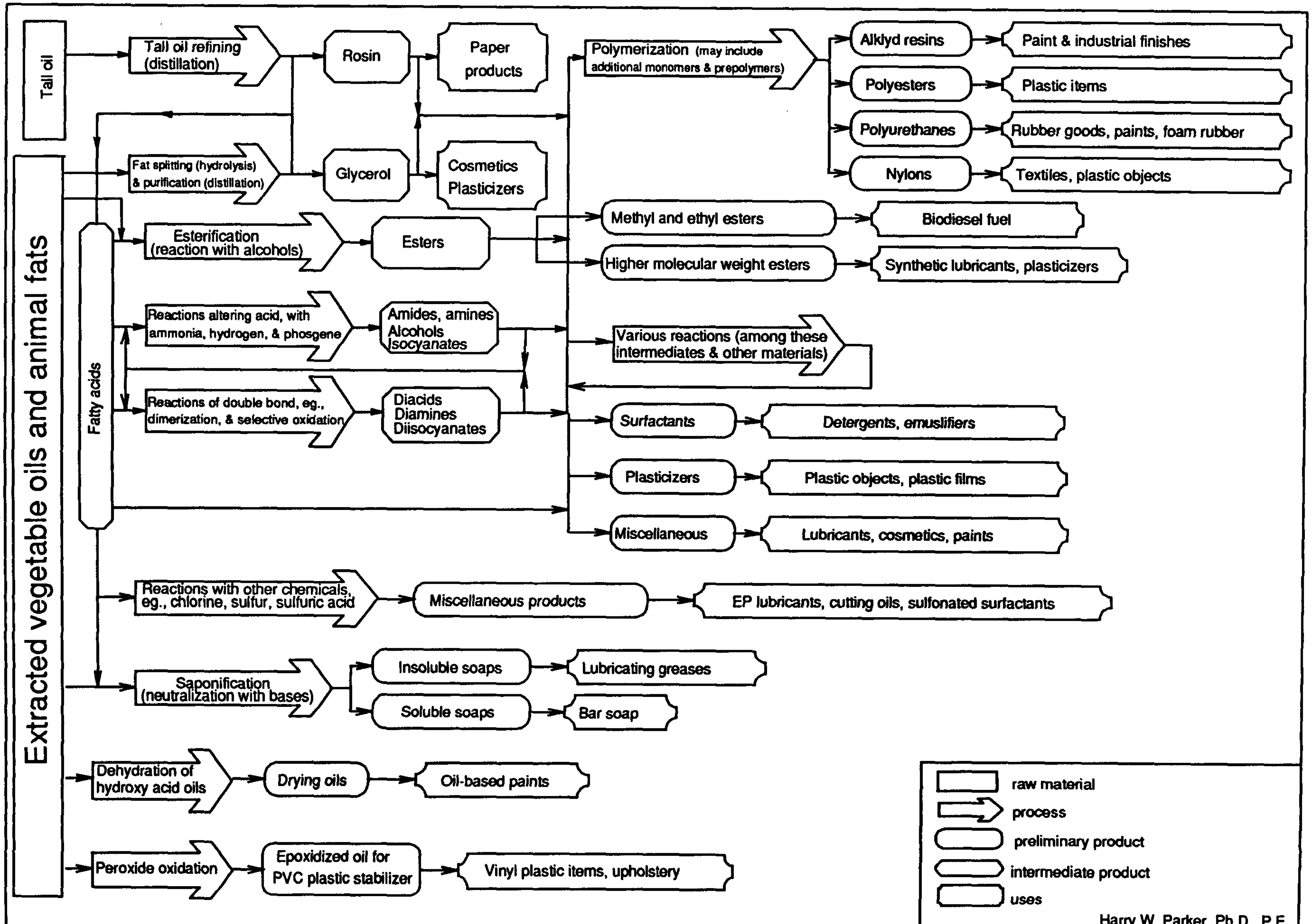


Table 3--Crambe acreage, United States, 1990-93 1/

Year	Area	Yield 2/
	Acres	Pounds/acre
1990	2,200	1,300
1991	4,500	1,338
1992	24,000	1,138
1993	3/ 60,000	N.A.

N.A. = Not available.
1/ Commercial acreage. 2/ North Dakota only. 3/ Estimated planted.
Source: National Sun Industries.

where National Sun Industries has constructed a sunflower crushing plant that is capable of processing both crambe and industrial rapeseed.

