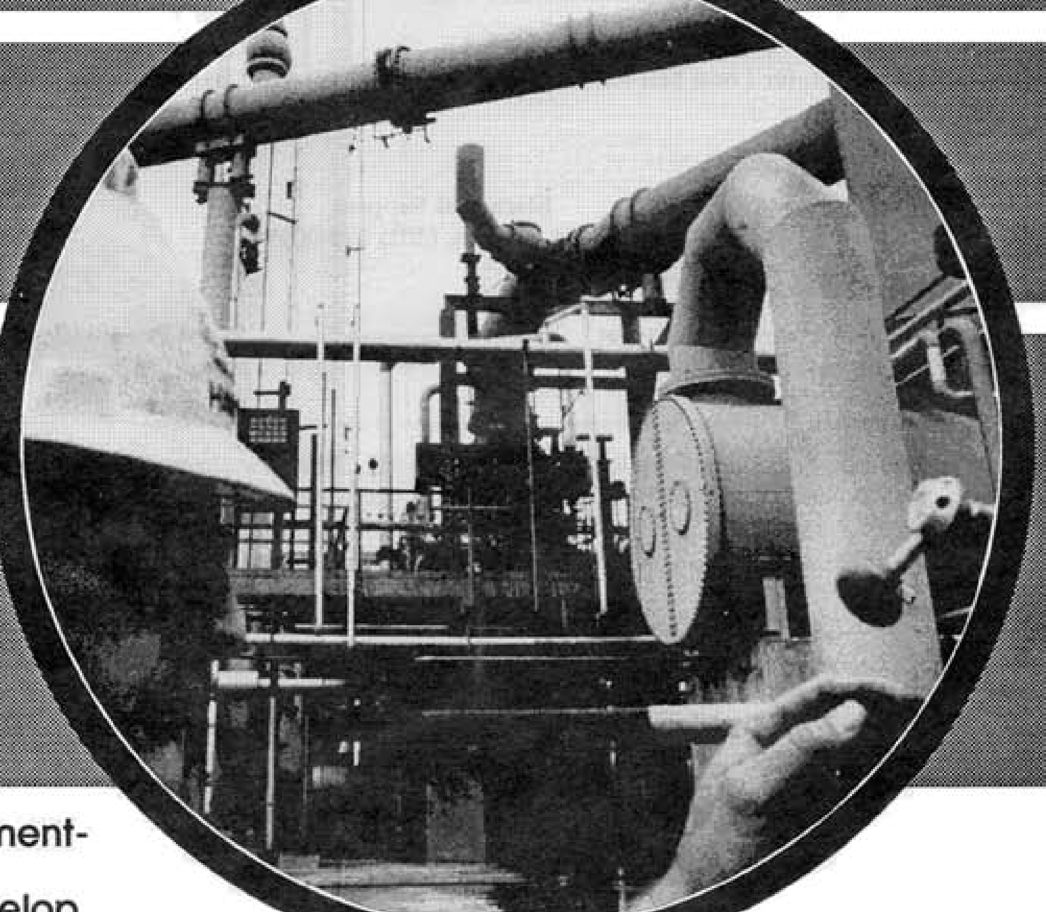
United States
Department of
Agriculture

Economic
Research
Service

IUS-2
December 1993

Industrial Uses Of Agricultural Materials

Situation and Outlook Report



Federal Government-Private Sector Partnerships Develop Biobased Industrial Products

Industrial Uses of Agricultural Materials Situation and Outlook. Commodity Economics Division, Economic Research Service, U.S. Department of Agriculture, December 1993, IUS-2.

Contents

Page
Introduction 4
Current Macroeconomic and Industrial Outlook 7
Starches and Sugars 10
Fats and Oils 13
Natural Fibers 19
Animal Products 22
Forest Products 24
Specialty Plant Products 28

Special Article:

The Feasibility of Producing Biodiesel in the United States Using a Community-Based Facility 30
List of Tables 35

Coordinators

Lewrene Glaser
Douglas Beach

Voice (202) 219-0085, Fax (202) 219-0042

Contributors

Douglas Beach
Gregory Gajewski
David Torgerson
Arthur Wiese
Irshad Ahmed, Inst. for Local Self-Reliance
Ronald Babula
Lewrene Glaser
David Pace, Univ. of Kentucky
Alan Weber, Univ. of Missouri
Donald Van Dyne, Univ. of Missouri
David Harvey
Thomas Marcin, Forest Service

Statistical Support
David Johnson, (202) 219-0085

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

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

Approved by the World Agricultural Outlook Board. Summary released December 15, 1993. The next summary of ***Industrial Uses of Agricultural Materials Situation and Outlook*** is scheduled for release on June 22, 1994. 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 were 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. Thomas Marcin, an economist from USDA's Forest Service, wrote a section of the report. Donald Van Dyne, Professor of Economics at the University of Missouri, and Irshad Ahmed, Senior Research Engineer of Biochemical Technologies of the Institute for Local Self-Reliance (Washington, DC), made strong contributions to this report.

Summary

U.S. agriculture likely will have substantial excess capacity for the foreseeable future. However, technological breakthroughs, heightened environmental awareness, and tougher environmental regulations are creating opportunities to use this capacity to produce industrial products.

A host of Federal programs are working in partnership with the private sector to develop these opportunities. For example, scientists from USDA's Agricultural Research Service (ARS) have entered into Cooperative Research and Development Agreements with private firms to commercialize ARS research. The newly created USDA Alternative Agricultural Research and Commercialization Center provides seed capital to help private firms bridge the gap between research and commercialization. USDA's Cooperative State Research Service, Office of Agricultural Materials, helps develop and commercialize agriculturally based industrial products and processes by funding university research teams and forming product-oriented consortia designed to leverage Federal investments in biobased technologies. Biomass conversion and utilization efforts within the Department of Energy focus on the production of biofuels and related chemicals.

An accelerating but moderate recovery means solid U.S. economic growth in 1994. Most analysts expect that inflation-adjusted Gross Domestic Product will grow about 3 percent next year. Business spending on plant and equipment and, recently, consumer spending on housing and durable goods have led overall GDP growth. Economic growth in 1994 will give a lift to many agricultural producers selling to the industrial sector. Inflation and interest rates are expected to remain low, although picking up slightly.

The carbon monoxide provisions of the 1990 Clean Air Act Amendments were implemented last winter and the resulting demand for oxygenates, primarily corn-based fuel ethanol and natural gas-based methyl tertiary butyl ether, was much lower than expected. Nevertheless, oxygenate demand increased dramatically. Although cornstarch dominates the industrial starch market, wheat starch is also used to manufacture industrial products. Roughly 2 to 3 percent of the 2.5-billion-bushel domestic wheat crop will be used industrially.

The United States has imported castor oil since domestic production ceased in 1972. Because of widely fluctuating world supplies, major castor oil buyers have expressed an interest in U.S. production. In response, Browning Seed, Inc., and National Sun Industries are working with scientists and farmers to reestablish castor as a domestic crop. In addition, a consortium of industrial, university, and government organizations has come together to commercialize lesquerella, an experimental crop. Castor and lesquerella are sources of hydroxy fatty acids used by industry in a variety of applications, including cosmetics, waxes, nylons, plastics, coatings, and lubricants.

Glycerine is a byproduct of producing soaps, fatty acids, and fatty alcohols from vegetable oils and animal fats. It has over 1,500 commercial applications, including drugs, cosmetics, resins, polymers, and explosives. The world market for glycerine has fluctuated in recent years. In 1993, expected supplies did not develop while demand remained strong, causing producers to raise their prices. The outlook for the glycerine market is uncertain. Future supply increases may be met by an equally large growth in demand.

The 1993 kenaf harvest has been completed in Louisiana and is underway in California, Mississippi, and Texas. Harvested acreage is estimated at about 3,800 acres. Kenaf processors continue their search for new markets--promising areas include seeding mats and oil-absorbent materials.

In the United States, flax is the most extensively used nonwood fiber employed in papermaking, except for cotton. Because of its long slender fibers, flax pulp is ideal for the production of thin strong papers, such as cigarette, airmail, bible, and light-weight bond papers.

Animal byproducts are used to manufacture pharmaceuticals with a wide range of applications. Advances in biotechnology have resulted in the development of transgenic animals, which may be used as future sources of drugs and organs for human transplants. Chitin--whose most common source is the tough outer shell of shellfish--is used to treat sewage effluent and remove metals from waste water.

U.S. pulp manufacturing is dominated by the kraft process, which uses chemicals in production and bleaching. However, chlorine use has come under scrutiny by the Environmental Protection Agency. Improvements in mechanical pulping, increased wastepaper utilization, and alternative pulping methods are options available to meet changing market and regulatory conditions.

Over 300 medical devices and more than 40,000 products contain hevea latex. Since the mid-1980's, many people have developed allergic reactions to hevea products. Guayule rubber latex has the potential to be a hypoallergenic alternative.

Biodiesel blended with petroleum diesel is being examined as a potential fuel in urban areas to met Clean Air Act standards. But what about using biodiesel on the farm? The special article examines a simulation model that evaluates the feasibility of a community-based 500,000-gallon biodiesel plant in the United States. Soybeans were found to be the most cost-effective feedstock, mainly because the meal is a useful coproduct. Biodiesel costs are heavily dependent upon both the prices paid for the beans and received for the meal. At present, the resulting biodiesel is not competitive with the price farmers pay for conventional diesel fuel.

Federal Programs Help Develop Biobased Industrial Uses

U.S. agriculture likely will have substantial excess capacity for the foreseeable future. However, technological breakthroughs, heightened environmental awareness, and tougher environmental regulations are creating opportunities to use this capacity to produce industrial products. A host of Federal programs are working to help the private sector take advantage of these opportunities.

In recent years, 15 to 20 percent of U.S. cropland is idled annually by Federal farm programs. At present, much of this land is tied up in the Conservation Reserve Program (CRP) and in rebuilding supplies from the effects of this year's poor harvest. But as supplies are restored and CRP ends, the long-term capacity dilemma will reassert itself. This dilemma involves both agriculture's natural resource endowment and productivity growth relative to demand.

The United States has a well developed land base, with over 340 million acres being cropped on a regular basis and another 30 to 40 million acres readily available for conversion from less intensive uses, such as pasture, to intensive cropping. The total number of arable acres has changed little over time.

Productivity growth, 1.5 to 2 percent annually, exceeds increases in domestic demand for farm products associated with income and population growth, possibly 1 to 1.5 percent per year. Without other sources of demand growth, excess capacity may grow and resources will leave agriculture.

Rising exports are one source of demand growth. The North American Free Trade Agreement, the General Agreement on Tariffs and Trade, and U.S. export programs are important efforts to boost demand through improving access to foreign markets. These offer the largest immediate gains in demand for U.S. agricultural products.

Over the long run, however, new uses for agricultural products also promise to expand both domestic and foreign demand for U.S. agriculture goods. Industry has developed some products from agricultural and forestry materials he., biobased feedstocks) over the years, but until recently successes have been few, mainly due to a lack of adequate cost-effective technology. Fortunately, there have been major advances in metabolic engineering, advanced fermentation, reactor development, and separations technology that were not available as recently as 5 years ago. These advances are creating new opportunities.

Industrial Uses Receive Attention at USDA

New opportunities for biobased products have received increased attention at USDA. Many agencies are involved. USDA's Office of Energy and Economic Research Service, together with the Colorado School of Mines, have initiated a major study to determine emission effects of ethanol-blended fuels.

The newly created Alternative Agricultural Research and Commercialization (AARC) Center is now helping a number of public-private ventures bridge the gap between research and commercialization of biobased industrial products. Unique to the AARC Center is a provision for repayment by successful projects. Repayment is typically linked to product sales, so if sales are slow, a firm not strapped for cash in order to meet its repayment obligation.

In its first call for suggested partnerships, the AARC Center received more than 400 preproposals requesting $175 million. While many of the applicants were considered worthy, the AARC Board had less than $10 million to invest, which limited the number of projects it could support. The funded projects include:

- Ethanol from grasses and other biomass sources--three projects in California, Florida, and Texas;
- Paper pulp from straw--Oregon;
- Newsprint from kenaf and recycled fibers--Texas;
- Lawn mats from kenaf--California;
- Structural composites from kenaf--California;
- Furniture parts molded from flaked low-grade lumber--Michigan;

  A granite-like composite board for furniture, tile, and structural use from soybeans and waste newspaper--Minnesota;
- On-farm composting utilizing animal manure, animal bedding, yard waste, and starch-based biodegradable polymers--Pennsylvania;
- Biodegradable films and coatings from wheat starch--Kansas;
- Cornstarch-encapsulated pesticides--two projects in Kansas and Missouri;
- Nontoxic ethanol-based windshield washer fluid--Missouri;
- Three biodiesel projects: production and processing technology in Kansas, production from animal by-products in Florida, and performance standards in Washington, DC;

- Biodegradable lubricants from crambe and industrial rapeseed oils--Washington;
- Biodegradable concrete-release agents from canola and industrial rapeseed oils--Illinois;
- High-value industrial chemicals from corn--Washington;
- Industrial booms, pads, socks, and other items to clean-up chemical spills from low-grade wool--Texas;
- Biodegradable specialty lubricants and cosmetics from lesquerella oil--California/Arizona; and
- Insulation material using milkweed floss--Nebraska.

The third program is being sponsored by USDA's Agricultural Research Service (ARS). ARS strongly encourages its scientists to enter into Cooperative Research and Development Agreements (CRADA7s)with private firms in order to commercialize technology based on their research. These agreements provide the cooperator with the right of first refusal to an exclusive license on patented inventions made under the project. Since the CRADA system was first established in 1986, ARS and the Department of Energy (DOE) have implemented over 800 agreements. Over the last 4 years, ARS has accounted for over 60 percent of USDA expenditures on new uses.

ARS also helped establish the Biotechnology Research and Development Corporation (BRDC). BRDC is a consortium involving ARS, the University of Illinois Biotechnology Center, and seven stockholders; Agricultural Research and Development Corp., American Cyanamid, Amoco Technology Co., The Dow Chemical Co., Allexion, Inc., Hewlett-Packard Co., and IMCERA. The consortium defines research projects that have market potential and enables industry to enter into high-risk ventures that might otherwise be too risky for a single firm to undertake.

BRDC has licensed ARS patents to encapsulate pesticides within a starch matrix. The resulting granule not only protects the active ingredient from deterioration due to handling or storage, but also provides for controlled release when the pesticide is applied. BRDC and four of its shareholders--American Cyanamid, Dow Chemical, ECOGEN, and Pitman-Moore--are investing $475,000 in the new encapsulation process and the AARC Center is investing an additional $500,000.

USDA's Cooperative State Research Service (CSRS), Office of Agricultural Materials, also sponsors biobased activities. Their mission is to foster the development and commercialization of industrial products and processes for the value-added utilization of agricultural raw materials. The Office of Agricultural Materials works with, and funds, university teams to develop processes to manufacture biobased industrial products. Two product-oriented consortia have been formed with non-Federal sources to leverage Federal investments. One is the High Erucic Acid Development Effort (HEADE), consisting of nine States and ARS. HEADE's goal is to assist the development and commercial production of industrial rapeseed and crarnbe, crops high in emcic acid. The other is a consortium to develop technologies to produce natural rubber and other products from guayule.

CSRS also collaborates with the Department of Defense. In fiscal year 1993, 40 projects were funded under the Advanced Materials From Renewable Resources and the Biodegradable Packaging Programs, including:

- Functional fluids--made from rapeseed, crambe, castor, lesquerella, and jojoba oils;
- Oil-selective adsorbents--many plant materials, including kenaf, have a natural affinity for oils and can be used as oil-absorbent pillows and booms and in food processing equipment;
- Vegetable oil epoxies--naturally occumng fatty acids in many plants can be converted to epoxies for use in high-temperature polymers and adhesives, biodegradable adhesives, paints, and coatings;
- Nylon--development of high performance nylons based on agricultural products;
- Biodiesel fuels--facilitation of biodiesel use in selected niche markets;
- Natural biocides and biocidal coatings--several natural sources of biocidal materials from present and new crops are being investigated; and
- Biodegradable polymers from starch--the goal is to provide the Navy with biodegradable eating utensils and packaging materials for use aboard ships. This will help them comply with the MARPOL Treaty which requires, beginning in **1994,** that all materials disposed of at sea be biodegradable.

DOE, NRC, and EPA Also Sponsor Activities

Biomass conversion and utilization research within DOE **are** centered in the Office of Transportation Technologies (OW, the Office of Utility Technologies (OUT), and the Office of Industrial Technologies (OIT). OTT focuses on the **production** of biofuels, such as ethanol and biocllesel from lignocellulosic feedstocks. OUT concentrates on biomass utilization for electricity generation. OIT focuses on the production of non-fuel related chemicals, such as organic acids and solvents.

One of DOE'S most ambitious efforts is the Alternative Feedstocks Program (AFP). AFP recognizes that worldwide use of biomass for food, feed, and fiber accounts for only 7 percent of total biomass production--a tremendous untapped source of energy. Therefore, this program is targeted at developing processes to produce high-volume chemicals from renewable resources. **AFP** is working with the agricultural and forestry industries and the research community to develop high-volume chemicals used to manufacture value-added products.

Environmental considerations should increase the demand for renewable resources. For example, key international companies and industrial organizations recently met in Rotterdam to endorse a set of principles and a charter that will commit them to environmental protection into the 21st century. Also, the 1992 Earth Summit emphasized the need for developing partnerships between countries, industries, and governments to establish a stewardship over the planet's resources and environment.

Moreover, environmental legislation is increasing the costs of traditional processes and, consequently, boosting the attractiveness of biobased alternatives. The Chemical Manufacturer's Association estimated that in 1990, capital expenditures by the chemical industry for pollution abatement amounted to $1.68 billion and associated annualized operating expenditures were about $3.83 billion *(1).* Needless to say, these capital investments coupled with administering applicable laws and regulations have increased product prices. Furthermore, there will likely be efforts to pass tougher environmental legislation.

Given these opportunities, the objective of **AFP** is to develop bio-processes that:

- Enhance profitability and competitiveness of U.S. industry,
- Give significant savings of energy and imported oil over present technology, and
- Serve environmental goals to reduce emissions of greenhouse gases and discharges of hazardous waste.

An initial technical and economic assessment of project opportunities was recently completed through a joint collaboration of five DOE national laboratories and an industry panel. Several USDA scientists and managers contributed to the assessment and are providing suggestions on future analyses. Through various partnerships with industry, AFT will develop biobased processes for large-scale industrial production of high-volume intermediate chemicals. Partnership opportunities include industry solicitations and CRADA's between firms and DOE researchers.

AFP's first report is entitled ***The Alterative Feedstocks Program--Technical and Economic Assessment.*** It contains quantitative, comparative, and process analyses and an economic evaluation of the potential costs and benefits of making 70 chemical products from renewable resources. The report also suggests how these products will be incorporated into the chemical industry.

Another objective of AFP is to demonstrate through industry partnerships the commercial feasibility of biobased processes. AFP managers recommend that two processes be added each year, resulting in a total of 12 under development by the year 2000. Ongoing assessments and program reviews will determine future targets--those technologies of investment grade quality.

