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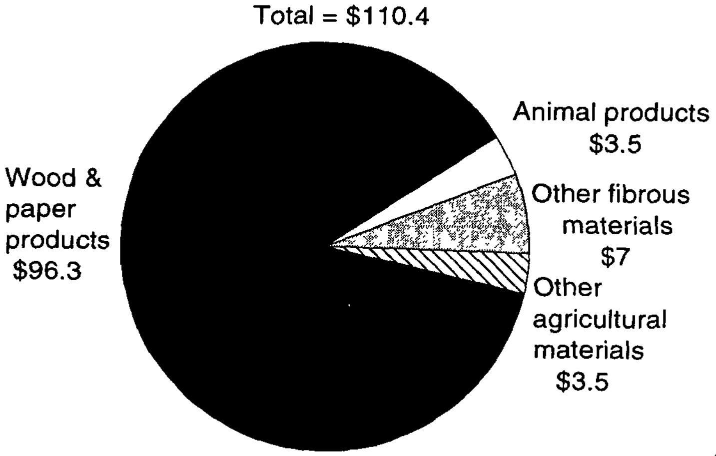
Industrial Uses of Agricultural Materials

Situation and Outlook Report

Value and Type of Agricultural and Forestry Materials Used in Manufacturing in 1992
(Billion dollars)



Last Issue!
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Summary

Industrial Use of Agricultural and Forestry Materials Estimated at $110 Billion in 1992

An estimated $110 billion worth of agricultural and forestry products were used as raw materials in the manufacture of industrial (nonfood, nonfeed) products in 1992, according to the most recent census data available. Wood and paper products accounted for $96 billion, more than 87 percent of the total. Other fibrous materials, animal products, natural rubber, and vegetable oils were among the other agricultural materials used in the manufacture of nonfood items.

After wood and paper products, other fibrous materials (with a total value of nearly $7 billion) were the next largest category of agricultural materials used by industry in 1992. Raw cotton use (estimated at $3.1 billion) accounted for 45 percent of all fibers. Other cotton products, including cotton yarns, fabrics, felt, linters, and waste, added another $3.3 billion. Animal products were the third largest category of agricultural materials used as industrial inputs in 1992, totaling nearly $3.5 billion. Hides, skins, and pelts, valued at $1.2 billion, were purchased by the leather and leather products industry. Another $1.5 billion of finished leather was used in the manufacture of leather products and apparel.

The extraordinary 5.9-percent growth in the U.S. Gross Domestic Product (GDP) in the first quarter of 1997 will give way to more moderate growth for the rest of 1997 and 1998. Even as GDP growth moderates, the economy will support manufacturing output growth of 4.0 percent for 1997. Forces driving the manufacturing sector will spur modest growth in industries that use agricultural inputs.

Industrial uses of corn in 1996/97 are expected to total 681 million bushels, up from the 642 million used in 1995/96. Ethanol production has rebounded from the low levels experienced in 1995/96, averaging 81,000 barrels per day from January to June 1997. Markets are growing for citric and lactic acids, two organic chemicals usually derived from starch and sugar feedstocks.

Soybean meal is being used to make adhesives and composites. Soybean oil is finding its way into plastics, inks, and solvents. In 1996, about 300 million pounds of soybean oil were used in inedible applications, accounting for 2.5 percent of total consumption.

In the United States, composite building materials are being made from straw. Straw bales are being used in the construction of buildings. Researchers are investigating straw as a raw material for paper. Uses of kenaf continue to expand. Numerous companies are producing and selling kenaf-based products.

Crambe is a new industrial oilseed being grown in North Dakota. A special article presents analysis, using an input-output model, estimating the economic effects of crambe production, the construction of an oilseed processing plant to handle the crop, and the crushing of the crop in a 15-county region in central North Dakota. The results indicate that nearly $10 million in total sales and 42 new wage and salary jobs will be added to the region as a direct result of the increase in the production and processing of the 1997 crambe crop. Through local purchases of supplies and the spending of crambe-related income, the industry will generate an estimated additional $2.8 million in total sales and 46 wage and salary jobs. Building the plant added an estimated 46 temporary construction positions in the region, which generated an estimated increase of $2.2 million in sales and another 40 jobs in various industries as the workers spent their wages.