In the past, most industrial rapeseed and crambe oils were processed into erucamide. Plastic-film manufacturers have used erucamide for decades in bread wraps and garbage bags. It lubricates the extruding machine during manufacture of thin plastic films. After processing, the erucamide migrates to the surface of the films and keeps them from clinging together.

More recently, erucic acid oils have been showing up as raw materials in a wider array of industrial products. Because they have a high degree of lubricity, rapeseed and crambe oils are used either as direct lubricants or in lubricant formulations. Calgene Chemical (Skokie, IL) has introduced a line of erucic acid esters to the textile and automotive fluids industries. International Lubricants, Inc. (Seattle, WA) markets an automatic transmission fluid (ATF) supplement and a metal cutting oil based on derivatives of rapeseed oil. In independent third-party tests, the ATF fluid supplement decreased wear by more than 50 percent compared to the wear associated with factory-fill ATF fluid. The metal cutting oil lengthens tool life, produces smoother cuts, lasts longer, and is more worker friendly.

In 1991, Mobil Oil began marketing a biodegradable, nontoxic, antiwear hydraulic fluid. The product is composed of 97 percent canola oil and 3 percent other natural materials. It has environmental advantages for machinery used near water, such as hydraulic equipment at barge- and ship-loading docks, and at hydroelectric plants. It is also used in lawnmowers and other equipment on golf courses to prevent killing the grass when hydraulic oil leaks occur. Mobil projects that the U.S. market for biodegradable lubricants could exceed 20 million pounds per year by 1995.

Work continues on additional uses for rapeseed and crambe oils and their derivatives. USDA's Cooperative State Research Service leads the High Erucic Acid Development Effort (HEADE), consisting of ten state organizations (University of Georgia, University of Idaho, University of Illinois, Iowa State University, Kansas Board of Agriculture, Kansas State University, University of Missouri, University of Nebraska, New Mexico State University, and North Dakota State University). Begun in 1986, HEADE's purpose is to expand commercial use of crambe and industrial rapeseed in the United States.

Through HEADE and other USDA programs, extensive research and development has been conducted on the potential uses of these two crops (table 4). For example, erucic acid can be split into brassylic and pelargonic acids. The brassylic acid can be further modified to make nylon-13,13. This nylon offers superior performance characteristics--low moisture absorption, good strength and dimensional stability, and excellent insulating properties.

The commercialization of nylon-13,13 has been hindered by the lack of a reliable supply of domestically produced erucic acid and a cost-effective method of producing brassylic acid from erucic acid. However, North Dakota State University chemists and University of Nebraska chemical engineers have recently developed a new, lower cost and safer catalytic method of making brassylic acid. Nylon-13,13 is presently being tested for the Electric Power Research Institute for use as a cover for underground electrical cables.

Jojoba Prices Down

Jojoba is a perennial evergreen shrub native to the southwestern United States and northwestern Mexico. Some plants bear seed after 3 years, but it takes about 5 years for a plantation to produce enough seed for commercial harvest. The jojoba industry began in the mid-1970's when the oil was touted as a replacement for sperm whale oil. From 1976 to 1983, seed was gathered from wild stands in Arizona and southern California. Since 1984, jojoba has also been harvested from commercial plantations. Production has increased from 12 tons in 1976 to 2,073 tons in 1992 (table 5). Over the past 15 years, jojoba has grown to be an $11 million industry at the farm gate and about $14 million out the processor's door, with at least 70 percent of these revenues derived from exports.

U.S. production is centered in Arizona, with some in California (table 6). From their annual survey of growers, the Jojoba Association reports that 1992/93 production was about 4.1 million pounds. According to the Association, several growers reported stopping their harvest of the 1992/93 crop because seed prices were falling below $1 per pound. If prices do not improve, it is unlikely that the 1993/94 crop will reach current estimates.

In 1992/93, five major U.S. processors purchased over 2.4 million pounds of seed and produced over 96,000 gallons of oil (table 7). Jojoba oil is chemically different from other seed oils. Instead of being a triglyceride, it is made up of liquid wax esters. The cosmetics industry uses more than 90 percent of jojoba oil output and will likely continue as the major industrial consumer over the next decade. According to International Flora Technologies, Ltd., a jojoba processor, this trend is partly due to the cosmetic industry's shift from products of animal origin to materials of botanical origin.