Classes of products that could have the biggest potential impact on commodity chemical production were chosen and specific examples for further development within each class were considered. For example:

- Organic acids--succinic acid will be processed from corn syrups, which provides an opportunity to demonstrate the feasibility of producing a commodity chemical from renewable resources, and
- Cellulosic materials--the clean fractionation of biomass is a process being developed that allows separating lignocellulosic material into its three primary components--cellulose, hemicellulose, and lignin--more cleanly than current technologies.

A complementary program within OIT is the Biological and Chemical Technologies Research Program. This applied research and development program provides enabling technology for new industrial chemical and biological processes. A primary focus of the research is to resolve process limitations in converting renewable resources to chemical feedstocks.

The National Research Council W C) has recently begun an analysis of biobased industrial materials. NRC believes the lack of a realistic assessment of key research areas and their commercial viability is preventing the adoption and utilization of many biobased technologies. So, NRC has assembled a committee of experts to address key aspects of researching and commercializing biobased products. The committee is preparing a report designed to provide guidance for future actions by government, industry, and academia. The major sponsors of this study include DOE, USDA, and the National Science Foundation.

In addition, USDA, DOE, and the Environmental Protection Agency entered into a memorandum of understanding in October to establish the AgSTAR program. AgSTAR, a voluntary program, encourages the widespread use of methane recovery technologies to increase livestock producers' profits and demonstrate that industrial and environmental interests can work together to achieve common goals. AgSTAR participants will be able to cut their energy bills and get extra income from manure byproducts. The program will establish demonstration projects, work on improving technology transfer, and facilitate workable financial packages for participants.

To recap, there are a host of Federal efforts to develop biobased industrial products. The goal is to create demand-driven needs for farm-based industrial products that will enhance the profitability and competitiveness of U.S. agriculture and industry, save energy and cut use of imported oil, and serve environmental goals. Douglas Beach and Gregory Gajewski (202) 219-0085]

1. Bozell, Joseph J. and Ron Landucii, editors. ***The Alternative Feedstocks Program: Technical and Economic Assessment.*** Prepared for the U.S. Department of Energy, Office of Industrial Technologies by Argonne National Laboratory, Idaho National Laboratory, National Renewable Energy Laboratory, Oak Ridge National Laboratory, and Pacific Northwest Laboratory, July 1993.

Modest U.S. Economic Growth Ahead for 1994

An accelerating but moderate recovery means solid U.S. economic growth for 1994. This will give a lift to many agricultural producers selling to the industrial sector--especially for goods going to housing, industrial equipment, and consumer durables. Inflation and interest rates are expected to remain low, although picking up slightly.

Most analysts expect that inflation-adjusted Gross Domestic Product (GDP) will grow at about a 3-percent annual rate in 1994. They have revised forecasts upward after seeing surprisingly good third quarter growth, 2.7 percent, even after adjusting for the impacts of the Midwestern flood. An improved fourth quarter, with GDP growth well above 3 percent, is foreseen. The strong growth in employment and industrial production in October and November have led many analysts to expect 4-percent GDP growth in the last quarter of 1993. Few anticipate growth as high as the 5.7-percent gain of 1992's fourth quarter, however.

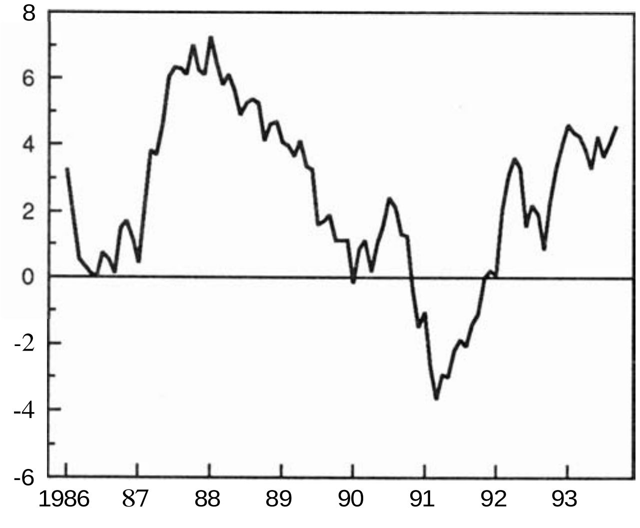
Analysts see a slightly higher than 4-percent annual growth in industrial production (figure 1) for 1993. Although faster growth will increase employment, the unemployment rate will decline erratically as individuals are coaxed back into the labor force in particular months. Rural unemployment is likely to remain close to urban rates for the fourth quarter of 1993. Many analysts expect continued growth in manufacturing employment in December and into 1994, consistent with strong growth in industrial production.

Moderate employment growth and low industrial-capacity use coupled with strong business investment have kept inflation near 2 percent for overall producer prices and under 3 percent for consumer prices for 1993. Despite some initial concern about the impact of the Midwestern flood on inflation, 1993 has been a year of low inflation. Interest rates are expected to rise slightly in the last quarter. They still remain very low by historical standards, leaving 1993 average rates well below those of 1992. Most analysts expect only a modest increase in inflation in 1994. A few analysts, however, are projecting lower inflation in 1994 due to the sharp drop in oil prices at the end of 1993.

Figure 1

Industrial Production

Percent change form previous year



Business spending on plant and equipment and, recently, consumer spending on housing and durable goods have led overall GDP growth during the last few months. In the third quarter of 1993, business investment rose over 10 percent from a year ago. Further, after starting slowly, housing starts are expected to be up 10 percent in 1993 over 1992 and then rise another 8 to 9 percent in 1994. Residential investment for the third quarter was up 5.4 percent from a year ago.

The growth in 1993 was hampered by two major factors: declining Federal spending, particularly on defense, and a sharply increasing trade deficit brought on by stagnant exports and the usual growth in imports as U.S. income increased. The stagnant Japanese economy, the Canadian recession, and a mild decline in the German economy accounted for weak exports, despite a weakening dollar.

The Key to 1994 Is Low Interest Rates

The key to the outlook for 1994 is higher, but still low, interest rates. The consensus has short-term rates rising from 60 to 100 basis points (10 basis points is 0.1 percentage points) above 1993 and long-term rates rising between 40 to 80 basis points. As short-term rates have been flat and long-term rates have taken an unanticipated dive during August to October, most see an average T-bill rate of about 3.8 percent for 1994. Yle 10-year bond rate is forecast to be about 6 percent by the end of 1993. The 10-year bond yield will rise slightly to make the projected 6.5-percent yield average for 1994. By recent historical standards, these low rates will give strength to the continued recovery.

Why will interest rates remain low? Most analysts note that (1) inflation and inflation expectations have abated; (2) growth in Germany and Japan are expected to be about 1 and 2 percent, respectively; (3) the budget accord has credibly reduced out-year deficits and, thus, future demand for credit; and (4) while increasing more than in 1993, U.S. growth will not likely induce a sharp expansion in credit demand. Despite some concern about a resurgence of inflation, recent modest wage growth, low but increasing capacity utilization, strong business investment that indicates future productivity improvement, and slow world growth will likely keep inflation from accelerating.

While business investment was strong throughout 1993, consumer spending is likely to grow at the same rate as GDP, since consumers have used lower interest and mortgage rates to reduce monthly payments--leaving more spendable income. In recent months, consumers have been willing to take on additional non-mortgage debt, contrary to earlier in the recovery. This suggests moderate-to-good growth into 1994 for sales of consumer goods. Continued low interest rates lead most analysts to expect strong growth in consumer durables, with continued good-to-strong growth in auto sales and parts, consumer textiles, and furniture. Government purchases are expected to decline modestly in 1994. The trade deficit will be a drag on U.S. economic growth in 1994, exacerbated by an expected small appreciation of the dollar.

Cost increases are slated to be small in 1994. Low interest rates should keep interest expenses down, and will present opportunities to expand production cheaply. Wage increases have been modest, and with a relatively high unemployment rate, are not likely to accelerate. Unit labor costs in manufacturing should be flat in 1994. The strong investment we have seen suggests good productivity growth in 1994.

Most analysts expect the downsizing of the last 2 years to continue, albeit at a slower pace, as large companies restructure to become more competitive. Industrial production and capacity should move up faster than in 1992 and early 1993. Employment in relatively high-wage manufacturing should continue to rise. So, the pace of the recovery will likely pick up.

With consumption picking up, investment will not have to be the major engine driving growth. The recovery up to mid-1993 had extremely strong growth in business plant and equipment investment. Since then, housing and consumer spending on durables have come in as secondary factors. The typical recovery would have housing starts and consumer durables leading the economy, with business investment picking up sometime thereafter. Most analysts expect to see a pattern more like this in 1994.

Declines in Government Spending and Exports Drag Down Growth?

From the third quarter of 1991 through the third quarter of 1993, spending on defense goods and services fell almost 14 percent (figure 2). while overall and Federal purchases declined 8.3 percent. Most analysts expect this drop to continue, albeit at a slower rate. They also anticipate that lower Federal government spending in 1994 will be the largest drag on economic growth.

This year, net exports have dropped dramatically through the first three quarters, leading some analysts to expect the trade deficit to severely hamper U.S. GDP growth in 1994. The answer to their concern lies in world economic recovery. An expected modest recovery by our trading partners will likely raise U.S. exports enough to prevent the trade deficit from increasing as sharply as it did in 1993. Given the dollar's value, many American manufactured goods are priced very competitively relative to foreign goods of comparable quality. If foreign income increases, more U.S. goods will be exported. This will mitigate the expected rise in imports, which comes with growth in U.S. income.

Figure 2

Production of Defense and Space Equipment

Percent change from previous year

U.S. export growth slowed in 1992 and stagnated in 1993. A large surge in imports led to a large trade deficit in the United States. Although the foreign-exchange value of the dollar remains low and has risen slightly since the beginning of the year--keeping U.S. exports competitive in foreign markets--economic growth abroad has slowed substantially. The developed economies, excluding the United States, have hardly grown. So, were it not for some pickup in our exports to less-developed countries, U.S. exports would have declined instead of stagnated. Large growth in imports, because of strong growth in consumer demand, and no growth in exports has resulted in three consecutive quarters of rising trade deficits--starting with $60 billion in the first quarter of 1993 and expanding further to $80 billion in the third quarter.

The very modest growth expected in developed countries other than the United States implies a modest upturn in U.S. exports in 1994. This will likely be enough to keep the trade deficit from being as large a drag on U.S. growth as it was in 1993. But the deficit probably will be a drag, nonetheless. With growth in Japan expected up 2 percent and Germany expected up only 1 percent, U.S. export growth will likely be muted and, because of expected high imports, the trade deficit will increase moderately in 1994. Agricultural exports in 1993194 are forecast at $42.5 billion, virtually unchanged from a year earlier.

Outlook for Industries Using Agricultural 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. In 1992, housing starts rose 18 percent, and most analysts expect them to rise an additional 10 percent by the end of 1993. Other indicators suggest a continued rebound in construction activity. For example, building permits--an indicator of future construction activity--rose 12 percent for the 12 months ending in September. 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. Most housing analysts forecast a continued 8- or 9-percent increase in housing starts in 1994.

This solid growth will fuel the demand for lumber and wood products, and hence the demand for timber. The residential construction industry uses 21 percent of the output from the nation's saw and planing mills. These mills used 89 percent of the timber harvested in 1987.

While the overall demand for petroleum products is forecast to grow at approximately 2 percent in 1994, the increased demand for lubricants is expected to exceed 5 percent. This presents opportunities for industrial oilseeds, such as castor, industrial rapeseed, and crambe. Wholesaling and retailing, construction, and domestic petroleum and natural gas production are major industrial users of lubricants (table 1). All but domestic petroleum production are expected to grow in 1994. Final demand elements also account for significant shares of lubricant use: 27 percent for personal consumption expenditures and 8.8 percent for gross exports. Light vehicle sales are expected to grow by 5.8 percent in 1994 from the previous year.

Plastics are produced from petrochemicals (natural gas liquids and aromatics produced during petroleum refining). Large amounts of plastic products are used in the packaging, building and construction, and automobile-parts industries. The pickup in housing construction forecast for 1994, fueled by low long-term interest rates, and the expected strong demand for domestic automobiles throughout 1994, translates into strong demand for plastic products and, hence, the petrochemicals from which they are made. These are market opportunities for businesses selling fats, vegetable oils, and starches as ingredients in or substitutes for plastics.

Petroleum Prices Are Declining

Energy markets are important for industrial markets and for industrial uses of agricultural materials. A sharp rise in the price of oil, for example, would stimulate production of alternatives to petroleum-based fuels and lubricants, including those derived from agricultural materials. However, the outlook is for lower petroleum prices in 1994.

The price of crude oil is the key determinant of petroleum-based product prices. Weather and world growth are important secondary factors. A common proxy for aggregate crude oil prices is the weighted-by-sales cost of crude oil imported into the United States--known as the refiner acquisition cost (RAC).

The most commonly reported prices, such as West Texas intermediate crude oil or the New York Mercantile Exchange price, will often be $1 per barrel (42 U.S. gallons) more than the RAC. The Energy Information Administration's (EIA) short-term forecast has the RAC averaging $17.13 per barrel in 1993 and $17.18 in 1994. The RAC was $18.20 in 1992 and, in the first half 1993, it was down to $17.67 per barrel.

The late-November OPEC meeting failed to halt the recent decline in crude oil prices. West Texas crude fell from $18.75 per barrel in mid-November. The oil markets either do not believe that OPEC will adhere to agreed upon quotas andor that the world recovery will gather enough momentum to greatly increase the amount of crude demanded in 1994. As a result, most analysts are expecting that crude oil prices will be about 10 percent lower in 1994 than in 1993--corresponding to EIA's low-price scenario of the RAC averaging about $13 per barrel in 1994. If these analysts are correct, gasoline price should average about $1.20 per gallon and diesel fuel should average about $1.18 in 1994 despite the motor fuel tax increase. [David Torgerson and Arthur Wiese (202) 219-0782]

Table 1--Major industrial users of lubricants and their projected 1994 growth 1/

Industry	Share of lubricant use 2/	Expected 1994 growth 3/
	--Percent--	
Coal mining	3.4	+4.1
Crude petroleum and natural gas	3.9	-4.9 for domestic crude +2.0 for domestic natural gas
Construction	4.3	+3.0
Primary iron and steel	2.7	+3.0
Wholesale and retail trade	5.5	+2.2 for wholesale +2.5 for retail
Automobile repair and service	2.7	N.A.

N.A. = Not available.
1/ Based on the U.S. Department of Commerce's 1982 Input-Output Tables and U.S. Industrial Output 1993. 2/ Industrial users only, does not include commercial or service industries. 3/ From the 1993 base. 9

Future Demand for Ethanol and Adhesives Depend on Environmental Regulations

Producers are optimistic about ethanol's role in the 1990 Clean Air Act Amendments and are expanding their production capacities. The future of biodegradable polymers depends on government legislation and the development of a composting infrastructure. Given a stable 40-percent market share, natural adhesives and glues have great potential for environmentally friendly products. Roughly 2 to 3 percent of the total wheat crop will be used for industrial products in 1993/94, with 1- to 2-percent annual growth expected through 1996/97,

In the last issue of ***Industrial Uses of Agricultural Materials Situation and Outlook Repon*** (June 1993). the combined demand for fuel-oxygenateadditives (primarily corn-based fuel ethanol and natural gas-based methyl tertiary butyl ether [MTBE])--as a result of the 1990 Clean Air Act Amendments (CAM)--was estimated at 3.7 billion gallons of ethanol equivalent by 1995196, or more than three times current ethanol production. Assuming that corn-based ethanol captures 35 percent of the oxygenated fuels market, the demand for ethanol would reach 1.3 billion gallons. This would require an additional 123 million bushels of corn for fuel-ethanol production, thus raising the total use of corn for fuel ethanol to approximately 568 million bushels by 1995196. These estimates depend heavily on ethanol's role in the ozone prevention provisions of the CAAA.

The carbon monoxide (CO) provisions of the CAAA were implemented last winter and the resulting demand for oxygenates was much lower than expected. Estimates of MTBE use range between 1.02 and 1.14 billion gallons, far lower than the 1.40 billion-gallon minimum some industry sources had expected. There were various reasons for the lower-than-expected demand. Fist, some cities that were expected to participate in the program did not--for example, Boston, MA; Duluth, MN; Memphis and Nashville, TN. Second, most analysts believed that refiners would supply towns and areas surrounding non-attainment cities with fuels to meet the CO provisions. Instead, refiners provided the outlying areas with cheaper grades that did not meet the provisions. Third, the number of towns surrounding non-attainmentcities that voluntarily opted to join the program was much smaller than anticipated. Nevertheless, while total use fell short of expectations, oxygenate demand did increase dramatically due to the program.

The second stage of the CAAA is to be implemented in 1995. It requires reformulated gasoline in the nine worst ground-level ozone areas. Because splash-blended ethanol may increase evaporative emissions of volatile organic compounds (VOC's) and ethers like MTBE and ETBE (ethyl tertiary butyl ether) do not, ethanol blends will require lower volatility from the gasoline component than ether-gasoline mixtures. Depending on the cost of decreasing the volatility of gasoline, this could drive up the relative price of ethanol blends, and make it more difficult for ethanol to compete in the ozone non-attainment market. The Environmental Protection Agency (EPA) was scheduled to decide on December 15, 1993, whether to grant ethanol mixtures a waiver from the C A M volatility requirements. At press time, the ruling had not been announced.

Fuel Ethanol Capacity Increases

Even with the possible problems facing biobased fuel ethanol in ozone non-attainment markets, ethanol producers are optimistic about its future. A number of producers are raising their ethanol capacities. On July 24, Cargill broke ground for a $200 million wet-milling corn plant in Blair, NE, that will go on line in 1995. The plant will produce a variety of corn products, including ethanol. The company already has an ethanol facility and will have a capacity of over 100 million gallons when both sites are operational. Also, last January, Midwest Grain Products announced a $40 million expansion in their Pekin, IL, facility that will increase their ethanol capacity to over 90 million gallons per year%y 1997.

Currently, over 32 companies produce ethanol through fermentation, with an annual capacity of over 1.37 billion gallons. Archer Daniels-Midland is the nation's largest ethanol producer with a capacity of 700 million gallons. Pekin Energy, the second largest fermentation producer, has a capacity of 100 million gallons. Other large fermentation producers include New Energy, 70 million gallons; Minnesota Corn Processors, 67 million gallons; South Point, 65 million gallons; A.E. Staley, 50 million gallons; and Midwest Grain Processing, 36 million gallons.

Biodegradable Polymer Use Depends on Legislation, Improved Technology, and Cornposting Infrastructure

In 1992, biodegradable polymer resins captured less than 5 million pounds 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 0 puts total demand at roughly 8.4 million pounds of resin in 1995196.

According to industry analysts, the rate of market penetration of biodegradable polymers will depend upon three factors: the speed at which Federal, State, and local governments enact legislation requiring the use of degradables; how quickly the technology is improved and upgraded; and how quickly the industry can develop an adequate infrastructurefor the collection and subsequent composting of organic waste materials.