Lesquerella is a new oilseed crop under development in the southwestern United States. A second special article evaluates the possibility of growing lesquerella in 21 counties in Arizona, New Mexico, and Texas. A sensitivity analysis was prepared to estimate lesquerella's net returns per acre given varying combinations of production costs, seed yields, and seed prices. Estimated net returns of traditional crops in these counties were analyzed to assess lesquerella's chances of being economically competitive with other crops.

Industry Used an Estimated $110 Billion of Agricultural Materials In 1992

An estimated $110 billion worth of agricultural and forestry products were used as raw materials in the manufacture of industrial (nonfood, nonfeed) products in 1992, according to the most recent census data available. Wood and paper products made up more than 85 percent of the value. Cotton, natural rubber, and vegetable oils were among the other raw materials used by industry.

Very little data are publicly available on industrial uses of agricultural materials. Moreover, when data are available, the information often reflects a particular raw material or use. There are no overall statistics on the volume or value of agricultural materials used by industry.

In an attempt to get a comprehensive estimate of industrial uses of agricultural materials, the Economic Research Service (ERS) focused on data sources for industrial production. Using data from the 1992 Census of Manufactures, ERS analysts have estimated the value of agricultural materials used by industry. The Census of Manufactures is part of the economic census of the Nation's economy taken every 5 years in the second and the seventh year of each decade. The Census of Manufactures contains statistics for individual industries or groups of related industries, including the number of establishments, employment, payroll, value added by manufacture, value of materials consumed, product shipments, and other industrial statistics.

The census reports the value of materials consumed or used in production by establishments in various industries based on six-digit material codes. With the help of chemists and chemical engineers, ERS analysts developed a list of material codes that are classified as agriculturally derived, partially agriculturally derived, or potentially derived from agriculture (see tables 8-11 for a list of codes that were used in the analysis).

The agriculturally derived category contains materials that are obtained from agricultural, forestry, or natural-plant sources. Agricultural materials used by the food and tobacco industries were not included in this analysis, since the objective was to isolate industrial (nonfood, nonfeed) uses of agricultural materials. The materials in the agriculturally derived category have received various amounts of processing, from goods with little processing, like raw cotton, to finished products used as intermediate goods, such as vegetable oils. The partially derived category contains:

- materials or chemicals that are partially derived from agricultural sources,
- agriculturally based materials or chemicals that are in an aggregated group containing agriculturally based and nonagriculturally based materials or chemicals, and
- materials or chemicals that can be derived from either agricultural or petroleum sources, but information on the derivation is not provided in the code description.

Finally, the potentially derived-from-agriculture group includes materials that may in the future be derived from agricultural or forestry products, but presently petroleum sources are used. The U.S. Department of Agriculture and other researchers are actively exploring new processes and procedures to expand industrial uses of agricultural materials, and these are examples of potential future products.

Using material codes as a basis for estimating the value of agricultural materials used by industry has some limitations. The codes are part of the Standard Industrial Classification, which is the classification used for all establishment-based Federal economic statistics on industries. The value of agricultural materials used as inputs by manufacturing industries may be underestimated because of how the data are collected and reported.

Underestimation can occur for several reasons. First, in addition to the total cost of materials, which every establishment was requested to report, information was collected from most manufacturing industries on the consumption of major materials used in manufacturing. The inquiries were restricted to those materials that were important parts of the cost of production in a particular industry and for which cost information was available from manufacturers' records. The value of materials used by the establishment but not listed separately on the census form are included as "not elsewhere classified." Also, the cost of materials for small establishments for which either administrative records or shorter census forms were used was imputed by the Census Bureau as "not specified by kind." Thus, because the use of agricultural materials in a manufacturing process may not be significant or well known makes their inclusion in the census unlikely. For example, information from small establishments that may use agricultural materials in production to satisfy niche markets would not be identified.

Second, if establishments consumed less than a specified amount, usually $25,000, of a specific material, they were not requested to report consumption of the material separately. Since the value of some agricultural materials may be low, particularly for specific establishments, it is likely that they may have been among those materials included in the "not elsewhere classified" category. Third, because the census is conducted on an establishment basis, some data are withheld from publication to avoid disclosing information for individual companies. Finally, some material codes include a large variety of materials. If the majority of the materials in these codes were deemed likely not to be agriculturally based, they were excluded from the partially agriculturally derived category.