Potential markets include industrial and automotive lubricants, as additives in automatic transmission and differential fluids, for example. However, for jojoba oil to compete in these

Table 4--Potential uses for crambe and industrial rapeseed

Raw material	Intermediate products	Industrial and consumer products
Meal		Livestock protein, protein isolates, fertilizer
Oil	Triglycerides	Pharmaceuticals, lubricants, heat transfer fluids, dielectric fluids, waxes
	Erucic acid	Erucamides (slip agents), plasticizers, amines (surfactants, antistats, flotation agents, corrosion inhibitors)
	Behenic acid	Antifriction coatings, mold release, mixing and processing aids, flow improvers, food itmes
	Erucyl alcohol	Surfactants, slip and coating agents
	Behenyl alcohol	Surfactants, slip and coating agents
	Wax esters	Lubricants, cosmetics, functional fluids
	Fatty acids	Existing C14-C20 fatty acid markets
	Brassylic acid	Nylons, perfumes, plasticizers, polyesters, synthetic lubricants, paints and coatings
	Pelargonic acid	Plasticizers, plastics, coatings, perfumes, cosmetics, flavors, lubricants

Source: Kenneth D. Carlson and Don L. Van Dyne, editors. Industrial Uses for High Erucic Acid Oils from Crambe and Rapeseed. Columbia, MO; University of Missouri, October 1992, p.8.

high-volume, relatively low-value markets, production needs to go up and prices must come down.

Soaps, Detergents, and Surfactants Are Major Outlets

Various fats and oils are used to make soaps, but generally tallow and coconut oil are blended at varying ratios ranging from 85/15 to 45/55. In recent years, palm kernel oil has been substituted for coconut oil because of their relative prices, and palm oil has been suggested as a substitute for tallow. Most soaps are made directly from fats and oils, but they can also be manufactured using fatty acids.

After World War II, detergents replaced many traditional uses of soaps. Surfactants (surface-active agents) are one of the main ingredients in detergents. They lessen the surface tension between oil-loving dirt and other compounds and the water. (Soap is itself a surfactant.) Surfactants also are used heavily by industry. For example, they impart lubricity for mold release, prevent caking of fertilizer salts, emulsify resins and asphalt, disperse and soften pigments, and waterproof and soften leather.

In 1990, the total U.S. market for surfactants was about 3.5 million tons. Industrial uses accounted for the biggest share, followed by laundry detergents, soaps, dishwashing products, shampoos, and other cleaning agents (figure 6). Surfactants are derived both from oleochemicals and petrochemicals (table 8). In 1990, petrochemical-based surfactants accounted for 52 percent of production, while oleo-based had 21 percent and mixed surfacants, 27 percent.

Fatty alcohols, which are surfactant raw materials, can be made from natural and synthetic sources. Oleochemical-based fatty alcohols are often made from tallow and coconut and palm kernel oils. The U.S. market for fatty alcohols used in detergents is dominated by petrochemically derived products. Henkel Corporation, Procter & Gamble, and Sherex produce oleo-derived alcohols.

Table 5--Historical U.S. production of jojoba seed, 1976-92

Year	Production
	Tons 1/
1976	12
1977	16
1978	80
1979	80
1980	160
1981	300
1982	300
1983	400
1984	600
1985	600
1986	820
1987	875
1988	1,500
1989	1,500
1990	1,500
1991	1,755
1992	2,073

1/ Processed seed.

Source: Jojoba Association.

Table 6--U.S. jojoba acreage and production, 1992/93-1993/94 1/

Area 1992/93	Harvested	Not harvested	Total
		--Acres--	
Arizona	7,366	1,360	8,726
California	2,144	995	3,139
Total	9,510	2,355	11,865
Production		1992/93 actual	1993/94 estimated
		--Pounds--	
Beginning stocks		232,050	2,039,438
Production		4,110,503	5,293,000
Yield per acre		354	446
Seed sold		2,303,115	N.A.
Ending stocks 2/		2,039,438	N.A.

N.A. = Not available.

1/ Data covers May 1, 1992-April 1, 1993. 2/ Inventories held by growers.

Source: Jojoba Association Annual Growers Survey.