On the legislative front, EPA recently issued guidelines stating that six-pack container rings must disintegrate within 35 days of placement in a marine environment. Also, a Florida law mandates that materials labeled as biodegradable do so within 120 days in a landfill. However, most of the legislative response has been aimed at funding increased biodegradable polymer research and development. In 1991, Congress passed an initiative mandating exploration of starch-based technologies and potential applications in biodegradable packaging materials. (See the Introduction.)

With respect to composting, most manufacturers believe that a composting infrastructure is key to the success of biodegradable packaging. Dr. Narayan at Michigan Biotechnology Institute (MBI) argues that the foodservice industry is especially appealing for biodegradable polymers. The industry uses a great deal of plastic packaging daily. Because the plastics are contaminated by food waste, it would require a lot of time and effort to sort and clean the plastics to recycle them. In comparison, food wastes and biodegradable packaging could be collected together, placed in a composting facility, and disposed of in an ecologically friendly way.

Accordingly, MBI created a consortium, Compost Tech, which includes Cargill, Novon, Ecochem, the Minnesota Corn Growers Association, Philip Environmental, and Michigan State University. USDA is providing some basic research funding. The consortium will involve about 17 Burger King restaurants in Grand Rapids, MI, to demonstrate the logistics and economics of composting restaurant waste.

There are two parallel technologies being developed for biobased polymers--one uses starches and the other sugars derived from starch. Currently, the starch-based polymers dominate the industry and are less expensive. Starches are converted to plastic-like materials using a hydraulic, pressurized, mechanical process. However, moisture sensitivity has been a major concern. In comparison, sugar-based polymers make use of a fermentation process to chemically change the sugar directly to a polymer like poly-hydroxbutyrate/valerate or indirectly to lactic acid, which can then be converted into the polymer polylactic acid (PLA). The advantages of sugar-based polymers include high rigidity, long shelf life, and good moisture resistance.

Prices for most biodegradable resins range anywhere from $2 to $5 per pound. In comparison, petroleum-based alternatives cost between 30 and 50 cents per pound. By the most optimistic estimates, biobased polymers will be at least twice as expensive as their non-degradable counterparts in the foreseeable future. Therefore, in the short term, promoters and investors are counting on the environmental advantage of biodegradable polymers to help drive product demand.

Novon Products, a division of the pharmaceutical giant Warner-Lambert, was the leading U.S. producer of starch-based biopolymers, with the capacity to produce 100 million pounds per year. Novon closed its facility in November 1993 and is now using its equipment for other purposes.

Novon's closure could have an impact on the industry, but there are other manufacturers prepared to step into the market. For example, Archer Daniels-Midland has gone into full-scale production of PLA from corn fermentation and Cargill is planning an $8 million, 10-million-pound-per-year PLA plant that will be operational in February 1994. Cargill will produce polylactic acid from corn and other agricultural products. Ecochem, a partnership between DuPont and ConAgm, is also investing in PLA technology. Ecochem currently operates a $20 million lactic acid plant and is planning a $160 million addition to be built by 1995. Ecochem produces PLA from whey, a byproduct of cheese manufacturing.

A number of other companies are also producing biobased polymers. Uni-Star Industries produces a starch-based polymer that is currently used for loose-fill packaging. And American Excelsior produces a starch-based packaging material called Eco-Foam. The leading European producers of biodegradable polymers are Zeneca Bio Products in England (formerly ICI) and Novamont in Italy.

Environmental Concerns Drive the Adhesives Market

As stated in the June 1993 issue of this report, natural adhesives account for over 40 percent, or roughly 2 million tons annually, of total U.S. adhesives demand. Furthermore, the demand for natural adhesives was projected to exceed 2.2 million tons by 1995196. This translates to an additional 600 million pounds of starch by 1995196.

The main difference between natural and synthetic adhesives is in their applications. Synthetic adhesives are tougher and generally more water resistant than natural adhesives. However, current environmental concerns over synthetic adhesive systems and accompanying legislation have spurred new technologies using plant-derived starch.

Many of these new systems are intended for the packaging market.

Continued governmental pressures to reduce VOC emissions in adhesives and sealants are driving manufacturers to use formulations containing 100-percent solids, waterborne materials, and other nonvolatile compounds. There is no current or anticipated Federal legislation to cause radical disruption in the market. However, regional and State regulatory agencies will add greater pressure on lowering VOC's in adhesive formulations in the coming years.

Currently, there are over 600 adhesiv~manufacturers in the United States, producing a variety of both natural and synthetic adhesives and sealants with an estimated market value of over $2 billion annually. H.B. Fuller Company is the leading producer of synthetic adhesives in the United States, while National Starch and Chemical Corporation is the leading producer of natural adhesives. Given a stable 40-percent market share, natural adhesives and glues show great potential for environmentally friendly products.

Industrial Uses of Wheat Starch

Although cornstarch dominates the industrial starch market, wheat starch is also used in manufacturing industrial products, albeit at a much lower level While most of the 2.5-billion-bushel domestic wheat crop produced in 1993194 will be used for food, feed, and seed; the Institute for Local Self-Reliance (ILSR)--a Washington, DC, based non-profit organization--estimates that 50 to 75 million bushels, or roughly 2 to 3 percent of the total crop, will be used for industrial products. ILSR expects a growth rate for existing industrial uses of 1 to 2 percent annually through 1996197.

Also according to ILSR, approximately 3 percent of all fermentation ethanol made in the United States comes from wheat, using about 12 million bushels of wheat each year. Since the late 1980's, industry has been using wheat starch to produce several special grades of biodegradable polymeric resins for plastic applications. Wheat starch is also used in adhesives, building insulations, fertilizers, pesticides, cosmetics, pulp and paper products, pharmaceuticals, and drugs. Other industrial opportunities include body powders, nasal sprays, aerogel insulation in refrigerators and greenhouses, and dish-washing detergents.

Examples of wheat-based industrial producers are:

- Xylan, Inc. (Madison, WI) produces a wide spectrum of goods from wheat components, including dietary fiber from wheat hulls, vital wheat gluten for the paper industry, and ethanol from the wheat kernel;

- Croda (Pasippany, NJ) has recently introduced wheat-based skin care and cosmetic products;

- Nature's Answer (Hauppauger, NY) supplies a line of wheat germ and avocado skin-care products. Specific products include wheat-germ body lotion and wheat-germ face cream;and

- Midwest Grain Products produces fuel ethanol from wheat and is currently in the process of increasing their fermentation ethanol capacity to over 90 million gallons per year by 1997. The company is also expanding its wheat gluten production facility. Wheat gluten is a high-protein ingredient used extensively in bakery products, pet foods, cereals, and has shown promise for nonfood consumer end-products, Douglas Beach (202) 219-0085 and Irshad Ahmed (202)232-4108]

Agriculture and Industry Explore New Crop and Market Opportunities

Castor and lesquerella, both potential U.S. oilseed crops, are sources of hydroxy fatty acids that are used by industry in a variety of applications. Glycerine markets are tight as expected supplies have not developed and demand remains strong. Biodiesel research and testing continues.

Native to Africa, castor is grown throughout the world. In temperate climates, it is an annual crop, while in tropical climates, it is a perennial. Castor seeds contain a high amount of oil--over 50 percent on a dry-weight basis--that is used in a variety of ways. Ancient Egyptians burned it in their lamps. Modem manufacturers have developed many products using castor oil and its derivatives, ranging from lipstick to jet-engine lubricants. The United States has imported an average of 40,630 metric tons of castor oil per year since domestic production ceased in 1972 (figure 3). India is the major U.S. supplier, followed by Brazil.

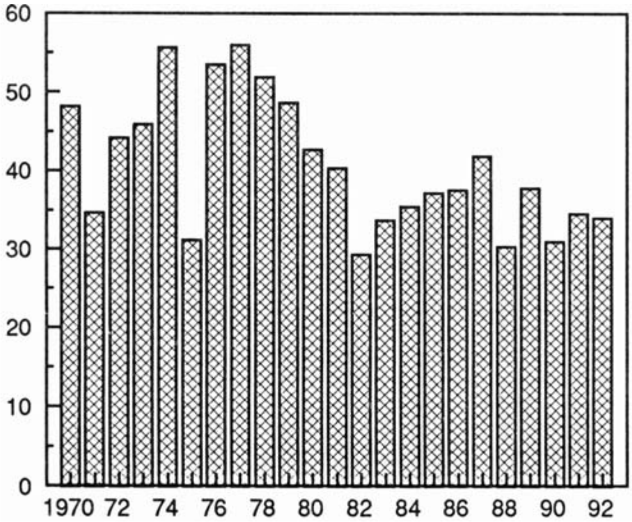
Because of widely fluctuating world supplies and the structure of the world market, prices for castor oil vary considerably. These supply and price instabilities impact cash flow, make corporate planning difficult, and discourage research and investment in castor products. Therefore, major castor oil buyers--Union Camp, CasChem, Alnor, and Atochem--have expressed interest in U.S. castor production. In response, Browning Seed, Inc. (Plainview, TX) and National Sun Industries (Minneapolis, MN) are working with scientists and farmers to reestablish castor as a domestic crop. During the 1950's and 1960's, about 80,000 acres of castor were grown in Texas.

Lesquerella, an experimental crop, may also provide U.S. manufacturers with a domestic source of hydroxy fatty acids and U.S. farmers with a new source of income. A consortium of industrial, university, and government organizations has come together to commercialize lesquerella. USDA's Alternative Agricultural Research and Commercialization Center has committed $776,110 to the project and USDA's Cooperative State Research Service, Office of Agricultural Materials is supporting research to increase yields in 10 U.S. locations.

Figure 3

U.S. Imports of Castor Oil

1,000 metric tons



Plants of the genus Lesquerella are native to North and South America. Of the 85 species, 23 have been examined for agronomic potential and seed composition. Species native to the southwestern United States and northern Mexico are generally rich in lesquerolic acid. Of these species, Lesquerella fendleri--a winter annual--appears to have the best agronomic potential. Its tiny seeds contain over 25-percent oil on a dry-weight basis.

Considerable genetic variation has been observed both within the genus and in L. fendleri, which appears to be highly cross-pollinated. These characteristics provide plant breeders with opportunities to improve yield, the oil content of the seed, the amount of hydroxy fatty acids in the oil, its growth habit (so the plants stand more upright), and other traits needed in a commercial oilseed crop.

The primary fatty acids in castor and lesquerella oils are hydroxy fatty acids. The hydroxyl group (an oxygen atom and a hydrogen atom) gives a fatty acid special properties, such as higher viscosity and reactivity compared with other fatty acids. Ricinoleic acid is the dominant fatty acid in castor oil; it accounts for almost 90 percent of castor's fatty acids. Researchers have identified three principal hydroxy fatty acids in the Lesquerella species examined thus far--lesquerolic, densipolic, and auricolic acids. Depending on the species, one of the fatty acids is dominant. Some species also contain up to 15 percent ricinoleic acid. About 55 percent of L. fendleri's oil is lesquerolic acid.

Hydroxy Fatty Acids Have a Wide Range of Uses

Because of their special chemical attributes, hydroxy fatty acids are used in a wide range of products, including cosmetics, waxes, nylons, plastics, and coatings. Furthermore, they are used in grease formulations for military and industrial equipment. These latter uses have prompted the Department of Defense to include ricinoleic and sebacic acids, castor-oil derivatives, in their stockpile of strategic and critical materials.

Castor oil is used directly in many products, such as transparent soaps, waxes and polishes, hydraulic fluids, inks, and metal drawing oils. However, most castor oil is further processed. The resulting derivatives are used in a wide range of applications. For example, hydrogenated castor fatty acids are an ingredient in lubricating greases for cars, trucks, boats, railcars, aircraft, and industrial equipment. Nylon-11 is used in engineering plastics and powder coatings. Dehydrated castor oil and its fatty acids are components of coatings, inks, and sealants. Polyurethanes are used in electrical and telecommunication casting resins and coatings.

Polymer scientists at the University of Southern Mississippi have used *L. fendleri* oil to make urethane foams, wood stains, and alkyd resins, a common component of paints and coatings. Polyurethane foams are frequently used in dashboards, car seats, and similar items.

In addition, the known properties of fatty acids indicate that lesquerella should be a good raw material in other applications. Ricinoleic and lesquerolic acids have similar chemical structures. This means that both common and different products may be derived from the two hydroxy acids. Where higher molecular weights are important for the chemical properties of the products, lesquerolic acid could be superior. For example, precursors for nylon-13 and nylon-1212 can be produced from lesquerolic acid. Nylon-1212 now comes from petrochemicals, while nylon-11 and sebacic acid are derived from ricinoleic acid.

The remainder of *L. fendleri* oil is composed of oleic, linoleic, and linolenic acids. These fatty acids are commonly found in other fats and oils used for animal feeds and industrial raw materials. Scientists, processors, and manufacturers are faced with the challenge of finding uses that utilize the entire oil or ways to economically separate lesquerolic acid from these other fatty acids. Researchers at USDA's Agricultural Research Service (ARS), National Center for Agricultural Utilization Research (NCAUR) have developed two methods--enzymatic and physical--to concentrate lesquerolic acid to 85 to 90 percent. Another alternative, which is currently being investigated, is to increase the amount of hydroxy fatty acids in the oil.

Lesquerella meal and treated castor meal could be used as protein supplements in livestock rations, primarily for beef cattle. Feeding trials with lesquerella meal are currently underway, and preliminary results are encouraging. Treating lesquerella meal may not be necessary, depending upon the level used in the feed. Texas A&M University has developed technology to detoxify castor meal, which has been proven commercially in Thailand. This process improves the feed value compared with the detoxified castor meal that was fed to Texas cattle during the 1960's and early 1970's.

The Next Steps for Castor and Lesquerella

With domestic production of both castor and lesquerella, U.S. supplies of hydroxy fatty acids would not depend on

Coconut and Castor Oil Prices Forecast to Rise

According to times-series forecasting models, coconut and castor oil prices are expected to rise moderately through January 1994 (table 2). By January, coconut oil prices are to increase 2.9 percent and castor oil prices are forecast at 4.3 percent above October 1993 levels.

The forecasts published in the June 1993 issue of this report are also in the table, as are the actual values. Last issue's coconut oil price forecasts were accurate, while forecasts of castor oil prices generally fell below actual values. Castor oil prices took a sudden 16-percent jump from 32 cents per pound in April to 37 cents in May. This is credited to drought conditions in Brazil's castor production areas, causing a shift to Indian supplies. Prices rose further by about 4 percent in September and 14 percent in October due to concerns over the Indian crop. When making the forecasts for November through January, the castor-oil-price model was adjusted to account for the two large price increases in May and October.

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

Table 2--Price forecasts for castor and coconut oil, 1993194

	Castor oil		Coconut oil	
Month	Forecast 1/	Actual	Forecast 11	Actual
	--Cents/pound--			
May	31.8	37.0	23.7	24.1
Jun	30.6	37.0	25.5	25.0
Jul	31.5	37.0	26.1	25.4
Aug	33.5	37.0	25.4	25.6
Sep	N.A.	38.5	N.A.	24.4
Oct	N.A.	44.0	N.A.	24.0
Nov	44.9	N.A.	24.1	N.A.
Dec	45.7	N.A.	24.0	N.A.
Jan	45.9	N.A.	24.7	N.A.

N.A. = Not available.

1/ May to August forecasts were published in the June 1993 issue of this report.

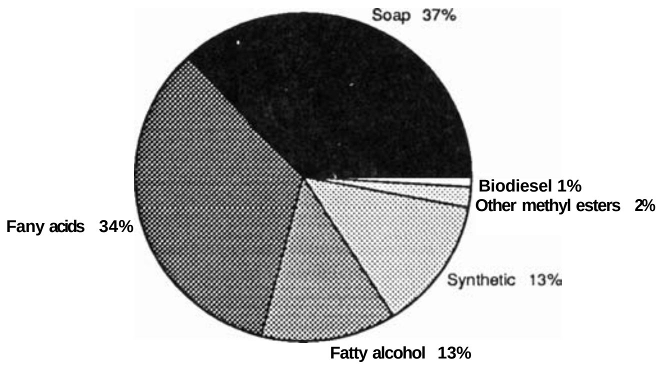
a single commodity. The two crops would be grown in different seasons; lesquerella is planted in the fall and harvested in late spring, while castor is planted in the spring and harvested in late fall. Also, due to disparate requirements for water, temperature, and other climatic conditions, the crops will probably be grown in different parts of the country. Multiple production regions would provide a more reliable domestic supply. This in turn could encourage further product research and development, thus opening additional markets for both crops.

The lack of a crushing facility has been the major obstacle impeding domestic castor production. Plans to produce 10,000 metric tons of castor seed in the Texas High Plains in 1991 stalled when negotiations for crushing the crop failed. Some farmers in the area were also wary of growing castor because of the possibility of contaminating adjacent crops, particularly food-grade corn. However, plans are now underway to crush castor at National Sun's facility in western Kansas. The parties are exploring funding options.

Much work still needs to be done on lesquerella's crop and product development. The consortium, led by Mycogen Corporation (San Diego, CA), has signed a Cooperative Research and Development Agreement with ARS's Water Conservation Laboratory (Phoenix, AZ) to explore lesquerella's growing requirements and other agronomic characteristics. The lab will also work on germplasm collection, evaluation, and enhancement. Mycogen will conduct plant breeding, variety development, and biotechnology research. NCAUR (Peoria, IL) will evaluate a variety of potential applications. International Flora Technologies, Ltd. (Apache Junction, AZ) will develop oil processing technology and high-value applications for the cosmetic industry. The collaborators expect that it will take 5 to 7 years to develop a commercial variety for large-scale production.

Figure 4

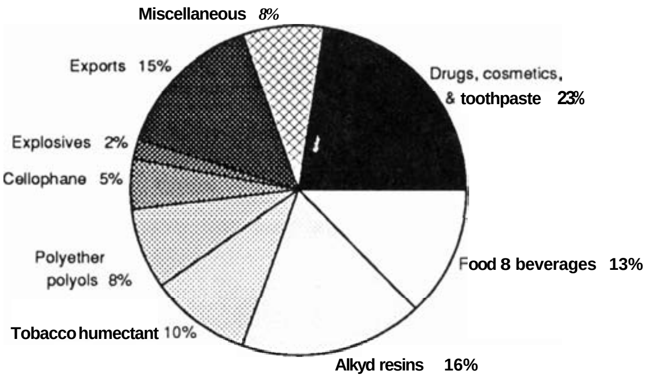
World Production Sources of Glycerine by Primary Product or Process, 1992 1/



1/1992 world production of glycerine is estimated at 1.2 billion pwnds.
Source: Institute for Local Sell-Reliance. Washington. DC.

Figure 5

Estimated End Uses of Glycerine in the United States 1/



1/Annual consumption is estimated at 300 million pounds per year.
Source: Institute for Local Self-Reliance. Washington. DC.