Overestimating the value of agricultural products may occur through duplication in the cost of materials among industries. Within a census industry, inputs are additive. However, when combining material codes from different industries representing successive stages in the production of finished manufactured goods, the possibility of double counting occurs. For example, the value of cotton is counted twice when it is first an input into the manufacture of an intermediate good (yarn), and second, when the yarn is used as an input in the manufacture of fabric.

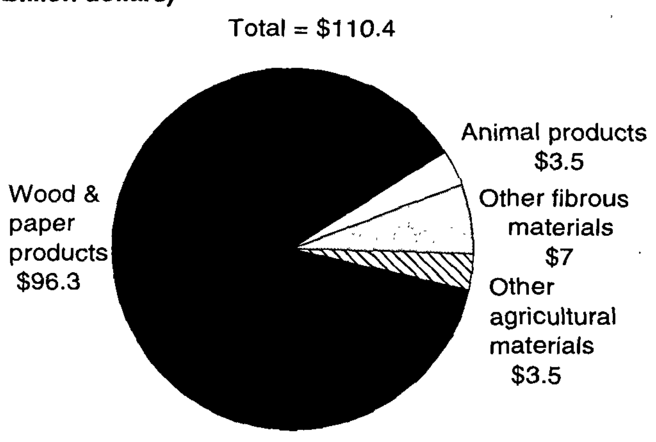
Industries Spent $96 Billion on Wood And Paper Inputs in 1992

Given the limitations, it is estimated that more than $110 billion of agricultural and forestry products were used as raw materials in the manufacture of industrial products in 1992, according to the most recent census data available. Wood and paper accounted for more than 87 percent or $96 billion (figure 1, table 9). Other fibrous materials, animal products, natural rubber, and vegetable oils were among the other agricultural materials used in the manufacture of nonfood items (table 8).

After wood and paper products, other fibrous materials were the next largest category of agricultural materials used by industry, with a total value of nearly $7 billion. Raw cotton use accounted for 45 percent of all nonwood fibers, estimated at $3.1 billion. Other cotton products, including cotton yarns, fabrics, felt, linters, and waste, added another $3.3 billion. Industries also used $370 million worth of raw wool and wool materials in 1992, such as felt, yarn, noils, and waste.

Figure 1

Value and Type of Agricultural and Forestry Materials Used in Manufacturing in 1992
(Billion dollars)



Animal products were the third largest category of agricultural materials used as industrial inputs in 1992, totaling nearly $3.5 billion. Hides, skins, and pelts, valued at $1.2 billion, were purchased by the leather and leather products industry. Another $1.6 billion of finished leather was used in the manufacture of leather products and apparel. Nearly $600 million worth of animal fats, oils, greases, and tallow were inputs into the production of perfumes, cosmetics, and chemical preparations. Establishments involved in the manufacture of medicinal chemicals and pharmaceutical preparations purchased $51 million worth of pharmaceutical-grade gelatin. Finally, $16 million of dressed hair, including horse hair, was used to make brooms and brushes.

An additional $69 billion of raw materials that are partially derived from agricultural sources were used as manufacturing inputs in 1992 (table 10). However, $69 billion may overestimate the value of agriculturally based materials because the category includes intermediate goods that are derived both from agricultural and petroleum sources. For example, the "knit fabrics" material code is considered partially agriculturally derived because it includes natural fabrics, like wool, along with synthetic fabrics, like polyester.

In 1992, industry used $3.6 billion of raw materials that came from petroleum sources, but in the future may come from agricultural and forestry products (table 11). This estimate is meant to give researchers only a rough indication of potential market size. For each new use, agriculturally derived materials will have to compete with their more well-established, petroleum-based counterparts. For example, a new technology has been developed for turning cornstarch into propylene glycol, glycerine, and ethylene glycol but is not yet in commercial use. Also, researchers are studying the use of soybean and other vegetable oils in printing inks (see Fats and Oils section for more information).

Agricultural Materials Were Used by All Industry Major Groups

All Industry Major Groups used agriculturally derived materials in 1992 (table 1). The paper and allied products industry was the largest user, spending nearly $39 billion on agricultural inputs and $2.6 billion on intermediate goods partially derived from agricultural sources (figure 2). The lumber and wood products industry was next, using $23 billion and $0.6 billion of agriculturally derived and partially agriculturally derived materials, respectively. The chemicals and allied products industry was the third largest industry group, spending $5.5 billion on agriculturally derived materials and $16 billion on partially derived intermediate goods.