Table 7--1992/93 jojoba processor activity 1/

Items	Pounds
Carryover inventory, as of May 1, 1992	
Cosmetic grade oil	342,000
Technical grade oil	64,800
Total	406,800
Unprocessed seed	509,896
Seed volume received	
Native stands	
United States	36,372
Mexico	79,809
Plantations	
United States	2,273,447
Mexico	51,102
Total	2,440,730
Oil produced	
Cold-pressed oil	581,200
Solvent-extracted oil	120,000
Total	701,200
Oil sold	
Cosmetic grades	764,400
Technical grades	88,800
Total	853,200
Unsold inventory, as of April 1, 1993	
Cosmetic grade oil	217,600
Technical grade oil	96,000
Total	313,600
Unprocessed seed	1,830,437
Custom-processed seed	676,924

1/ Data covers May 1 ,1992-April 1, 1993.

Source: Jojoba Association Annual Processors Survey.

Henkel is a major world producer of coconut and palm kernel oil-based fatty alcohols. The company's traditional surfactants, like lauryl sulfates or alcohol ethoxylates, combine a natural oil-soluble alcohol with a synthetic water-soluble group such as ethoxylate or sulfonate. However, in Henkel's new line of nonionic surfactants--alkyl polyglycosides--the water-soluble group is also based on a natural feedstock, glucose derived from cornstarch. The company sees markets for such new surfactants in cosmetics and personal care products, as well as in laundry detergents, dishwashing liquids, and other cleaning products.

According to a recent report by the Freedonia Group (a Cleveland, OH, market consulting firm), demand for detergent alcohols from coconut, palm, and palm kernel oils will grow at a significantly higher rate than that for petrochemical-based synthetics. The expected market growth is based on claims of superior biodegradability relative to synthetics, increasingly dependable supplies of tropical oils and improved price stability, expectations that long-term oleochemical prices will be more competitive with petrochemical feedstocks, and increasing capacity for oleochemical-derived alcohols production. Demand will depend largely on the commercial success of products made with ingredients perceived as natural, environmentally friendly, and derived from renewable resources.

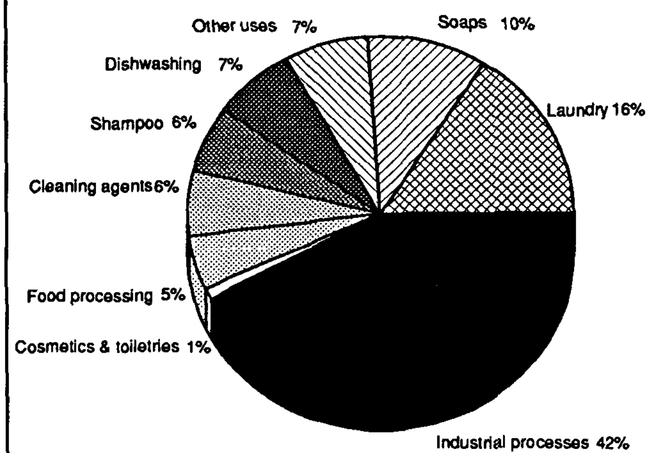
Table 8--U.S. production of surfactants, 1990

Items	Oleo derived	Petroleum derived	Mixed	Total
	--1,000 metric tons--			
Anionic	796.7	962.0	827.3	2,586.0
Nonionic	2.2	708.0	134.4	844.6
Cationic	0.0	287.1	56.4	343.5
Amphoteric	2.0	18.4	0.2	20.6
Total	800.9	1,975.5	1,018.3	3,794.7

Source: Synthetic Organic Chemicals, United States Production and Sales, 1990. United States International Trade Commission, USITC Publication 2470, December 1991, pp. 12-3 to 12-9.

Figure 6

U.S. Utilization of Surfactants by Product Type 1/



1/ Approximately 3.5 million tons of surfactants were consumed.

Source: "Surfactants Aim for Niche Markets," Chemical Engineering, 2 (1992):53-55.

Color Soy Oil Inks Are Well Established

Inks generally consist of a fine dispersion of pigments or dyes in a solvent vehicle, with or without resins and other additives. Since conventional inks depend heavily on petroleum-based raw materials for most of their components, the ink industry faced problems during the oil shocks of the 1970's, both in terms of cost and availability of raw materials. In response, the American Newspaper Publishers Association (ANPA) developed soybean-oil-based inks for its members, which were first marketed in 1987. Starting with

Castor Oil Prices Forecast To Rebound, Coconut Oil Prices To Dip

According to a time-series forecasting model, castor oil prices are forecast to have declined slightly in May and June and then to bounce back in July and August (table 9). Another model forecast that the price of coconut oil would have risen in May and June, is expected to peak in July, and then slip in August.