Glycerine Markets Are Tight

Glycerine is a byproduct of producing soaps, fatty acids, and fatty alcohols from the triglycerides in vegetable oils and animal fats (figure 4). Lower cost synthetic glycerine has provided stiff competition since its development around the turn of the century. During the last decade, however, glycerine recovery has been a significant factor in the economics of producing soaps and surfactants from renewable resources. The glycerine credit from biodiesel production has similarly increased the competitiveness of that renewable fuel (see the special article).

End uses for glycerine include diverse products like drugs and cosmetics, resins, polymers, and explosives. Glycerine's chief end uses are drugs, cosmetics, toothpaste, alkyd resins, and tobacco (figure 5). However, it has over 1,500 commercial and industrial applications (table 3). The primary function of glycerine in many cases is that of a humectant (a substance for retaining moisture and, in turn, softness). It also acts as a solvent, sweetener, and preservative in food and beverages, and as a carrier and emollient in cosmetics. Glycerine's properties as a plasticizer and lubricant give it wide applicability, particularly for food processing machinery because it is nontoxic. Glycerine also is used in alkyd resin manufacture to assure flexibility. Alkyd resins find their way into products such as paints and inks where brittleness is undesirable.

Specific examples of glycerine based products that have recently been introduced into U.S. markets include a 100-percent glycerine bar soap that is marketed by Jason Natural Cosmetics (Culver, CA), under the brand name Jason Natural Aromatherapy. Wal-Mart has introduced its own line of glycerine liquid soap under the Sam's American Choice label. And St. Ives Laboratories (Chatsworth, CA) is in the process of introducing a glycerine-based extra mild facial cleansing liquid under the brand name St. Ives Swiss Formula. 3

Table 3--Uses of glycerine by industry

Product category	Uses
Food and beverages	Humectant, solvent, sweetener, and preservative.
Pharmaceuticals	Solvent, moistener, humectant, and bodying agent in tinctures, elixirs, ointments, and syrups; plasticizer for medicine capsules; other uses include suppositories, ear infection remedies, anesthetics, cough remedies, lozenges, gargles, and carrier for antibiotics and antiseptics.
Cosmetics and toiletries	Humectant, vehicle, and emollient in toothpaste, skin creams and lotions, shaving preparations, deodorants, and makeup.
Tobacco	Keeps tobacco moist and soft to prevent breaking and crumbling during processing; ensures freshness in packaged cigarettes and other tobacco products.
Surface coatings	Used in the manufacture of alkyd resins, which are an important component of surface coatings.
Paper and printing	Plasticizer, humectant, and lubricant in the manufacture of paper; used with other ingredients in specialty treatments such as grease-proofing; alkyd resins also an important constituent of many printing inks.
Lubricants	Because of its nontoxic character, used in lubricants for food and other machinery where product purity is essential.
Textiles	Conditioning agent used widely in lubricating, sizing, and softening yarn and fabric; lubricates many kinds of fibers in spinning, twist setting, knitting, and weaving operations.
Rubber and plastics	Lubricant and plasticizer for plastic.
Urethane polymers	Fundamental chemical component of polyethers for urethane foams.
Electrical and electronics	Widely employed in manufacturing electrolytes for electrolytic condensers, which are used in radios and neon lights, and in processes for electrodeposition and treatment of metals.
Nitration	Used to make nitroglycerine, which is the usual explosive in dynamite and a cardiovascular agent.

Source: Glycerine: An Overview, Soap and Detergent Association, Glycerine and Oleochemical Division, New York, NY, undated.

More applications of glycerine are being discovered. Substituting glycerine for polyols is a rapidly growing area. Among the candidates for further substitution are personal-care products, pharmaceuticals, alkyd resins, and detergents.

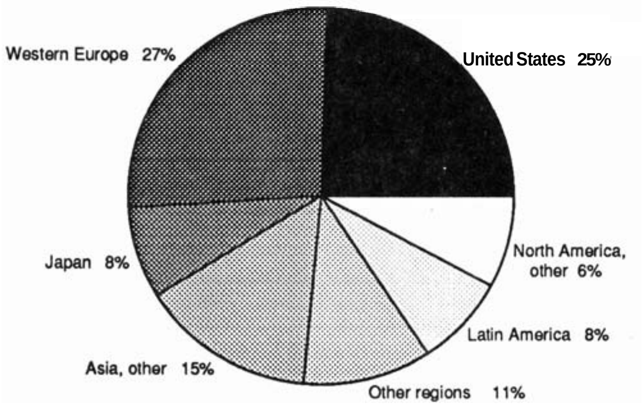
Currently, total world consumption of glycerine is estimated at 1.2 billion pounds annually (figure 6). The United States accounts for 25 percent or 300 million pounds. A 2- to 3-percent annual growth is expected through 1997. If glycerine prices fall to 1991 levels, annual demand could grow 5 to 6 percent.

Analysts are having fits trying to pin down the volatile glycerine market. Last year, prices were expected to fall because of projected increases in supply resulting from greater biodiesel production in Europe and new fatty alcohol production facilities in Asia. These projections, however, have not panned out due to the recession in Europe that lowered fatty acid production, the over-estimation of biodiesel industry expansion, and the slower than expected market entry by new Southeast Asian producers.

In fact, Procter & Gamble Co. (P&G), the largest U.S. producer of natural glycerine, estimates that since 1990, 120 million pounds of glycerine capacity and 85 million pounds of actual production have disappeared from the world market due to plant shutdowns, flat fatty acid production,

Figure 6

World Glycerine Consumption 1/



1/Worldwide use of glycerine is estimated at 1.2 billion pounds per year.
Source: institute for Local Self-Reliance. Washington. DC.

and revised manufacturing processes. This sharp decline in supply prompted P&G to raise prices of glycerine 16 to 20 cents per pound this year. Although many industry experts doubted that the price increase would hold, most of the major producers followed P&G's lead and raised their prices.

The outlook for the glycerine market is still uncertain. Increased interest in natural sources for soaps and surfactants--driven by both cheap vegetable oil supplies and greater demand for "green" cleaners--has resulted in a greater supply of natural glycerine. And an upturn in the biodiesel industry worldwide, coupled with new fatty alcohol production in Malaysia and Indonesia, may further expand glycerine supplies.

These supply increases may be met by an equally large demand expansion. More glycerine uses are being developed each year. And even with the recent price hikes, glycerine is less expensive than its main competitor, propylene glycol.

Biodiesel Research and Testing Continues

Government, industry, and trade associations continue to research and test biodiesel. For example, the National Institute for Petroleum Energy Research recently completed biodiesel engine exhaust emissions tests. Blends of diesel and biodiesel–processed from soybean oil, beef tallow, and/or waste grease (used fats and oils discarded by foodservice operations)--were run in diesel engines commonly found in buses and pickup trucks. The results indicate that the more biodiesel used in the blend, the lower the emissions of hydrocarbons (HC) and carbon monoxide (CO) compared to low-sulfur diesel fuel. However, nitrousoxide (NOx) emissions rose as the amount of biodiesel in the blend increased.

ORTECH, an engine-testing laboratory in Canada, recently completed timing change tests on a Detroit Diesel 6V-92 engine using a diesel fuel blend containing 20-percent biodiesel. Previous research suggested that 20 percent may be the optimum biodiesel blend for city buses using the 6V-92 engine. Results show that a 3-degree timing change decreased NOx exhaust emissions slightly and maintained lower emissions of CO, HC, and particulate matter (table 4).

Numerous demonstration projects are underway in the United States. Most of the demonstrations are being conducted on mass transit fleets in major cities where meeting Clear Air Act standards may be an issue. Many are sponsored by the National SoyDiesel Development Board (table 5). In addition, testing will soon begin at the U.S. Bureau of Mines Twin Cities Research Center (Minneapolis, MN). In order to meet pending regulations, the bureau has been researching strategies to reduce exhaust emissions in mines.

MFA Oil Company, Inc. (Columbia, MO) is the first commercial petroleum distributor to handle biodiesel in the United States. MFA oil is marketing a biodiese/diesel blend to four rural electric cooperatives in Missouri. The cooperatives will use the fuel in their truck fleets. Eewrene Glaser (202) 219-0085, David Pace (606) 257-7272, Irshad Ahmed (202) 232-4108, and Alan Weber (314) 882-4512]

Table 4--ORTECH emissions test results

Test with a Detroit diesel 6v-92 engine	Emissions			
	Nitrous oxides	Carbon monoxide	Hydrocarbons	Particulates
	--Grams per brake horsepower hour--			
Blend of 80-percent #2 diesel and 20-percent biodiesel with a 3degree timing change	4.25	1.50	0.38	0.216
#2 diesel fuel	4.46	1.67	0.45	0.261

Source: ORTECH International, Report No. 93-E14-36. addendum to Final Report No. 93-E14-21,1993.

Table 5--Biodiesel demonstrations sponsored by the National SoyDiesel Development Board and/or State soybean boards

Location	Type of vehicle	Number of vehicles	Status
Lambert International Airport St. Louis, MO	Ground vehicles	100	complete
Bi-State Transit St. Louis, MO	Buses	50	ongoing
Sioux Falls, SD	Buses	16	ongoing
Cincinnati, OH	Buses	6	ongoing
Topeka, KS	Trolley buses	3	ongoing
Gardena, CA	Buses	2	ongoing
Spokane, WA	Buses	18	ongoing
Oakland, CA	Mass transit vehicles	114	ongoing
Santa Cruz, CA	Boats, trucks, and a dredge	7	ongoing
New Jersey	State highway equipment	10	ongoing
Illinois	Mass transit vehicles, farm equipment, truck fleets, and individual trucks	over 100	ongoing

Source: Biodiesel Alert. September 1993.

Natural Fibers

Kenaf and Flax Find Niche Markets

Kenaf processors continue their search for new markets--promising areas include seeding mats and oil-absorbent materials. Fibers from oilseed and textile flax are used in specialty papers.

The 1993 kenaf harvest has been completed in Louisiana and is underway in California, Mississippi, and Texas. Harvested acreage is estimated at 3,795 (table 6). Yields in Louisiana were down slightly from last year due to low rainfall. Yields in Mississippi will be reduced due to late planting (wet field conditions) and the lack of rainfall during the summer. Yields in Texas and California are expected to be over 7 tons per acre on fields grown for fiber, about the same as last year.

Farmers are fitting kenaf into their local production patterns. In Louisiana, kenaf is planted on some fallow sugar cane land. Generally, sugar cane is planted and then harvested annually for 3 years. The field is left out of production for a year before being replanted. Thus, about a quarter of the land is available at any one time for kenaf and other crops. In 1993, 260 acres of kenaf were harvested in Louisiana. The per-acre planting rate is determined by the need for more bast fiber, which would dictate a higher plant density, or more core material, which would mean a lower density per acre.

In Mississippi and Texas, farmers are producing kenaf in addition to traditional crops, such as cotton, soybeans, corn, and sorghum. In Mississippi, farmers sample their fields for nematodes prior to planting susceptible crops, such as kenaf and cotton. When nematodes are present, farmers are using crop rotations--for example, kenaf following corn or sorghum--to reduce their effect. In California, kenaf is being grown on land that has been used in the past for cotton and sugarbeets. In South Texas, a 5-year experiment with a kenaf-sorghum-cotton rotation is in its last year of study.

Table 6--Kenaf acreage, United States, 1992-93 1/

State	1992	1993	Source of moisture
	--Acres--		
California	560	560	irrigated
Georgia 2/	--	60	N.A.
Louisiana	330	260	rainfall
Mississippi	2,800	2,000	rainfall
New Mexico	50	205	rainfall
Texas	481	650	both
Other 2/3/	40	60	N.A.
Total	4,261	3,795	

N.A. = Not available. – = Not applicable.

1/ Data for 1992 represent harvestedacreage. Data for 1993 respresent harvested or projected harvested acreage includina acreage for fiber, seed, and-forage production. 2 /For research.

3/ Arkansas, Florida, and Hawaii.

In Georgia, 60 acres of kenaf--20 acres in three locations--were planted this year to determine if the crop has potential in the State. At this time, it has not yet been harvested. Plans are also underway to test kenaf to make paper, linerboard, and other products.

Kenaf Processors Continue Search for Market Opportunities

During the summer, the Mississippi Delta Fiber Cooperative (Charleston, MS) replaced a major portion of their separation system. Retooling was completed in October, with minor modifications continuing. The facility is operational--processing kenaf into bast fiber for the paper and nonwovens industries and the remaining core material for animal bedding and litter.

Agro-Fibers, Inc. (Angiola, CA), which manufactures and markets lawn-starting and erosion-control mats, is building a mat production facility next to the Mississippi Cooperative. The company received $800,000 from USDA's Alternative Agricultural Research and Commercialization (AARC) Center to install in the Mississippi facility the first manufacturing li'ne devoted solely to kenaf fibers. Commercial production is expected in 1994.

Agro-Fibers now ships bast fibers to a Minnesota mat-manufacturing facility from its fiber-separation plant in California. In Minnesota, grass seeds are embedded in mats of kenaf bast and refined wood fibers. The mats are marketed through garden supply, hardware, and department stores throughout the United States.

The mats are rolled out over lightly prepared soil and watered. The mat stabilizes the seeds until they start growing, usually within 6 to 15 days. As the grass develops, the mat degrades, providing mulch for the newly established lawn. The company also offers a kenaf mat seeded with wildflowers and an unseeded erosion-control mat for use on hillsides and slopes.

K–Mix, Inc., is completing the first phase of their mixing and bagging facility near Kenaf International, Ltd.'s fiber separation facility in LaSara, TX. According to the company, the core material is used in the manufacture of soil-less potting mixes for commercial nurseries.

Kenaf International is developing a strategic plan to establish a kenaf pulp and paper **mill** complex in South Texas, with the help of a $100,000 repayable cooperative agreement from **the** AARC Center. The assistance will enable the company to evaluate the project's current economic viability, prepare financing presentations, and execute implementation strategies.

In cooperation with Kenaf International, Gridcore Systems International Corporation (Carlsbad, CA) has carried out tests with Gridcore panels made from kenaf. The company will evaluate the kenaf-based panels for use in stage sets and trade-show displays. Longer term, Gridcore plans to expand portable applications and develop panels for use in the housing and construction industries. The AARC Center is supporting Gridcore's research program with a $50,000 investment. The company is testing different raw materials and manufacturing processes for various construction, arts-and-crafts, and sporting-goods applications.

Kenaf Exhibits Oil Absorption Properties

Harold and Christopher Willett of Natural Fibers of Louisiana, Inc. (Jeanerette, LA) have received notice that their application for a patent using separated kenaf bast fiber and core material for oil absorption from **dry** or oil-on-water surfaces has been granted. The patent also defines the method of action--the fiber attracts and holds the oil by adhesion while the core absorbs the oil.

Both natural and synthetic fibers can be used for oil absorption. The best materials have surfaces that attract oil and repel water. Natural fibers with wax-like compounds on their surface possess these properties. The porous, sponge-like nature of a material is also important for oil absorption. Kenaf, cotton, milkweed floss, and peat moss meet both these criteria (2).

Inorganic materials, mostly clays, and manufactured synthetic fabrics, predominantly polypropylene mats, have been the main types of sorbents used. Recently, however, natural organic materials have made inroads in specific markets. Several reasons are cited for such a shift, including the following:

- They are biodegradable, which means the used product could be disposed of in a compost facility if the spilled/absorbed liquid could legally be discarded in such a manner.

- They are mostly renewable resources, such as wool, corn cobs, wood byproducts. Peat moss, however, is mined from bogs.

- They have lower per-unit costs than the polypropylene fabrics.

- They have less of an impact on the environment if released or lost during spill clean-up operations.

- They are perceived as environmentally friendly by the public *(1)*.

USDA's Cooperative State Research Service, Office of Agricultural Materials, in collaboration with the Department of Defense, is funding research at the University of Pittsburgh to compare the characteristics of organic oil absorbents and at the University of Houston to develop further uses of organic absorbents such as kenaf. USDA's Agricultural Research Service **(ARS)** is working with several universities on kenaf product research. Scientists at Mississippi and Louisiana State Universities are investigating chemical methods **to** process kenaf into a superior grade fiber for nonwoven applications. Kenaf, in combination with peat moss and/or vermiculite, has shown promise as a horticultural growth medium in tests at Mississippi State University and the University of Delaware. In addition, scientists at USDA's Forest Products Laboratory are developing resin composites based on kenaf and researchers at ARS's Southern Regional Research Center are examining various methods of forming nonwovens made from kenaf.

Flax Fibers Are Used in Specialty Papers

It is estimated that about 250,000 tons of nonwood fiber pulp is produced annually in the United States for use in paper, paperboard, and insulating board. According to Joseph E. Atchison, an expert in the use of nonwood fibers for paper production, these include pulp for specialty papers, such as staple cotton fiber for currency, cotton linters for high-quality letterhead paper, flax straw for cigarette paper, bagasse for insulating board, and abaca (manila hemp) and other specialty fiber pulps for tea bags, filter papers, and sausage casings.

In the United States, flax is the most extensively used nonwood fiber employed in papermaking, except for cotton. Because of its long slender fibers, flax pulp is ideal for the production of thin strong papers, such as cigarette, airmail, bible, and light-weight bond papers.

Two types of flax are grown throughout the world--fiber varieties for the long linen fibers and oilseed varieties for linseed oil and meal. The shorter fiber strands that are a byproduct of processing raw textile flax are known as flax tow. The plant material left in the field after oilseed varieties have been harvested is known as seed flax straw.

Oilseed flax is grown in North and South Dakota, Minnesota, and the prairie provinces of Canada. Two U.S. manufacturers--Ecusta Division of P.H. Glatfelter Company (Pisgah Forest, NC) and the Specialty Division of the Kimberly Clark Corporation (Spotswood, NJ)--buy baled flax straw that farmers deliver to portable decorticating rigs. The straw is processed, separating the long outer fibers from the inner core of the stem. The resulting fiber, called seed flax tow, is then shipped to the two paper mills. At this time, a majority of **seed** flax tow comes from Canada.

Seed flax tow is used as the main ingredient in cigarette paper pulp. According to Frank Riccio of Danforth International

Trade Associates (Point Pleasant, NJ), more than 50,000 tons of seed flax tow are used annually in the North American market. In addition, flax tow and waste are imported to enhance the quality of the cigarette paper pulp. Such imports are estimated to average 7,000 to 10,000 tons per year. The use of flax in cigarette paper may be declining, however. Recent trends indicate that cigarette companies may be moving away from flax-based paper to wood-based paper because it is less expensive.

Noils, a byproduct of linen spinning, is also imported for currency paper. Standard U.S. currency is 80 percent cotton and 20 percent flax. Riccio estimates that about 6,000 tons are imported per year. Most of the high quality flax fiber and yarn imported into this country is shipped to spinners and weavers. Upholstery and draperies are the major uses of the resulting linen fabric. Lewrene Glaser (202) 219-0085]

1. Schrader, Edward L. "A Practical Comparison of Organic, Synthetic, and Inorganic Sorbents." Paper presented at Clean Gulf '93 and the American Chemical Society: Emerging Technology in Hazardous Waste Management.