Table 1—Use of agricultural inputs in manufacturing in 1992, by Major Group, excluding food and tobacco usage

Major industry group	Agriculturally derived products	Share of total inputs	Partially agriculturally derived	Total 1/	Share of total inputs
	Million dollars	Percent	Million dollars		Percent
All industries	110,360	4.9	69,458	179,818	7.9
Paper and allied products	38,944	30.2	2,553	41,497	32.2
Lumber and wood products	22,902	26.9	593	23,495	27.6
Chemicals and allied products	5,469	2.3	16,104	21,573	9.2
Printing and publishing	18,083	23.7	3,429	21,512	28.2
Apparel	1,209	2.3	15,617	16,826	31.4
Textile mill products	5,685	7.8	8,339	14,024	19.4
Transportation equipment	817	0.2	11,836	12,653	2.9
Furniture and fixtures	4,145	11.1	2,814	6,959	18.6
Rubber and miscellaneous plastics products	2,941	3.0	1,766	4,707	4.8
Leather and leather products	2,637	29.5	778	3,415	38.3
Measuring, analyzing, and controlling instruments	1,273	1.7	1,312	2,585	3.4
Fabricated metal products	952	0.7	1,336	2,288	1.6
Electronic and other electrical equipment and components, excluding computers	1,800	1.1	465	2,265	1.4
Industrial and commercial machinery and computer equipment	753	0.4	1,311	2,064	1.0
Stone, clay, glass, and concrete products	1,442	3.4	199	1,641	3.9
Miscellaneous manufacturing	1,130	3.9	415	1,545	5.3
Petroleum refining and related industries	160	0.1	590	750	0.3
Primary metal industries	19	2/	0	19	2/

1/ Sum of agriculturally derived and partially agriculturally derived materials. 2/ Less than 0.1 percent.

How important agricultural and forestry materials were as inputs varied among industries. Nonfood manufacturing industries spent nearly $180 billion on agriculturally derived and partially agriculturally derived materials in 1992, which is nearly 8 percent of the $2.3 trillion spent on raw material inputs used in production. The two categories were most important to the leather and leather products industry, accounting for 38 percent of all inputs (figure 3).

Agriculturally derived and partially agriculturally derived materials were also an important source of inputs to the paper and allied products and apparel industries, accounting for 32 and 31 percent of all inputs, respectively; although for the apparel industry, most of the inputs came from the partially derived category. [Jacqueline Salsgiver, ERS, (202) 501-7107, jsalsgiv@econ.ag.gov]

Figure 2

Industries That Used the Highest Value of Agricultural Materials in 1992

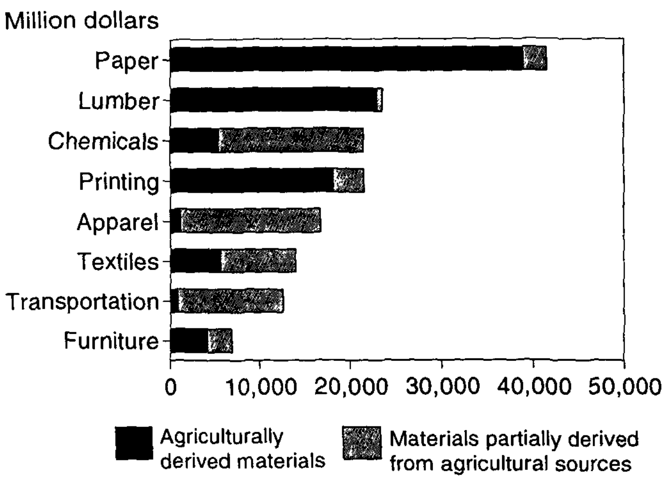
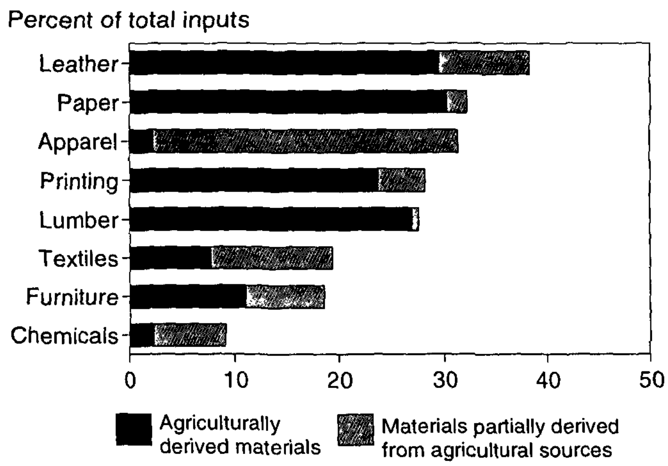