The single-equation time-series models used here were estimated with monthly price data from January 1977 to April 1993. Prices from the previous 2 months and monthly seasonal factors are used to explain each month's price. These models capture the historical regularities in these two markets. Forecasts are based solely on historical patterns. These forecasts do not account for random and atypical events, such as political unrest and violent weather. [Ronald Babula (202) 219-0785]

Table 9--Price forecasts for castor and coconut oils, 1993

Month	Castor oil prices	Coconut oil prices
	--Cents/pound--	
1993: 1/		
April	32.0	23.3
May	31.8	23.7
June	30.6	25.5
July	31.5	26.1
August	33.5	25.4

1/ April actual, May-August forecast.

only six newspapers, color soy ink is now used by half of the nation's 9,100 newspapers that use color inks, including 75 percent of the 1,700 U.S. dailies.

Color soy inks have been widely adopted because of their superior performance--brighter colors and more printed pages per volume of ink used--despite their slightly higher price. Color ink prices are based primarily on the cost of the pigments. In contrast, the price of the vehicle oil strongly influences the price of black printing inks. Thus, black soy inks have had a hard time being cost competitive when refined soybean oil is generally more expensive than petroleum-based mineral oil.

According to ANPA, soy oil could replace 75 percent of the 311 million pounds of oil used annually to formulate newspaper inks. As formulas have improved, many companies are beginning to produce and market soy oil inks. As of March 1992, 40 different ink producers had been licensed by ANPA to produce soy inks.

Researchers at USDA's National Center for Agricultural Utilization Research (Peoria, IL) have patented a line of soy inks for use by newspaper publishers. The inks contain no petrochemical compounds (except for pigments), provide a wide range of viscosities, and are more cost competitive with petroleum-based inks.

Newspaper inks are only one of the potential markets for soy oil. In 1990, all printing inks had an estimated combined market size of 3.5 million tons and a value of $200 million. Newspapers used about 7 percent of the ink manufactured in the United States in 1990, while commercial printers used 19 percent, and magazines used 28 percent (figure 7).

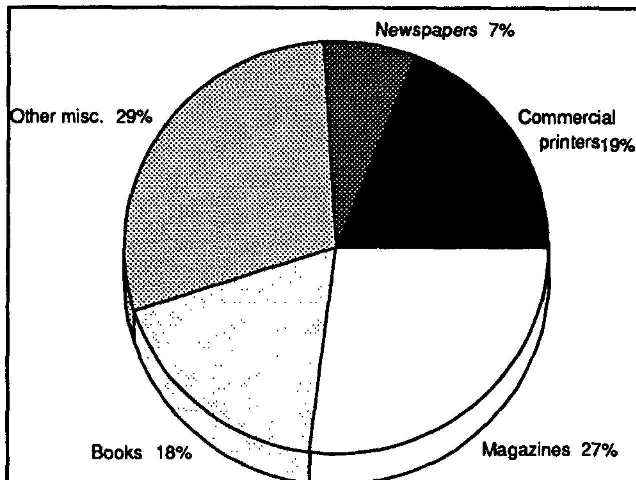
Not only does the volume of soybean oil in ink vary from one manufacturer to another, but it also varies depending on whether the ink is used for newspapers (over 50 percent soy oil), sheet-fed printing (20 to 40 percent), magazines (10 to 15 percent), or business forms (40 percent).

Use of soy inks in other printing categories is showing great promise. One of the most important breakthroughs in soy ink formulations--inks for sheet-fed presses--is responsible for opening up the large commercial printing market to soy inks, particularly for color printing. For example, Alden and Ott (Arlington Heights, IL) has a heat-set ink--available in all four process colors (black, blue, red, and yellow)--containing 12 percent soy oil.

The fundamental problem with soy inks for sheet-fed presses has been its slow drying time compared with mineral oil-based conventional inks that dry in 20 to 30 percent of soy-ink drying time. Although newer soy ink formulations produced for sheet-fed presses dry better than their predecessors, it still takes almost twice as long as for conventional inks. Efforts are underway to further improve soy oil inks' drying properties.

Figure 7

U.S. Ink Markets by Application Type, 1990 1/



1/ Approximately 3.5 million tons of printing inks were used.

Sources: American Ink Maker, November 1991; American Soybean Association, St. Louis, MO, March 1992.