2. Tiler, Frank M. Department of Chemical Engineering, University of Houston.

Livestock Byproducts and Seafood Wastes Contain Valuable Ingredients

Animal byproducts are used to manufacture pharmaceuticals with a wide range of applications. Advances in biotechnology have resulted in the development of transgenic animals, which may be used in the future as a source of drugs and organs for human transplants. Chitin, isolated from seafood waste, has numerous industrial and food applications.

Many animal byproducts have a vast range of human and industrial applications, which are unknown to most people. In addition, scientific advances, especially biotechnology, are increasing potential uses.

Animal Glands and Byproducts Have Medicinal Value

Numerous pharmaceuticals derived from animal byproducts aid in the treatment of diseases and injuries and facilitate patient recovery. For example, the thyroid gland produces thyroxine, which controls the rate of chemical reactions in the body. Thyroxine from animals is often used to regulate chemical reactions in humans with damaged or diseased thyroid glands. Shortages of thyroxine can bring on lymphatic swellings known as myxedema. Excess secretions can cause resources insomnia, tachycardia, loss of weight, and digestive disturbances.

The pituitary gland produces adrenocorticotrophic hormone (ACTH). ACTH from animals is used to treat rheumatic disorders such as arthritis, rheumatoid arthritis and rheumatic heart disease; collagen diseases like lupus erytheinatosus; various skin diseases; allergic conditions such as bronchial asthma and chronic bronchial asthma; and ulcerative colitis.

Insulin is probably the most well known pharmaceutical derived from animal byproducts. In 1921, Dr. Banting (University of Toronto) established that the failure of the pancreas to supply insulin leads to diabetes, a disease causing damage to blood vessels, eyes, kidneys, and other organs. Two years later, Banting and Dr. Best discovered a method of mass-producing insulin. Since then, progress has been made to improve and develop new sources of insulin from animals. Currently, it requires on average the pancreases of 35 beef cattle or 130 hogs to provide enough insulin for one diabetic for one year.

Animal byproducts are also used to treat circulatory ailments. For example, heparin prevents blood clot formation, growth, and movement. It is extracted from cow lungs and pig intestines. Discovered in 1915 and used since 1938, heparin is essential in open heart surgery, kidney dialysis, and catheterization. And, hog heart valves are widely used to replace defective valves in human hearts. It is estimated that over 30,000 heart valves from pigs have been implanted into humans.

Blood albumin is used as a reagent in testing for Rh factor, as a nutrient in tissue culture media, and as a stabilizer in vaccines. Albumin is generally made from "edible" blood. Edible blood comes from the carcasses of wholesome animals that have passed USDA inspection, and the blood is collected and stored in a sanitary manner. Two percent salt is usually added to the blood to preserve and keep it from thickening.

Blood plasma is obtained by centrifuging whole-beef blood and adding an anti-coagulate to prevent clotting. After centrifuging, the plasma is frozen to manufacture thrombin. Thrombin is a concentrated plasma, capable of clotting blood in a matter of seconds. It is supplied as a sterile, dry powder and applied to bleeding areas in a saline solution. It is used in several types of surgery, skin grafting, and dentistry.

In comparison, "inedible" blood is used in the manufacture of shoe polish and in the sizing of leather. Furthermore, it is used as a feedstock for glues and in animal feeds. Dried blood contains about 87-percent protein. It can also be used by calico printers in fixing certain pigment colors in cloth.

Other pharmaceutical uses of animal byproducts include:

- Pepsin is a digestive ferment obtained from the lining of the pyloric end of pig stomachs and used to aid protein digestion;
- Rennin is a digestive ferment obtained from the fourth stomach of suckling calves, which is used extensively as a milk coagulant in cheese making;
- Peptones of different kinds are prepared from lean muscle tissue and are easily assimilated as proteins or are used in culture media; and
- Thromboplastin is made from the brains of cattle and is used as a blood coagulant.

Genetically Engineered Animals Are a Future Trend

Some of the first animals to be genetically manipulated were mice and rats. More recently, research has been conducted on pigs. Scientific study of these animals is useful because they have physiologies very similar to our own. Thus, they can be used to test potential cures for various diseases, such as AIDS, sickle cell anemia, cystic fibrosis, heart disease, and many other human ailments. Moreover, scientists believe that in the future they will be able to genetically alter animals to supply transplant organs for humans.

Around the world, genetic modification of rodents has become commonplace. Modifications have become so frequent and widespread that a system for cataloging each of the various traits is being established at Oak Ridge National Laboratory. When completed, a scientist can locate rodents with a particular human gene or set of genes.

The United States Patent and Trademark Office issued patents in December 1992 to three organizations for their discoveries on "transgenic" mice. Transgenic animals incorporate a gene from another organism and are able to pass that gene to offspring. This is invaluable for studying how normal genes function and how defective genes cause inherited diseases or lead to other diseases, such as cancer and AIDS. These patents were issued to Harvard University for a mouse that develops an enlarged prostate, a common problem in older men; Gen Pharm for a mouse without a working immune system, developed primarily for AIDS research; and Ohio University for a virus-resistant mouse for use in developing agricultural livestock that are less vulnerable to disease.

Some scientists believe that therapeutics from transgenic animals could be available as soon as 1996. Between 1983 and 1985, researchers showed that transgenic animals could be produced. In 1988 and 1989, transgenic production of livestock was proved possible. Clinical trials began in 1993. Examples of transgenic animals include:

- Genetically engineered pigs are yielding milk containing a complex human protein that prevents blood clotting. With this source, large supplies can be attained more quickly and less expensively than from human sources.

- DNX Corporation (Princeton, NJ) has created pigs with human hemoglobin, which they hope to begin testing in humans as a blood substitute next year. This new supply of human-quality blood will help reduce the cost of collecting blood from humans and eliminate potential disease problems in the blood supply.

- A new blood substitute, called Hemopure, has been developed by Biopure Corporation (Boston, MA) from an extract of cow's blood.

Chitin--A Versatile Product from Seafood Waste

Chitin is a naturally occurring biopolymer, whose most common source is the tough outer shell of crustaceans, such as crabs, shrimp, and crawfish. Chitosan is the deacetylated derivative of chitin, which is a linear polymer of acetylamino-D-glucose. While chitin is used in some applications, chitosan is the preferred material for most uses.

Chitin is the second most commonly occurring organic compound next to cellulose. Even tllough it is found in plankton and mushrooms, commercial applications will most likely come from shellfish wastes.

The United States is a major harvester of crustaceans. In 1992, over 624 million pounds of various crab species were landed. The biggest proportion of these were snow crabs, 350 million pounds, and blue crabs, 192 million pounds. Another large source of chitin would be the 338 million pounds of marine shrimp landed domestically in 1992. **A** third domestic source would be the fresh water crawfish industry. Louisiana annually produces approximately 100 million pounds of crawfish. Over half of this is farm-raised and the rest comes from wild harvests.

The tonnage of domestic crustacean shells available for chitin extraction would be considerably less than the 1 billion plus pounds of landings noted for crabs, shrimp, and crawfish. First, shells are a relatively small portion of the total landed weight. Second, a fairly large percentage of these species are sold to retail markets and restaurants with the shell intact.

The only economic and logistically viable source of chitin would be from facilities where crustaceans are processed in large quantities for meat. While the domestic supply of crustacean shells for chitin extraction is considerably less than total landings, there would still be a substantial amount of raw material available. Since the shells are normally considered a waste product, acquisition costs should be relatively low. Plants would likely be located close to the raw material source because of transportation costs, perishability, and bulk.

To produce chitin, the raw shells are first coarsely ground and then treated with sodium hydroxide to remove proteins. Next, the shells are demineralized in hydrochloric acid. The demineralized shells are dried and ground to the desired size. Chitosan is derived by treating chitin with a strong caustic solution. After this procedure the material is rinsed, ph-adjusted, and dehydrated.

Due to its chemical versatility, chitin or chitosan is used or is being tested for a wide variety of applications. Powdered chitin is used in waste water treatment, while most chitosan is used in food and medicinal applications.

In the industrial area, the major use for chitosan is as a flocculating agent. Chitosan greatly increases the rate at which materials precipitate out of waste water. It is used to treat sewage effluent and the waste water from paper mills. In textile plants, powdered chitosan is being tested to see if it can absorb dyes before the waste water is discharged.

Another major industrial use takes advantage of chitosan's chelating properties. It is used to remove metals from waste materials at metal-finishing facilities. The ability to chelate iron, combined with its flocculating properties, make chitosan especially well suited for use in water-treatment applications.

Moreover, films of chitosan are being evaluated as edible food coatings to prolong the shelf life of fruit products and to keep food ingredients separate during storage. The Army has also evaluated chitosan coatings as a biodegradable packaging wrap.

Currently, the largest agricultural use for chitosan is as a seed coating, primarily wheat. Chitosan protects the seed by activating the seed's natural defenses. Chitosan is also being used to recover soluble proteins from agricultural processing wastes. Still another use is as a binder in pelletized fish feeds.

Developing new uses for chitin and chitosan could also help solve waste problems in the seafood industry. The raw material for chitin production has traditionally been a waste product that was either dumped at sea or disposed of in a landfill. By developing these new uses, shellfish processors will be able to greatly reduce their waste disposal costs. [Donald Van Dyne (314) 882-4512 and David Harvey (202) 219-0085]

Technology and Environmental Issues Face the Pulp and Paper Industry

U.S. pulp manufacturing is dominated by the kraft process, which uses chemicals in production and bleaching. However, chlorine use has come under scrutiny. Improvements in mechanical pulping, increased wastepaper utilization, and alternative pulping methods are options available to meet changing market and regulatory conditions.

The U.S. pulp and paper industry is a competitive player in world markets and a major contributor to the U.S. economy. However, recent economic and environmental trends have buffeted the industry. The recent recession lowered mill utilization rates. At the same time, mandatory recycling and recycled-content laws and regulations brought additional pulping capacity on the market. Lethargic economic conditions in major overseas markets further depressed prices. The result has been poor profits and even some losses. In addition, concerns about dioxins--a byproduct of chlorine bleaching--has led the Environmental Protection Agency (EPA) to propose new regulations to reduce and eventually eliminate chlorine from pulpmaking.

A wide array of pulping methods exist for producing paper and paperboard products. Major categories are processes that use chemicals to dissolve wood and other fibers and those that use primarily mechanical energy to grind the fibers into pulp. Increasingly, recycled wastepaper is also an important source of pulp.

Chemical pulping is by far the most common processing technology. The sulfate or kraft process, as it is called, is the primary method used in the United States, accounting for over **80** percent of pulping capacity (table **7).** The older sulfite process still has a 2-percent share. In comparison, mechanical pulping methods account for about 10 percent of U.S. capacity and semichemical, 6 percent. Dissolving pulp for making rayon, acetate, cellophane, and cellulose products account for the remaining 2 percent.

In 1992, the United States used about **87** million tons of paper and paperboard. Half of this amount consisted of paper boxes and wrapping papers, another third was printing and writing papers and newsprint, while the remainder was tissue and miscellaneous products.

Table 7--U.S. woodpulp capacity, 1970-92

Year	Bleached softwood sulfate	Bleached hardwood sulfate	Unbleached sulfate	Sulfite	Semi-chemical	Mechanical	Dissolving and special alpha	Total 1/
				--1,000 tons--				
1970	7,798	5,781	16,811	2,490	3,811	4,799	1,736	44,725
1971	8,266	6,008	17,091	2,414	3,814	4,680	1,772	45,731
1972	8,971	6,093	17,702	2,353	3,937	5,812	1,756	46,760
1973	8,842	6,936	18,475	2,378	4,171	5,802	1,754	48,459
1974	8,923	7,138	18,451	2,401	4,233	5,930	1,824	48,995
1975	9,025	7,208	18,758	2,420	4,246	6,090	1,671	49,418
1976	9,355	7,227	19,293	2,417	4,402	6,204	1,571	50,469
1977	10,048	7,322	19,552	2,525	4,514	6,442	1,648	51,849
1978	10,442	7,729	19,732	2,095	4,572	6,507	1,573	52,714
1979	10,897	8,078	19,923	2,004	4,553	6,572	1,551	53,636
1980	11,339	8,356	20,288	1,909	4,601	7,069	1,590	55,214
1981	11,757	8,559	20,972	1,855	4,597	7,434	1,598	56,831
1982	12,052	8,705	21,435	1,780	4,734	5,780	1,606	57,638
1983	12,111	9,179	21,206	1,788	4,490	5,814	1,525	57,590
1984	12,490	9,867	21,372	1,750	4,652	6,122	1,487	59,001
1985	12,874	10,750	21,182	1,738	4,650	5,964	1,454	58,617
1986	13,169	11,402	21,381	1,703	4,631	6,058	1,399	59,743
1987	13,623	11,823	21,733	1,646	4,697	5,942	1,389	61,172
1988	14,056	12,450	22,145	1,627	4,787	6,432	1,450	62,950
1989	14,196	13,125	22,465	1,644	4,753	6,636	1,465	64,289
1990	14,412	13,407	22,742	1,689	4,669	6,957	1,486	65,985
1991	15,023	14,097	22,903	1,697	4,547	7,081	1,493	67,402
1992	15,636	14,919	23,062	1,706	4,473	7,077	1,493	68,977

11 Includes screening and other miscellaneous pulps. Therefore, columns do not add to the total.

Source: Pulp and Paper 1993 North American Factbook. Miller Freeman Publications, San Francisco, CA. 1993.

Chemical Pulping Popular With Industry

Chemical pulps are distinguished by cooking woodchips or other fiber sources in a digester that separates the cellulose fibers from the hemicellulose, lignin, and other components. Lignin--a brown, organic material that accounts for about 20 to 30 percent of wood--tends to discolor and weaken paper products over time. Chemical treatments usually remove most of the lignin, while mechanical processes leave much of it.

Kraft pulping can use many wood species and yield strong, easily bleached fibers. The spent cooking liquor (a residual black liquid) also can be washed from the pulp, concentrated, and used for chemical recovery or burnt for fuel in the pulp mill. Bleached haft pulp possesses strength and whiteness, which are preferred for most grades of paper, particularly printing and writing papers. Because of its strength, unbleached kraft pulp is used for brown paper bags, wrapping paper, and shipping sacks.

One of the chief advantages of the kraft process is its economies of scale. Since it is based upon liquid vessels, enlarging their size increases the volume of production faster than the associated variable costs. Therefore, new kraft pulp mills have grown larger over time. A new mill may require $1 billion or more to build. However, few new kraft mills have been built in recent years. Most capacity expansion has been incremental additions to existing mills.

The disadvantages of haft pulping include:

- Low pulp yields of about 45 to 55 percent of wood input;
- Corrosiveness that requires special metals and equipment;
- Potential safety hazards, such as those associated with sulfur compounds; and
- Adverse environmental impacts, such as bleaching waste water discharged into lakes and rivers, which might contain traces of dioxin and other undesirable chlorinated organics, as well as reduce the amount of dissolved oxygen in the water.

Bleaching Techniques Under Scrutiny

Pulp is often bleached to improve purity and brightness. Pulp brightness is measured by optical test instruments using an index of brightness points. Bleached chemical pulps have brightness indices of 85 to 90, semi-bleached chemical pulps of 70 to 80, and groundwood pulps of 55 to 65.

Various methods and chemicals are used for bleaching. One of the most common methods used with kraft pulps employs pure chlorine to remove the remaining lignin. The use of this process has been called into question because of the possible production of dioxins, which have been associated with some forms of cancer. In response, industry has greatly reduced unwanted dioxin byproducts, and new technology makes it possible to detect even minute amounts. EPA has issued proposed regulations that would virtually eliminate discharges of dioxin into rivers by 1998 through the use of chlorine-free technology and/or reduced chlorine use. The agency estimates these changes would cost at least $4 billion, while industry puts the price tag at up to $10 billion. Industry has proposed chlorine dioxide as an alternative to free chlorine.

Mechanical pulping processes use chemicals such as sodium hypochlorite, hydrogen peroxide, or sodium hydrosulfite that typically are not associated with dioxin problems. Totally chlorine free (TCF) pulps can be made with the sulfite and bleached chemi-thermomechanical methods. However, only a few producers--several companies in Sweden and Finland--are now capable of making TCF kraft pulp that is bleached with chemicals such as peroxide, ozone, and oxygen. USDA's Forest Products Laboratory is seeking to establish a consortium with industry to study the potential of an oxygen-and-metal-catalyst bleaching process it has patented with Clark Atlanta University. Research also has been conducted using enzymes for bleaching.

An alternative to bleaching would be to change the standards and preferences of paper users. High-quality business printing and writing papers typically contain chemical pulps bleached for high brightness. Nearly half of all paper and paperboard products use some bleached pulp. The Environmental Defense Fund has established a taskforce of major business users of high grade paper to study and define environmentally preferable papers and to promote these papers to meet personal and business needs. One problem is the large investment U.S. companies have in existing technology--kraft pulping and chlorine-based bleaching.

Technology Improving Mechanical Pulping and Related Processes

The mechanical energy used to convert pulpwood or woodchips to pulp is the distinguishing feature of the mechanical pulping process. The traditional groundwood (GW) grinding process has been only marginally improved since its invention a century ago. The process, which uses short logs, has been declining in popularity in recent decades, but still has a residual capacity of about 8 million tons per day in North America. Pressurized groundwood (PGW) uses a process developed in Finland that makes pulp by grinding logs in a pressurized atmosphere with a conventional grinder. This process improves the strength of the pulp *(1)*.

Refiner mechanical pulp (RMP) is made by fiberizing wood chips in large non-pressurized disc refiners. RMP typically uses sawmill residues and is especially popular in the Pacific Northwest. Thermomechanical pulping (TMP) improved the RMP process by prestreaming the chips and fiberizing them in a pressurized refiner. This method has been particularly successful in the southern United States. A further modification of the TMP process chemically pretreats chips prior to their exposure to steam heat. This method, called chemi-thennomechanical pulping (CTMP), was developed in Scandinavia in the late 1970's and is particularly popular in Canada.

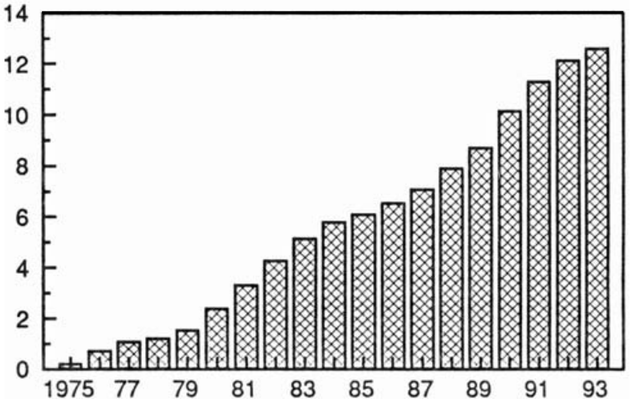
The principal advantage of mechanical pulping methods are higher yields, 90 to 95 percent, compared to chemical yields of 45 to 55 percent (table 8). Mechanical pulping mills are also less expensive to build and can be economical on a smaller scale. However, the pulping requires more energy. The pulps have lower strength and brightness compared to chemical pulps, but higher opacity. Chemical pretreatment of wood chips enhances fiber strength properties and slightly lowers the pulp yield. TMP and CTMP capacity has been growing rapidly in recent years and now exceeds groundwood capacity in North America (figure 7). Major uses for TMP and CTMP pulp include newsprint, uncoated groundwood, and coated publication papers.