Figure 3

Industries That Used the Greatest Share of Agricultural Materials in 1992



U.S. Economic Growth Is Expected To Moderate in the Rest of 1997 and 1998

The strong growth in the U.S. Gross Domestic Product (GDP) in the first half of 1997 will give way to more moderate growth for the rest of 1997 and 1998. Even as GDP growth moderates, the economy will support manufacturing-output growth of 4.0 percent for 1997. Forces driving the manufacturing sector will spur modest growth in industries that use agricultural inputs.

U.S. industries that use agricultural inputs tend to be mature industries and, as such, find their economic prospects closely tied to changes in the general U.S. economy. This section provides an overview of the U.S. economy and manufacturing sector, focusing on nine major industries that use agricultural materials.

The U.S. economy continues its seventh year of economic expansion. In the first quarter of 1997, the U.S. Gross Domestic Product (GDP) grew at an extraordinary annualized rate of 5.9 percent, which supported a 5.3-percent increase in manufacturing (table 2). Ordinarily, the strong manufacturing growth that has occurred in the previous year and the maturity of the economic recovery would bring a moderation in manufacturing output. However, that has not happened. The only major component of GDP that fell in the first quarter of 1997 was net exports, as the real trade deficit widened by almost $18 billion. Exports rose at an 11-percent annual rate, $18 billion, while imports rose by 23 percent, $36 billion. The growth of manufactured goods exports in the first quarter was concentrated in auto parts, computers, and airplanes. This export growth, along with a strong inventory buildup and a sharp increase in consumer demand for trucks, led to the strong manufacturing output seen in early 1997. Manufacturing growth remained strong in the second quarter, while GDP growth moderated.

Table 2--Growth rates for GDP, industrial production, and selected industries using agricultural materials

Item	3rd qtr 1996	4th qtr 1996	1st qtr 1997	2nd qtr 1997
	Percent change 1/			
Gross domestic product	2.1	3.8	5.9	2.5 2/
Industrial production	3.3	4.5	4.4	4.3
Manufacturing	5.0	4.3	5.3	4.4
Lumber and products	-1.9	-1.3	4.2	9.2
Furniture and fixtures	-2.7	7.1	-0.5	10.3
Industrial machinery and equipment 3/	11.6	6.8	12.3	12.5
Transportation equipment	7.6	-2.2	14.2	-3.4
Textile mill products	5.4	-1.8	-0.9	6.1
Paper and products	4.2	2.8	5.2	4.9
Chemicals and products	6.9	12.3	1.8	1.0
Rubber and plastic products	7.8	0.3	2.7	0.3
Leather and products	-6.2	-5.1	-2.3	-5.1

1/ Annualized on a quarterly basis. 2/ ERS estimate. 3/ Overall sector growth. Computers and office equipment grew 43.0, 22.1, 25.9, and 28.4 percent, respectively, during the four quarters. Growth in other industrial-machinery-and-equipment categories was much lower.
Sources: Gross Domestic Product Release, Department of Commerce, Bureau of Economic Analysis, June 1997; and Industrial Production and Capacity Utilization Report, Federal Reserve Bank, Washington, DC, July 1997.

Among the nine industries using agricultural materials, the increase in output during the first half of 1997 was even more remarkable for those not subject to strong foreign price competition. Lumber and products output rose 4.2 percent in the first quarter of 1997 due to a weather-induced increase in commercial and residential construction and a rise in building-supply-store inventories. Without a strong economy, lumber output and/or prices would have fallen despite the warm winter. With housing demand high because of strong labor income growth (from higher real wages and strong employment gains) and record high levels of consumer confidence, lumber product output rose 9.2 percent in the second quarter. Stable mortgage rates, strong corporate profits, and abundant credit further supported commercial construction.