A bleached chemi-thermomechanical pulp (BCTMP) mill, on a per ton basis, costs less than one half as much as a new kraft pulpmill and uses about half as much wood as a kraft mill, plus it does not use chlorine compounds for bleaching. Aspen and spruce BCTMP have brightness indexes comparable to chemical pulps. These levels combined with enhancing fillers and coating bring BCTMP close to the brightness of bleached kraft pulps. Switching to neutral alkaline sizing would further improve its smoothness and brightness. Demand for BCTMP is strong in the Far East and growing in Europe. In the United States, it has been restrained by established printing and writing standards that limit mechanical pulp content to 10 percent in free-sheet grades.

Figure 7

Thermomechanical and Chemi-Thermomechanical Pulping Capacity in the United States and Canada

Million metric tons



Source: Pulp and Paper 1993 Factbook,
Miller Freeman Publications, San Francisco. CA. 1993.

Deinking and Wastepaper Utilization on the Rise

Wastepaper recycling is a growing part of the paper industry. High-grade papers, newspapers, magazines, and corrugated boxes are recycled in large quantities. Typically, wastepaper goes through a deinking process to remove printing inks, paper coatings, and other contaminates to produce secondary pulp. Washing, screening, and flotation are used alone or in various combinations.

Deinking capacity has grown rapidly in the last 5 years. Overall wastepaper utilization by U.S. mills has increased from 18.7 million tons in 1987 to 26.1 million tons in 1992 (table 9). Further gains are an industry priority. The American Forest and Paper association recently announced a new goal of increasing wastepaper recovery rates by 25 percent by 2000. The principal uses of deinked pulp are newsprint, tissue, and paperboard grades for making boxes, bags, and wrapping paper.

Table 8--Comparison of kraft and mechancial pulp properties 1/

Pulp type	Yield	Burst index 2/	Tear index 2/	Tensile index 2/	Opacity	Density
	Percent				Percent	Kg/m3
Kraft	45-55	7.10	6.40	116	82	773
Groundwood pulp	95	0.91	1.90	28	97	421
Refiner mechanical pulp	95	0.92	2.00	30	92	389
Thermomechanical pulp	95	1.00	3.80	28	92	417
Chemi-thermomechanical pulp	94	2.10	6.70	47	84	499
Biomechanical pulp	84-95	1.3-1.6	2.5-4.0	30-35	95	402

1/All measurements standardized to 100 ml Canadian Standard Freeness. 2/ Measures the strength of paper in international system units.

Source: Mary Beth Wall, Analysis of Biopulping, a preliminary report submitted in partial fulfillment of Ph.D., 1990, on file at USDA Forest Products Laboratory, Madison. WI.

Table 9--Utilization of wastepaper by U.S. paper and paperboard mills, 1970-92

Year	Wastepaper	Paper and paperboard produced	Utilization rate
	--1,000 tons--		Percent
1970	11,803	51,671	22.8
1971	12,106	53,163	22.8
1972	12,925	57,434	22.5
1973	14,094	59,900	23.5
1974	13,982	59,040	23.7
1975	11,748	50,976	23.0
1976	13,622	58,329	23.4
1977	14,058	60,040	23.4
1978	14,760	62,047	23.8
1979	15,361	64,345	23.9
1980	14,922	63,600	23.5
1981	15,037	64,259	23.4
1982	14,433	60,951	23.7
1983	15,638	66,748	23.4
1984	16,724	70,248	23.8
1985	16,371	68,683	23.8
1986	17,935	72,505	24.7
1987	18,694	75,949	24.6
1988	19,684	78,085	25.2
1989	20,219	78,356	25.8
1990	21,791	80,352	27.1
1991	23,808	80,971	29.4
1992	26,109	83,521	31.3

Source: Pulp and Paper 1993 North American Factbook. Miller Freeman.

One important and growing concept in wastepaper utilization is mini-mills, which are smaller mills located near wastepaper sources and end-use markets. They typically use existing technology and discharge little or no effluent into waterways because they use either a closed system or send it directly to a municipal sewer system. At least 35 wastepaper mills are operating or proposed for construction. They most often produce corrugated medium and linerboard for container board and boxes (2). They may also make tissue, newsprint, and fine grade papers.

Mini-mills provide an alternative where raw material availability and cost, environmental constraints, and/or market demand do not justify larger mills. The economic viability of mini-mills depends upon:

- An efficient design that minimizes capital investment and operating costs;
- A location that minimizes freight charges for rawmaterials and products, thus offsetting labor and other operating cost advantages that traditional mills may possess; and
- Dependable, low-cost raw materials, which may be encouraged by tax incentivesand cooperative programs with municipalities.

Various Technologies Offer Alternatives

The concept of organosolv pulping, which uses organic solvents such as ethanol and methanol to remove lignin, was first proposed in the 1930's, but only recently has a serious attempt been made to commercialize it. In 1989, Repap Enterprises, Inc., began operating a 33-ton-per-day demonstration project in Newcastle, New Brunswick, with the assistance of the Canadian government. The company is looking for a site for a 250-ton-per-day commercial-size mill. Another variation has been developed in Germany and is being commercialized by MD Papier Organocell. A third organosolv process has been investigated by researchers at the University of Alabama.

Advantages of organosolv pulping include lower capital costs, diminished environmental impacts (because byproducts are recovered), and no chlorine. The disadvantages are the complex technology required to wash the pulp and recover the volatile chemicals used in the process and a possible fire or explosion. The chemicals are best used on certain types of hardwoods and may not work with mixed wood species.

A number of processes using various chemicals to improve bleaching or pulping have also been developed. Andritz Sprout-Bauer of Germany has introduced an alkaline peroxide mechanical pulping process to improve bleaching and reduce energy use by as much as 35 percent. C-I-L, Inc. (Montreal, Canada) uses anthraquinone to enhance the kraft process by reducing cooking time and alkali consumption while increasing pulp yields. Kraftanlagen Heidelberg and Feldmuhle AG of Germany are developing an alkali-sulfite-anthraquinone-methanol (ASAM) process to produce a chlorine-free, kraft-like pulp with high brightness and improved yields. The ASAM method also does not produce the sulfur compounds responsible for the pungent odors associated with pulp mills.

Biopulping involves modifying the cell wall in wood by highly specialized white-rot fungi leaving the cellulose for pulping. The organisms soften up the chips for easier delignification by either mechanical or chemical methods. Research on biopulping has been conducted by a number of companies and institutions in the United States and Sweden during the last 40 years. In 1987, a biopulping consortium was established involving the USDA Forest Products Laboratory, the University of Wisconsin, and industry participants to study biomechanical pulping.

Biopulping provides an opportunity to reduce the energy required to refine wood chips and increase the refiner throughputfor mechanical pulping. In addition, organisms would replace chemicals used in the CTMPprocess. Biopulping may also be used in conjunction with chemical pulping processes to pretreat wood chips and reduce chemical use.

Two promising fungi have been found for aspen and loblolly pine. In laboratory experiments, using the organisms reduced electricity consumption in subsequent processing, which resulted in energy savings of 25 to 50 percent. The pulp also had better strength properties than GW, RMP, and TMP. [Thomas Marcin (608) 231-9366]

1. Pulp and Paper *1993* Fact Book. San Francisco, CA; Miller Freeman Publications; 1993.

2. "Will Mini-Mills Play a Maxi-Role in the Future of U.S. Papermaking?" Pulp and Paper, 67(1993):39-47.

Guayule, Neem, and Genetically Altered Tobacco Search for Niche Markets

Guayule rubber latex has the potential to be a hypoallergenic alternative to hevea latex. Neem pesticides are highly effective against target species, yet do not harm beneficial insects or animals. Researchers are beginning to tap into the tobacco plant's protein-producing capacity to make pharmaceutical and industrial compounds.

As stated in the June 1993 issue of this report, guayule rubber presently cannot compete with hevea rubber on price in traditional rubber markets. Establishing premium rubber-product markets, reducing agricultural production costs, and developing value-added products for guayule's other polymer and fiber materials are essential to its commercialization.

Due to the upsurge in demand for latex products in the mid to late 1980's, many foreign manufacturers increased output by cutting "washing" time, which removes proteins and other cell constituents from the latex. As a result, some people experienced allergic reactions to hevea latex products. Health care professionals who routinely wear rubber gloves and patients who undergo multiple surgeries are particularly susceptible. In 1992, more than 500,000 people in the United States were affected by this allergy. Recent studies of these allergic reactions confirm that several hevea proteins are the primary allergens. Since allergic reactions to these proteins can be severe, even fatal, and the number of sensitive people is increasing, alternatives are needed.

These proteins are not found in guayule. Therefore, people allergic to hevea latex could safely use guayule products. In two different clinical studies, a total of 62 hevea-sensitive individuals showed no allergic response to guayule rubber particles. However, they continued to be allergic to purified hevea latex. So, even if hevea-product manufacturers reduce the quantity of these proteins during processing, the small amount remaining would still cause allergic reactions in hevea-sensitive people.

To help commercialize guayule, researchers at USDA's Agricultural Research Service (ARS) have developed a continuous flow extraction process, amenable to industrial scale up, to isolate guayule rubber latex from the rest of the plant. ARS's research recently was supplemented by funding from the Advanced Materials From Renewable Resources Program, a cooperative effort by USDA and the Department of Defense for industrial product development.

The potential for guayule expansion into conventional latex products is promising. Over 300 medical devices and more than 40,000 products contain hevea latex. Surgical rubber gloves and condoms are just two examples. U.S. sales of surgical rubber gloves rose from $234.5 million in 1987 to $2.8 billion in 1992. The U.S. retail market for condoms rose from $103.3 million in 1987 to approximately $500 million in 1992. Considering the small portion of a condom's retail value attributable to higher the latex, higher priced guayule latex should be cost competitive with hevea latex. Furthermore, since manufacturers could market guayule condoms as hypoallergenic, they should be able to charge a higher price and possibly have a greater profit margin.

When guayule is processed for extraction of high-molecular-weight rubber *(HMWR)*, the major coproducts are resin and low-molecular-weight rubber (LMWR). While HMWR could be used for aircraft and land-vehicle tires and other traditional rubber products, value-added uses for resin and LMWR need to be developed. Polymer scientists at the University of Southern Mississippi have investigated several industrial uses for both coproducts. A marine coating that keeps barnacles from attaching to ships and a high-performance adhesive are two of the most promising prospects for guayule resin. Guayule LMWR can be used in high-quality polyurethane coatings, wood fillers, and wood finishes.

Scientists in Arizona, Texas, and California continue to improve agronomic practices for commercial guayule farming--soil nutrients, rainfall/irrigation, and planting and harvesting times, for example--in the hopes of improving yields and reducing costs. Plant breeding and genetic engineering approaches are also being used to improve guayule's natural rubber yields.

Neem Is a "Soft" Pesticide

Native to India and Burma, the neem tree has long been revered as "the village pharmacy" in many Asian cultures. However, some scientific work needs to be done before commercially successful products from neem can be used on U.S. food crops. Proponents of neem claim that the tree contains a powerful pesticide and repellent; is useful for cleaning teeth; is a natural contraceptive; and can heal wounds, infections, skin diseases, and fevers.

Neem-based pesticides are produced in many developing countries by crushing the seeds in a cloth bag and soaking the bag in a barrel of water. The water is then filtered and used as a spray. More modem refining processes can produce pesticides from neem seeds that can be applied as sprays, powders, or diluents in irrigation water.

Currently, neem-derived pesticides are being used in the United States on nursery and landscaping plants. Agri-Dyne Technologies and W.R. Grace have each released neem-based bioinsecticides and expect to enter the fruit and vegetable market once the Environmental Protection Agency approves neem derivatives for food crops.

Most promising is neem's potential to provide a "soft" pesticide--effective against target species and benign to most beneficial insects. Derivatives appear to be extremely effective antifeedants (feeding inhibitors), growth regulators, and repellents. Extracts appear to affect many different pests because of the wide variety of active compounds in the seed. In addition, neem derivatives appear to be completely benign to warm-blooded animals, including humans.

Many plants are able to absorb neem derivatives and transport them throughout the plant. Once absorbed, the pesticide cannot be washed off, the length of protection is often increased, beneficial insects that do not eat the plant tissue are not harmed, and new growth after application is protected.

Azadirachtin, the primary weapon found in neem, is responsible for about 90 percent of the tree's effect on insects and other pests. The chemical does not kill insects immediately--it repels them and disrupts their normal growth cycle. Affected insects often do not mature properly. For example, they do not reach advanced stages of the life cycle, certain features never develop (such as the wings or proboscis), and larvae never emerge from eggs. In addition, the compound repels females from laying eggs on sprayed plants and, in some cases, reduces the number of eggs that they lay. Azadirachtin also appears to be one of the strongest repellents ever found; thesmallest amount of the compound will cause insects to starve to death rather than eat the affected plant. Neem seeds contain 2 to 10 milligrams of azadirachtin per gram.

Meliantriol, vilasinin, and salannin are powerful antifeedants found in neem seeds. Small concentrations of these compounds can cause insects to stop eating altogether. Locusts and grasshoppers, California red scale, most beetles and flies, numerous destructive larva, weevils, fire ants, and several moth species are all greatly affected by these compounds. Other substances in neem apparently paralyze the "swallowing mechanism," thus causing the pest to die.

Neem seeds also contain two antiviral compounds, nirnbin and nimbidin. These are the first virus-inhibiting chemicals found in plants. They seem to be most effective against plant viruses carried by insects. The tobacco mosaic virus, which affects tobacco and some vegetable crops, has been susceptible to neem extracts in early trials. Further testing of neem's antiviral activity is needed before any strong conclusions can be made.

In tropical and sub-tropical climates, neem holds considerable potential as a plantation crop with numerous high-value products. The tree grows well in poor soils under extremely high temperatures and low rainfall. But it cannot withstand freezing, extended cold, or excessive amounts of water. Currently, almost all neem used in the United States comes from India, Africa, and Indonesia. Experimental plots have been planted in southern Florida, California, and Arizona.

Tobacco as a Protein and Drug Factory

Tobacco, long considered one of the major causes of cancer, may play a significant role in fighting that disease as well as other human ailments. Scientists at North Carolina State University (NCSU), along with RJ Reynolds Tobacco Company and Biosource Genetics, have field tested strains of tobacco and tobacco viruses that harness the plant's energy for production of anti-cancer and anti-AIDS drugs, human blood proteins, food-grade protein, and other pharmaceutical and industrial compounds.

According to Raymond J. Long, professor of Crop Science at NCSU, tobacco is readily amenable to genetic manipulation--"it's the white mouse of the plant world." The plant is ideal for producing large quantities of protein and protein products because the bulk of the plant's resources are aimed at developing leaves, not seed, fruit, or flowers as is the case with most food crops. Typical protein yields from tobacco are 2,200 to 2,600 pounds per acre.

Tobacco protein has been used to make an anti-AIDS drug and human serum albumin, a blood protein used to replace blood lost during surgery. Human antibodies and anti-cancer drugs are among the compounds being tested. Preliminary estimates suggest that production of such chemicals in tobacco could gross up to $12,000 per acre. However, farmers would probably not receive this entire amount. Current U.S. tobacco production grosses about $3,500 per acre. In addition, pharmaceuticals from genetically modified plants would have to compete with similarly modified bacteria and animals (see the animal products section).

Permanent gene transfer and the use of genetically altered viruses are two methods used to turn tobacco plants into chemical factories. Permanent gene transfer involves inserting a gene with the desired trait into a tobacco cell's DNA. The cell is then grown into an entire tobacco plant with the new genetic material. This plant is able to produce large quantities of the target chemical and can pass its newfound productive capability to its progeny.

At Biosource Genetics, biotechnologists have spliced into the tobacco mosaic virus and inserted instructions to make an anti-AIDS drug, human hemoglobin, and two enzymes. The altered virus was then sprayed onto a special field of tobacco and the infected plants began running the virus' genetic program. After harvest, the leaves were ground up and the target chemicals were extracted. Commercial use of this technology could occur by 1995. However, none of these new methods of protein production have been approved for commercial use by the Food and Drug Administration. [David Pace (606) 257-7272]

The Feasibility of Producing Biodiesel in the United States Using a Community-Based Facility

by

J. Alan Weber[1]

Abstract: Biodiesel fuel can be made from vegetable oils, animal fats, and waste grease from the food industry. Biodiesel blended with petroleum diesel is being examined as a potential fuel in urban areas to meet Clean Air Act standards. But what about using biodiesel on the farm? Farmer cooperatives in Austria are producing biodiesel for their members. A simulation model was developed to evaluate the feasibility of a community-based 500,000-gallon biodiesel plant in the United States. Soybeans were found to be the most cost-effective feedstock, mainly because the meal is a useful coproduct. Biodiesel costs were heavily dependent upon the prices paid for the beans and received for the meal. The resulting biodiesel is not competitive with the price farmers pay for conventional diesel fuel.

Keywords: Biodiesel, renewable fuels, diesel fuel, soybeans.

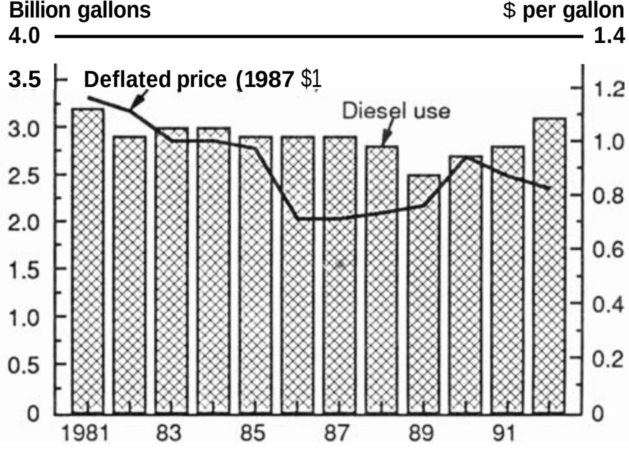
The idea of chemically altering vegetable oils for use as fuel was noted even before World War 11. For example, Walton wrote in 1938, "...to get the utmost value from vegetable oils as fuels it is academically necessary to split off the glycerides and to run on the residual fatty acid" (I). The glycerides are likely to cause excess carbon deposits in comparison with petroleum diesel.

Although not studied extensively until later, animal fats can also be converted into biodiesel. The chemical process used to transform vegetable oils, animal fats, and/or waste grease into usable energy is called "esterification." Esterification changes the large triglyceride molecules in fats and oils into three smaller molecules. The resulting biodiesel has performance characteristics similar to petroleum-based diesel fuel. Biodiesel can be burned in unmodified diesel engines either in pure form or blended with conventional diesel fuel. Extrusion and esterification also yield usable coproducts, like oilseed meal and glycerine.

U.S. Farms Are Significant Users of Diesel Fuel

Figure A-1

Diesel-Fuel Consumption and Price for Agriculture



Real diesel prices for agricultural production declined markedly between 1981 and 1986, stabilized in 1987 and 1988, and then rose slightly in 1989 and 1990 (figure A-1) (2). During this period, on-farm diesel use did not move opposite price as is generally expected. As shown in figure 1, on-farm diesel use trended downward between 1982 and 1989. The two primary reasons for the decrease are greater fuel-efficiency, due to improved technology and a shift toward larger, more fuel-efficient equipment, and dramatic changes in cropping practices, particularly the widespread adoption of no-till and conservation-till.

Since 1989, however, diesel consumption has moved upwards, even though real diesel prices have fluctuated. Greater on-farm use is most likely due to the depletion of agricultural stocks following the drought of the late 1980's, the subsequent lower acreage reduction requirements of Federal commodity programs, and the low price of diesel fuel relative to other energy sources (2).

Potential Demand for Biodiesel

With the increasingly stringent environmental regulations specified in the Clean Air Act Amendments of 1990, biodiesel is being examined as a possible alternative to

---

[1] **Agricultural Economist, Department of Agricultural Economics, University of Missouri, Columbia, MO.**

petroleum-based diesel fuel. Biodiesel is biodegradable and produces less carbon monoxide, sulfur oxides, hydrocarbons, smoke, and particulate matter compared to petroleum-based diesel. (See the fats and oils section for more details.)

Testing suggests that engine power and fuel efficiency of biodiesel and conventional diesel are similar. Biodiesel's viscosity (flow resistance of liquid) is approximately twice that of petroleum-based diesel fuel. Increases in viscosity may cause injector spray problems in some diesel engines. Moreover, the pour point and cloud point of biodiesel are a few degrees higher than regular diesel. Consequently, as with conventional diesel, additives will be necessary to prevent fuel-gelling and/or storage problems in cold weather. On the up side, the higher flash point of biodiesel means safer handling. And biodiesel's cetane rating, which measures a fuel's igniting ability, is greater than that of petroleum-based diesel fuel.

Non-Price Factors Spur Growth of Biodiesel Industry

There are two main forces affecting the biodiesel industry in the United States. Environmental benefits are creating increased interest and research, but poor economics is inhibiting production and use. In Europe, biodiesel is considered environmentally friendly and, in some areas, government incentives are being used to encourage biodiesel production and use. Testing in the United States also supports the claim that biodiesel will decrease engine exhaust emissions.

However, in the United States, refined vegetable oils, which are potential feedstocks for biodiesel production, are currently more expensive than petroleum-based diesel fuel. Lower cost inedible tallow and waste grease from restaurants and fast-food establishments may be cheaper feedstocks, but the resulting biodiesel would still be more expensive than standard diesel.

Nevertheless, because of clean air regulations, many users of diesel fuel--such as urban transit agencies--view biodiesel as a potential option. Some industry experts believe a blend of diesel and biodiesel may be the least expensive way to meet the new air quality standards. It may be less costly to purchase slightly more expensive biodiesel-diesel blends than to retrofit or purchase engines that bum other types of fuel, such as compressed natural gas or methanol. In addition, biodiesel can be used in existing handling facilities, unlike some other alternatives.

Until the Clean Air Act provisions are fully implemented, biodiesel cannot compete on price with petroleum-based diesel fuel in urban areas. But what about on farms? Some have argued that if farmers retain ownership of their oilseeds and eliminate some of the typical marketing charges paid to processors and transporters, then biodiesel may be an economically viable alternative for some agricultural producers.

Biodiesel Production and Use in Austria

Such a program is already underway in several Austrian communities. Austrian farmers grow oilseeds and have them processed into biodiesel and high-quality meal for livestock. Of particular interest is a cooperative arrangement in Neulangbach, Austria. They employ a closed-loop system that eliminates the additional costs that normally accrue to feed manufacturers, feed dealers, and transportation companies. Producers retain ownership of their crop and the resulting products during the entire process, and the cooperative charges a processing fee that covers capital and operating costs.

The cooperative has approximately 290 farmer-members. Production from the 1,235 acres of oilseeds--rapeseed and sunflower--amounts to about 150,000 gallons of biodiesel each year. In addition, around 1,000 metric tons of meal are used by the farmers as a protein source in livestock feed.

Labor requirements are relatively small due to the highly automated plant. Only 4 to 5 man-hours are required each day. The process is totally automated, except when the potassium hydroxide catalyst must be mixed with the alcohol to initiate the esterification process. Strict quality control procedures ensure a consistent product that meets proposed Austrian fuel standards. The plant has been in operation since 1990, producing high-quality biodiesel for use in approximately 700 machines owned by cooperative members. The farmers have recently doubled plant capacity.

Many of the components of this system could be transferred to the United States. However, there are policy differences between the two countries that influence its viability. For example, Austrian farmers receive subsidies to convert acreage from cereal grains to oilseeds. Furthermore, biodiesel is exempt from most of the taxes imposed on petroleum-based diesel fuel in Austria. Neither form of government assistance is currently available in the United States.

Evaluating a U.S. Community-Based System

Dedicated biodiesel plants do not presently exist in the United States. Current production is limited to industries that esterify oils for other products. Therefore, in order to analyze the economic feasibility of producing fuel at the community level, information was gathered from private firms that manufacture equipment that could be used for biodiesel production. This study uses a spreadsheet format to simulate potential economic changes resulting from various scenarios including different feedstocks, input costs, and coproduct values. The simulation model was created in an effort to allow farmers to evaluate potential profits of investing in a community-based biodiesel facility.

The model plant for this study closely parallels the Austrian cooperative. The facility is a closed-loop system, operated as a cooperative, in which farmer-members retain ownership of their oilseeds and processed products. Oilseed crushing and biodiesel production occur at the plant. The cooperative charges a processing fee that covers capital and operating costs. Because any triglyceride can be processed into biodiesel, several feedstock options exist. Oilseeds--like soybeans, canola, and sunflower—as well as animal fats and waste grease can be used.

Biodiesel and oilseed meal are intended for use by the farmer-members. However, either of these products can be sold on the open market. The glycerine coproduct can also be sold on the open market as a commodity chemical (see the fats and oils section).

The extrusion and expelling equipment used in this study is a mechanical-press-based system manufactured by Triple "F," Inc. (DesMoines, IA). The extruders/expellers were first developed in the mid-1960's and accurate operating information is available. The continuous-flow esterification unit is designed by Stratco, Inc. (Leawood, KS). This technology has been evaluated only in a pilot plant. All product input and output data, costs of equipment purchase and operation, repairs, utility usage, and other important cost information were provided by Triple "F" and Stratco for use in this analysis.

The biodiesel facility is assumed to be installed in an existing grain handling facility or feed mill, thus eliminating excessive capital costs. Presently, many small or private grain handling facilities and feed mills are experiencing excess capacity. By utilizing existing facilities overhead costs are minimized. Equipment costs represent the primary capital investment. The annual capacity of the plant is assumed to be 500,000 gallons of biodiesel per year. The unit is highly automated to minimize labor costs.

In order to simplify the analysis, it is assumed that the farmer-members have similar characteristics. They are diversified crop and livestock producers, each able to grow oilseeds and have a need for the meal. They also receive similar prices for their crops and pay similar prices for inputs. Because the model includes the feedstock costs and coproduct values of individual farmers, this assumption is important in order to examine the overall feasibility of the plant. In reality, farmers face various conditions, and individual circumstances would dictate the final residual cost of biodiesel fuels.

As an initial reference point, it is assumed that farmer-members value their oilseeds and meal at the following prices:

- Oilseed prices represent the June 1993 spot market price in central Missouri: $5.60 per bushel for soybeans, $4.25 per bushel for canola, and 11 cents per pound for sunflowers; and

- Two values for soybean meal (44-percent protein) are used: (1) the average 1992 wholesale price ($172 per ton) and (2) the midpoint between the average 1992 wholesale and retail prices (approximately $220 per ton); canola meal (38-percent protein) is valued at $190 per ton; and sunflower meal (28-percent protein) at $140 per ton.[2]

The extrusion/expelling equipment used to simulate a community-based facility is too small to produce 500,000 gallons of soybean-based biodiesel per year. If a higher-content oilseed were used, like canola or sunflower, then the esterification equipment would be fully utilized without purchasing additional extrusion/expelling equipment.

The following additional assumptions were made for this model:

- Utility hookups are available and on-site;

- The extrusion/expelling equipment operates 300 days per year, 24 hours a day;

- Oil yields from crushing are 10 percent for soybeans and 27 percent for canola and sunflowers;[3]

- Esterification equipment operates 330 days per year, 24 hours a day;

- Crude glycerine is valued at 30 cents per pound; and

- Electricity is purchased at 7 cents per kilowatt hour.

The simulation model was designed to consider multiple feedstocks. Soybeans, canola, sunflower, and tallow were evaluated as potential feedstocks (table A-1).

Using Soybeans as the Primary Feedstock

Capital costs for the extrusion and esterification equipment were amortized over 15 years. Under the scenario using soybeans as the primary feedstock, this resulted in an annual cost of $352,109 (table A-2). Soybean and canola purchases account for 79 percent of operating costs. Total annual costs equal $4,288,047.

In 1992, farmers paid approximately $260 per ton for soybean meal, while the average wholesale price was $172--a difference of $88 per ton. Included in this price

---

[2] The meal values for canola and sunflowers are based on a protein content similar to that for soybean meal.

[3] Mechanical presses remove less oil than solvent extraction. In addition, according to representatives from Triple "F," Inc., leaving some residual oil in the meal creates a higher energy protein source for animal feeds.

Table A-1--Economic comparison of multiple feedstocks in a community-based biodiesel plant

Item	Feedstocks				
	Scenario 1	Scenario 2			
	97 percent soybeans/ 3 percent canola 1/	97 percent soybeans1 3 percent canola 2/	100 percent canola	100 percent sunflower	100 percent tallow 3/
			--Percent--		
Capital as a share of total costs	8	8	19	17	35
Crush capacity used	100	100	38	38	0
			-Dollars per gallon--		
Biodiesel cost	2.82	1.26	1.58	2.48	1.83

1/Farmers pay the average 1992 wholesale price of $172 per ton for soybean meal. 2/ Farmers pay $220 per ton for soybean meal--the midpoint between the average 1992 wholesale and retail prices. 3/The price for tallow used in this analysis was 12 cents per pound.

difference are costs of business and ownership changes, a charge for risk, transportation costs, plus profits accruing to those industries that take the meal from the crusher to the farmer.

Given this large differential, two scenarios were examined. The first scenario values the meal at the wholesale price of $172, which means the farmer-members producing livestock would be getting the entire $88 per ton markup. Thus, the return from the community-based facility would be capitalized in the value of the livestock. Under this scenario, coproduct credits equal $2.9 million per year and the associated price of biodiesel is $2.81 per gallon.

The second scenario assumes that farmer-members pay $220 per ton of soybean meal--the midpoint difference between the 1992 average wholesale and retail prices for soybean meal. In this case, the return from the commodity-based system is capitalized in the price of the biodiesel. Coproduct credits equal $3.7 million per year and the associated price of biodiesel is $1.26 per gallon.

Biodiesel Costs Most Dependent on Soybean Prices and Meal Values

Because the assumptions for input costs and coproduct values do not represent the conditions in all rural communities that have an oilseed-livestock production base, sensitivity analysis is used to evaluate the economics of these plants under different conditions. Results indicate that the value of the soybean meal coproduct and the price of soybeans are the most important variables in biodiesel production. When soybean meal prices range from $172 to $240 per ton, the costs of biodiesel range from $2.81 per gallon--which is well above the 82 cents per gallon average on-farm price of diesel fuel in 1992--to 62 cents per gallon, which is slightly below the average diesel price (table A-3). In comparison, if soybean prices increased 20 cents from $5.60 to $5.80 per bushel and the meal price remained the same, then the cost of biodiesel would rise 24 cents to $1.50 per gallon. However, since meal and bean prices generally move together, an increase in the bean price without a subsequent increase in the meal price is unlikely.

All other variables have a smaller impact on the residual cost (price) of biodiesel. For example, a 5-cent increase in the price of unrefined glycerine decreases the price by 4 cents per gallon. Moreover, a 1-cent increase in the cost of a kilowatt hour of electricity boosts the price 8 cents per gallon. Lastly, a $100,000 expansion in facilities and/or equipment would increase biodiesel costs 5 cents per gallon.

The Potential for a Community-Based Facility

This analysis indicates the factors and conditions that must exist if biodiesel is to be produced economically at the community level. With soybeans as the primary feedstock, the study demonstrates the relative importance of coproduct meal and bean prices. Namely, a large spread must exist between the price that farmers receive for their soybeans and the price they pay for their protein meal. In addition, such a production facility would have to be located in areas where farmers raise both oilseeds and livestock. However, the trend in U.S. agriculture has been toward more specialized farms.

With 1992 farm prices for conventional diesel fuel at 82 cents per gallon and no regulatory requirements to use biodiesel in rural areas, farmer-members would be better off selling the soybean oil on the market, using the soybean meal in their livestock operations, and purchasing conventional diesel fuel. Further research on production and processing technology will help biodiesel's competitiveness.

References

1. Quick, G.R. "Oilseeds as Energy Crops." ***Oil Crops of the World.*** McGraw-Hill Publishing Co., 1989, pp. 118-131.

2. U.S. Department of Agriculture, Economic Research Service. ***Agricultural Resources: Inputs Situation and Outlook Report,*** October 1992. .

Table A2--Costs and coproduct credits for a 500,000-gallon community-based biodiesel plant in Missouri, 1993

Item	Scenario 1 wholesale price 1/	Scenario 2 midpoint price 2/
	--Dollars--	
Amortized annual capital costs 3/		
Extrusion & expelling	102,559	102,559
Esterification	249,550	249,550
Total	352,109	352,109
Annual operating costs		
Feedstocks		
Soybeans	3,333,455	3,333,455
Canola	34,775	34,775
Oilseed pressing	329,849	329,849
Esterification 4/	144,894	144,894
Sales and administration	83,408	83,408
Maintainence and other associated costs	9,557	9,557
Total	3,935,938	3,935,938
Total annual costs	4,288,047	4,288,047
Coproduct credits		
Soybean meal	2,764,372	3,535,825
Canola meal	21,057	26,881
Glycerine	115,263	115,263
Total	2,900,692	3,677,969
Net cost of biodiesel per year	1,387,355	610,078
	--Dollars/gallon--	
Net cost per gallon	2.77	1.22
Transportation costs 5/	0.04	0.04
Final biodiesel cost 6/	2.81	1.26

1/Farmers pay the average 1992 wholesale price of $172 per ton for soybean meal. 2/ Farmers pay $220 per ton for soybean meal--the midpoint between the average 1992 wholesale and retail prices. 31The capital costs provided by Triple "F" and Stratco were amortized assuming a 15-year book life, non-regulated firm with 30 percent equity and 10 percent debt, and no tax preferences. These data were developed based on methodology used in a report published by JACOR (a consulting firm in Arlington, VA). which was based on biomass cost estimates developed at Argonne National Laboratory. 41Esterification costs include labor and materials, such as methanol and the catalyst. The methanol was valued at 50 cents per gallon and the catalyst at 30 cents per pound. 5/Transpotiation costs (TC) were approximated by utilizing the following equation: TC = 7 + 0.623 D1. DI equals the distance traveled. Raw material transportation costs were found to be approximately 4 cents for each gallon of soybean oil. Because biodiesel and soybean oil have approximately the same weight. their per-gallon transportation costs are the same. 61Does not include profit margins ebove and beyond the returns to resources assumed needed to bring and hold the resources into use.

Table A-3--Estimated cost of biodiesel from a 500,000-gallon biodiesel plant with varying prices for soybeans and soybean meal

Item	Price	Biodiesel cost
	Dollars per bushel	Dollars per gallon
Soybeans		
	5.25	0.85
	5.50	1.14
	5.60	1.26
	5.80	1.50
	Dollars per ton	
Soybean meal		
	172	2.81
	200	1.91
	220	1.26
	240	0.62

List of Tables

Tables **Page**

1. Major industrial users of lubricants and their projected 1994 growth 9
2. Price forecasts for castor and coconut oil. 1993194 14
3. Uses of glycerine by industry 16
4. ORTECH emissions test results 18
5. Biodiesel demonstrations sponsored by the National SoyDiesel Development Board and/or State soybean boards 18
6. Kenaf acreage. United States. 1992-93 19
7. U.S. woodpulp capacity. 1970-92 24
8. Comparison of kraft and mechanical pulp properties 26
9. Utilization of wastepaper by U.S. paper and paperboard mills. 1970-92 27
10. Industrial rapeseed oil. crude and refined. imports. by country. 1989-92 36
11. Linseed oil. crude and refined, imports. by country. 1989-92 36
12. Linseed oil. crude and refined, exports. by country. 1989-92 36
13. Castor oil. crude and refined. imports. by country. 1989-92 36
14. Tung oil. imports. by country. 1989-92 37
15. Tung oil. exports. by country. 1989-92 37
16. Jojoba oil. imports. by country. 1989-92 37
17. Jojoba oil. exports. by country. 1989-92 37
18. Raw and processed flax. imports. by country. 1989-92 38
19. Raw and processed flax. exports. by country. 1989-92 38
20. Flax yarn. imports. by country. 1989-92 38
21. Flax yarn. exports. by country. 1989-92 38
22. Raw and processed jute and other textile bast fibers. imports. by country. 1989-92 39
23. Raw and processed jute and other textile bast fibers. exports. by country. 1989-92 39
24. Yarns of jute and other textile bast fibers. imports. by country. 1989-92 39
25. Yarns of jute and other textile bast fibers. exports. by country. 1989-92 39
26. Raw and processed sisal. imports. by country. 1989-92 40
27. Raw and processed sisal. exports. by country. 1989-92 40
28. Raw and processed abaca. imports. by country. 1989-92 40
29. Raw and processed abaca. exports. by country. 1989-92 40
30. Raw and processed coir. imports. by country. 1989-92 41
31. Raw and processed coir. exports. by country. 1989-92 41
32. Coir yarn. imports. by country. 1989-92 41
33. Coir yarn. exports. by country. 1989-92 41
34. Natural rubber latex. whether or not prevulcanized. imports. by country. 1989-92 42
35. Natural rubber latex. whether or not prevulcanized exports. by country. 1989.92 *. 42
36. Natural rubber in smoked sheets. exports. by country. 1989-92 42
37. Technically specified natural rubber. exports. by country. 1989-92 42
38. Other natural rubber. imports. by country. 1989-92 43
39. Other natural rubber. exports. by country. 1989-92 43
40. Other forms and aflicles of unvulcanized natural rubber. imports. by country. 1989-92 43

Article tables

A1 . Economic comparison of multiple feedstocks in a community-based biodiesel plant 33
A2 . Costs and coproduct credits for a 500,000.gallon community-based biodiesel plant in Missouri, 1993 34
A3 . Estimated costs of biodiesel from a 500,000.gallon biodiesel plant with varying prices for soybeans and soybean meal 34

Table 10--Industrial rapeseed oil, crude and refined, imports, by country, 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Canada	7,131,254	4,593,176	4,475,384	3,578,674	4,944,622
Germany, West	1,005,137	2,402,960	0	0	852,024
Germany, East	1,546,041	519,765	0	0	516,452
Netherlands	0	2,000,884	0	0	500,221
Sweden	0	2,000,375	0	0	500,094
France	0	1,797,600	0	0	449,400
Total	9,682,432	13,314,760	4,475,384	3,578,674	7,762,813

1/ Includes colza and mustard oils for industrial uses.

Source: Bureau of Census, Department of Commerce.

Table 11--Linseed oil, crude and refined, imports, by country, 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Canada	1,360	837	89,661	346,786	109,661
United Kingdom	874	6,061	3,657	3,866	3,615
Japan	7	0	1,360	0	342
Germany, West	1,217	0	8	0	306
Italy	800	0	0	0	200
Spain	53	129	79	206	117
Netherlands	0	172	69	0	60
France	92	114	0	0	52
Total	4,403	7,313	94,834	350,858	114,352

1/ Not chemically modified.

Source: Bureau of Census. Department of Commerce.

Table 12--Linseed oil. crude and refined, exports. by country, 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Mexico	3,360,557	1,925,760	1,708,302	463,383	1,864,501
Canada	3,102,012	494,202	1,862,142	1,529,508	1,746,966
Netherlands	0	86,235	46,993	882,025	253,813
Korea, South	1,333	0	187,996	412,484	150,453
Jamaica	0	124,495	82,096	31,736	59,582
United Kingdom	2,197	0	21,984	209,880	58,515
Aruba	0	0	206,420	0	51,605
Australia	10,178	19,836	43,510	92,744	41,567
Japan	35,631	0	74,332	27,682	34,411
France	20,126	0	0	80,352	25,120
Trinidad and Tobago	0	54,076	45,833	0	24,977
Other	235,053	322,876	190,105	212,624	240,165
Total	6,767,087	3,027,480	4,469,713	3,942,418	4,551,675

1/ Not chemically modified.

Source: Bureau of Census. Department of Commerce.

Table 13--Castor oil, crude and refined, imports, by country, 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
India	12,290,000	16,136,000	21,616,106	24,355,489	18,599,399
Brazil	22,555,000	13,214,000	12,025,713	8,067,742	13,965,614
Ecuador	1,615,000	1,615,000	804,796	1,042,181	1,269,244
Thailand	70,000	4,000	38,088	211,540	80,907
Philippines	0	0	0	195,840	48,960
Mexico	407,000	0	0	137,658	136,165
Other	898,000	0	39119	6,709	235,957
Total	37,835,000	30,969,000	34,523,822	34,017,159	34,336,245

1/ Not chemically modified.

Source: Bureau of Census. Department of Commerce.

Table 14-Tung oil, imports, by country, 1989-92 11

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Argentina	1,492,842	2,432,420	2,380,280	3,454,809	2,440,088
Paraguay	4,614,047	1,149,176	3,085,121	823,475	2,417,955
China	352,588	463,458	179,360	317,620	328,257
Other	14,825	0	0	400,293	103,779
Total	6,474,302	4,045,054	5,644,761	4,996,197	5,290,079

1 /Whether or not refined. Not chemically modified.

Source: Bureau of Census, Department of Commerce.

Table 15--Tungoil, exports, by country, 1989-92 11

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Canada	139,997	238,302	330,185	199,769	227,063
Mexico	43,286	48,443	103,250	106,437	75,354
Colombia	19,712	19,414	26,122	2,859	17,027
Chile	0	0	29,628	0	7,407
Trinidad and Tobago	0	0	0	14,270	3,568
Other	14,904	4,143	9,370	6,712	8,782
Total	217,899	310,302	498,555	330,047	339,201

11 Whether or not refined. Not chemically modified.

Source: Bureau of Census, Department of Commerce.

Table 16--Jojobaoil, imports by country, 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Mexico	214,524	178,269	381,953	233,210	251,989
Israel	0	2,730	4,004	0	1,684
Japan	0	0	0	864	216
Total	214,524	180,999	385,957	234,074	253,889

1 /Whether or not refined. Not chemically modified.

Source: Bureau of Census. Department of Commerce.

Table 17--Jojobaoil, exports, by country, 1989-92 11

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Germany, West	88,138	144,130	137,178	82,419	112,966
Japan	55,130	63,262	101,492	43,051	65,734
France	11,543	34,630	28,352	25,985	25,128
Netherlands	6,213	13,316	29,045	20,156	17,183
Korea, **South**	5,454	6,060	4,973	10,728	6,796
United Kingdom	3,669	3,757	5,131	9,153	5,428
Mexico	6,952	4,879	2,039	2,739	4,152
Spain	2,160	3,924	3,960	3,960	3,501
Australia	480	2,623	1,125	2,720	1,737
Other	32,832	5,941	10,532	12,722	15,514
Total	212,571	282,522	323,827	213,633	258,138

11 Whether or not refined. Not chemically modified.

Source: Bureau of Census, Department of Commerce.

Table 18--Raw and processed flax. imports, by country. 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Canada	102,835,498	116,412,179	95,886,968	80,692,805	98,956,863
Belgium	25,929,843	21,771,367	17,038,508	20,593,845	21,333,391
Egypt	10,577,158	6,396,933	7,817,589	3,808,706	7,150,097
France	10,001,922	4,469,988	563,523	771,802	3,951,809
China - Mainland	5,047,064	0	0	0	1,261,766
Romania	2,416,133	0	0	0	604,033
U.S.S.R.	1,272,816	0	0	0	318,204
Hungary	763,118	0	0	0	190,780
Other	377,602	115,549	52,045	324,452	217,414
Total	159,221,154	149,166,016	121,358,633	106.1 91.61 0	133,984,357

1/ Processed but not spun. Includes flax tow and waste.

Source: Bureau of Census, Department of Commerce.

Table 19--Raw and processed flax. exports. by country. 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Canada	96,097	107,171	1,146,004	7,843,422	2,298,174
Mexico	206,577	121,054	31,444	90,335	112,353
Brazil	0	104,228	15,660	39,107	39,749
South Korea	0	0	7,899	112,630	30,133
Japan	16,812	16,497	31,097	11,453	18,965
Other	23,649	7,581	5,965	37,967	18,791
Total	343,135	356,531	1,238,069	8,134,914	2.51 8,165

1/ Processed but not spun. Includes flax tow and waste.

Source: Bureau of Census. Department of Commerce.

Table 20--Flax yarn, imports, by country, 1989-92

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Belgium	686,926	969,870	567,429	663,999	722,057
United Kingdom	148,132	100,192	108,553	238,732	148,902
Hungary	128,687	120,737	79,468	106,318	108,803
Ireland	57,639	44,600	45,184	267,495	103,730
Canada	58,418	10,195	39,752	33,648	35,503
West Germany	67,500	37,244	8,192	10,351	30,822
China - Mainland	0	0	47,355	64,333	27,922
Other	18,433	12,493	15,237	136,856	45,757
Total	1,165,735	1,295,331	911,170	1,521,732	1,223,496

Source: Bureau of Census, Department of Commerce.

Table 21--Flax yarn. exports, by country. 1989-92

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Australia	0	215,983	94,795	219,272	132,513
Brazil	0	125,947	15,165	113,450	63,641
United Kingdom	0	51,156	33,590	0	21,187
France	0	7,340	12,092	32,970	13,101
Finland	0	0	42,722	7,849	12,643
Canada	25,503	8,042	9,021	7,430	12,499
Hong Kong	28,778	10,432	4,548	1,590	11,337
Other	15,486	65,692	59,528	78,688	54,854
Total	69,767	484,592	271,461	461,249	321,775

Source: Bureau of Census. Department of Commerce.

Table 22--Raw and processed jute and other textile bast fibers, imports, by country, 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
India	4,447,025	4,165,252	4,327,068	7,179,064	5,029,602
Bangladesh	6,142,991	762,310	2,813,046	3,528,153	3,311,626
China - Mainland	1,896,857	2,288,839	3,643,359	2,149,946	2,494,750
Canada	1,837,808	530,639	765,561	741,595	968,901
Belgium	42,285	112,642	219,539	130,201	126,167
Mexico	429,734	27,800	0	0	114,384
Netherlands	0	396,704	0	1,993	99,675
Thailand	185,040	34,322	44,302	0	65,916
Other	86,979	353,781	239,353	32,391	178,126
Total	15,068,719	8,672,289	12,052,228	13,763,343	12,389,147

1/Processed but not spun. Excludes flax, hemp, and ramie. Includes tow and waste.

Source: Bureau of Census, Department of Commerce.

Table 23--Raw and processed jute and other textile bast fibers, exports, by country, 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Mexico	4,280,485	5,208,013	2,842,093	471,708	3,200,575
Greece	284,125	36,738	1,889,685	1,267,348	869,474
Belgium	2,177,281	66,134	118,007	35,157	599,145
United Kingdom	889,310	458,507	430,353	64,116	460,572
West Germany	1,378,044	0	0	0	344,511
Portugal	1,031,501	0	88,158	0	279,915
China - Mainland	0	1,116,097	0	0	279,024
Canada	3,311	79,773	524,721	270,057	219,465
Other	2,904,300	843,074	1,007,305	1,274,050	1,507,190
Total	12,948,357	7,808,336	6,900,322	3,382,436	7,759,871

1/Processed but not spun. Excludes flax, hemp, and ramie. Includes tow and waste.

Source: Bureau of Census, Department of Commerce.

Table 24--Yarns of jute and other textile bast fibers, imports, by country, 1989-92

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Bangladesh	12,198,925	6,820,078	10,328,358	4,973,104	8,580,116
Thailand	3,111,131	3,505,556	3,323,140	2,208,484	3,037,078
India	671,097	957,946	1,935,672	3,684,483	1,812,300
United Kingdom	827,923	781,223	630,626	786,128	756,475
Canada	454,916	352,537	284,082	208,392	324,982
Belgium	0	191,231	0	0	47,808
Taiwan	39,886	52,145	9,779	580	25,597
Philippines	85,109	981	0	670	21,690
Other	13,086	30,847	480	196	11,154
Total	17,402,073	12,692,544	16,512,137	11,862,037	14,617,200

Source: Bureau of Census. Department of Commerce.

Table 25--Yarns of jute and other textile bast fibers, exports, by country, 1989-92

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
United Kingdom	1,676,864	1,073,989	1,111,341	1,147,519	1,252,429
Mexico	69,165	155,240	124,540	70,454	104,850
Canada	3,539	98,660	15,525	33,532	37,815
Other	17,413	54,103	81,099	53,331	51,488
Total	1,766,981	1,381,992	1,332,505	1,304,836	1,446,582

Source: Bureau of Census, Department of Commerce.

Table 26--Raw and processed sisal, imports, by country, 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Mexico	577,551	433,668	124,982	179,823	329,006
Tanzania	365,773	99,405	345,062	132,000	235,560
Brazil	552,326	119,684	3,307	25,585	175,225
India	143,023	246,026	182,708	80,640	163,099
Kenya	308,797	136,687	61,997	6,536	128,505
Haiti	344,139	79,735	0	0	105,969
Portugal	12,289	80,306	276,688	0	92,321
Canada	21,250	48,881	5,000	2,000	19,283
Philippines	326	61,954	0	13,536	18,954
Other	1,527	5,583	640	5,091	3,212
Total	2,327,001	1,311,929	1,000,384	445,211	1,271,134

1/Processed but not spun. Includes other textile fibers of the genus Agave and tow and waste of these fibers.

Source: Bureau of Census. Department of Commerce.

Table 27--Raw and processed sisal, exports, by country, 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Canada	0	275,467	1,563,368	1,318,259	789,273
Mexico	693,187	226,818	256,059	151,918	331,996
United Kingdom	0	0	804,308	0	201,077
South Korea	35,924	0	261,863	10,000	76,947
Colombia	17,796	79,778	149,832	6,156	63,391
France	0	0	174,516	0	43,629
Other	162,261	153,933	18,604	122,213	114,255
Total	909,168	735,996	3,228,550	1,608,546	1,620,568

1/Processed but not spun. Includes other textile fibers of the genus Agave and tow and waste of these fibers

Source: Bureau of Census. Department of Commerce.

Table 28--Raw and processed abaca, imports, by country, 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Philippines	16,825,248	15,968,271	16,763,547	12,706,916	15,565,996
Ecuador	7,442,099	7,895,837	9,083,169	7,528,651	7,987,439
United Kingdom	187,084	8,488	312,704	47,422	138,925
Chile	187,005	140,251	0	0	81,814
Brazil	99,208	0	198,416	0	74,406
Other	51,209	0	50,045	218,531	79,946
Total	24,791,853	24,012,847	26,407,881	20,501,520	23,928,526

11 Processed but not spun. Includes tow and waste.

Source: Bureau of Census, Department of Commerce.

Table 29--Raw and processed abaca, exports, by country, 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Spain	0	0	0	250,449	62,612
Yeman (Sana)	0	0	0	147,498	36,875
United Kingdom	0	0	56,474	0	14,119
Other	12,588	26,115	0	0	9,676
Total	12,588	26,115	56,474	397,947	123,282

11 Processed but not spun. Includes tow and waste.

Source: Bureau of Census. Department of Commerce.

Table 30--Raw and processed coir, imports, by country, 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Sri Lanka	11,941,444	19,053,166	16,825,256	17,556,301	16,344,042
Mexico	218,293	24,826	0	410,567	163,422
India	0	144,402	34,141	78,484	64,257
West Germany	463	0	231,083	7,716	59,816
Philippines	46,848	0	24,434	154	17,860
Dominican Republic	0	41,061	0	0	10,265
Other	70,944	467	0	5,556	19,242
Total	12,277,992	19,263,922	17,114,914	18,058,778	16,678,904

1/Processed but not spun. Includes tow and waste.

Source: Bureau of Census, Department of Commerce.

Table 31--Raw and processed coir, exports, by country, 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Canada	639,760	49,645	274,230	325,539	322,293
Japan	0	0	87,794	455,556	135,838
United Kingdom	0	0	0	340,692	85,173
Argentina	0	0	38,457	0	9,614
Jamaica	36,173	908	0	0	9,270
Other	0	25,719	31,883	2,582	15,047
Total	675,933	76,272	432,364	1,124,369	577,235

1/Processed but not spun. Includes tow and waste.

Source: Bureau of Census. Department of Commerce.

Table 32--Coir yarn, imports, by country, 1989-92

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Sri Lanka	2,406,509	4,729,525	5,944,484	5,206,422	4,571,735
India	912,553	1,225,338	1,103,558	1,252,418	1,123,467
Total	3,319,062	5,954,863	7,048,042	6,458,840	5,695,202

Source: Bureau of Census. Department of Commerce.

Table 33--Coir yarn, exports, by country, 1989-92

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
United Kingdom	10,007	0	0	0	2,502
Canada	4,433	0	0	0	1,108
Other	7,705	584	1,940	789	2,754
Total	22,145	584	1,940	789	6,364

Source: Bureau of Census. Department of Commerce.

Table 34-Natural rubber latex, whether or not prevulcanized, imports, by country, 1989-92

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Malaysia	47,281,074	30,647,343	40,000,125	45,279,103	40,801,911
Indonesia	24,854,303	18,984,373	26,186,096	35,261,454	26,321,557
Liberia	34,149,716	14,559,649	20,160	0	12,182,381
Other	13,506,287	8,266,081	12,832,958	6,111,053	10,179,095
Total	119,791,380	72,457,446	79,039,339	86,651,610	89,484,944

Source: Bureau of Census, Department of Commerce.

Table 35--Natural rubber latex, whether or not prevulcanized, exports, by country, 1989-92

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Canada	12,185,785	3,227,593	3,027,736	1,820,378	5,065,373
Mexico	711,748	989,194	892,819	1,589,600	1,045,840
Italy	1,134,076	908,833	770,549	1,075,446	972,226
Other	3,637,189	4,181,653	4,261,004	2,975,341	3,763,797
Total	17,668,798	9,307,273	8,952,108	7,460,765	10,847,236

Source: Bureau of Census. Department of Commerce.

Table 36--Natural rubber in smoked sheets, exports, by country, 1989-92

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Mexico	429,950	610,631	92,616	131,928	316,281
Canada	183,102	93,640	95,157	22,332	98,558
Korea, South	93,205	16,941	0	17,233	31,845
Other	208,378	114,821	28,951	17,564	92,429
Total	914,635	836,033	216,724	189,057	539,113

Source: Bureau of Census, Department of Commerce.

Table 37--Technically specified natural rubber, exports, by country, 1989-92

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Venezuela	7,837,358	3,098,034	3,555,964	552,087	3,760,861
Canada	9,872,707	860,875	803,002	1,040,715	3,144,325
Mexico	302,689	438,955	3,974,014	1,991,931	1,676,897
Other	195,775	716,280	1,213,533	683,496	702,271
Total	18,208,529	5,114,144	9,546,513	4,268,229	9,284,354

Source: Bureau of Census. Department of Commerce.

Table 38--Other natural rubber, imports, by country, 1989-92 1/

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Indonesia	6,466,297	5,230,125	25,591,984	32,927,796	17,554,051
Malaysia	7,486,177	7,058,857	6,972,848	10,872,011	8,097,473
Thailand	1,655,398	1,383,060	4,839,936	12,261,838	5,035,058
Other	5,262,915	5,868,934	5,037,709	8,938,940	6,277,125
Total	20,870,787	19,540,976	42,442,477	65,000,585	36,963,707

1 /Natural rubber other than smoked sheets and technically specified natural rubber.

Source: Bureau of Census. Department of Commerce.

Table 39--Other natural rubber, exports, by country, 1989-92 11

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Canada	337,777	845,538	498,827	490,532	543,169
Mexico	499,295	240,262	129,618	64,357	233,383
Venezuela	34,706	337,646	312,991	11,689	174,258
Other	302,469	266,492	496,574	478,878	386,103
Total	1,174,247	1,689,938	1,438,010	1,045,456	1,336,913

1 /Natural rubber other than smoked sheets and technically specified natural rubber.

Source: Bureau of Census, Department of Commerce.

Table 40--Other forms and articles of unvulcanized natural rubber, imports, by country, 1989-92 11

Country	1989	1990	1991	1992	4-yr avg
			--Kilograms--		
Thailand	3,957,064	604,976	408,930	274,925	1,311,474
Canada	103,507	143,016	1,054,661	1,698,189	749,843
Taiwan	1,540,468	686,934	421,398	289,144	734,486
Malaysia	331,282	309,957	72,089	36,506	187,459
Japan	503,465	24,483	1,843	3,053	133,211
Italy	263,563	403	522	0	66,122
United Kingdom	177,339	82,928	3,349	9	65,906
Brazil	207,311	26,891	2,628	2,802	59,908
Sri Lanka	115,108	77,589	0	41,513	58,553
Other	286,634	174,248	45,143	106,922	153,237
Total	7,485.741	2,131,425	2,010,563	2,453.063	3,520.199

11 ***Rods,*** tubes, and profile shapes are examples of other forms. Discs and rings are examples of other articles.

Source: Bureau of Census. Department of Commerce.