Similarly, transportation equipment output rose 14.2 percent in the first quarter due to an unusually strong 22.4-percent annualized growth in car and truck production. The strong vehicle output reflected a rebuilding of inventories and strong growth in light truck sales. Consumer vehicle spending was supported by good personal income growth and record consumer confidence levels. Because of warm weather, light truck sales occurred in January and February instead of the more usual April or May. Reflecting this early buying, transportation equipment output dropped 3.4 percent in the second quarter. Although furniture and household equipment sales were strong in the first quarter, the growth was from higher appliance sales and furniture inventory liquidation and not furniture output, which stagnated during the quarter. During the second quarter, furniture output expanded at an annualized rate of 10.3 percent because of strong disposable income growth and the previous quarter's inventory liquidation.

Of the nine industries, those that have more direct foreign competition did less well during the first half of 1997. Textile mill production was flat in the first quarter, despite booming clothing and vehicle sales. Because of the strong dollar, imported textiles supplied the increased demand. In contrast, textile production rose 6.1 percent in the second quarter. Rubber production and chemicals and products output were hurt by the strong dollar during the first half of 1997, which slowed exports, increased imports, and resulted in subpar growth.

Industrial machinery is a very competitive sector internationally. The roughly 10-percent growth in machinery output from the second quarter of 1996 to the first quarter of 1997 has been driven by computer and office equipment production, which expanded over 28 percent during the year. The spectacular growth in domestic equipment investment was supported by very strong computer export growth over the same period. The rest of the machinery sector, which is the part that uses agricultural materials, has been growing much less rapidly. The United States has a comparative advantage in the production of office equipment and a comparative disadvantage in making many other types of machinery. Similarly, leather goods production, which is quite labor intensive, continues to decline irrespective of the rate of economic growth.

The Outlook Is for More Modest Growth

A potential risk to continued economic growth evaporated in early 1997, as crude oil prices, which peaked at over $23 per barrel in December 1996, fell below $19 per barrel by May 1997. A rise in fuel prices is not expected this summer despite the usual summer increase in fuel demand because of plentiful world supplies. Crude oil prices should average below $19 per barrel for the next seven quarters; various forecasts range from $16 to $19 per barrel. Low energy prices will help support manufacturing by slowing input price inflation throughout 1997 and 1998.

Preliminary data show strong industrial production and employment growth and declines in retail sales during the second quarter, which suggest strong inventory accumulation that may exceed the first quarter's $31.5 billion. In the second quarter, GDP is estimated to have grown at an annualized rate of between 2.4 and 2.6 percent as manufacturing output increased 4.4 percent. Some of the first quarter's extraordinary growth spilled over into manufacturing in the second quarter. The slowdown via the corrections in inventories, business investment, and consumer durable spending should be evident by the third quarter of 1997.

The cyclical adjustments that will slow spending growth on consumer durables and producer equipment and generate a lower rate of inventory buildup may be facilitated by a modest tightening of interest rates by the Federal Reserve (Fed) this fall. This will mean more modest growth in GDP and manufacturing in the second half of 1997 and 1998. For those six quarters, GDP is expected to grow at an average annualized rate of about 2.2 percent. Record high consumer confidence will fall as employment growth moderates, although wage gains will keep confidence from falling sharply. Tight labor markets will result in real wage gains in both 1997 and 1998. The expected continued growth in real wages, as employment gains moderate, is key to strong disposable income growth for the rest of 1997 and 1998. Growing after-tax personal income will mean continued growth in consumer spending.

The growth of consumer spending on durable goods, which has supported manufacturing growth, will be modest. Consumer debt is at very high levels, so lenders will be more careful about making new loans. The Fed's likely hike in short-term interest rates, done to keep inflation from accelerating in 1998, will be reflected in somewhat higher long-term rates. Higher commercial interest rates and tighter standards for consumer credit will constrain growth in spending on durable goods, such as cars, furniture, and household appliances. Moreover, the pent-up demand for durable goods has mostly been filled. From 1994 through the first quarter of 1997, consumer spending on cars, furniture, and appliances was very high, largely reflecting postponement of purchases due to slow personal income growth, high interest rates, or lack of credit availability from 1990 to 1993. Near-term growth in durable goods demand will be based largely on demographics, such as new household formation. Consumer spending on services and nondurables will be the major components of consumer spending growth through the end of 1998.

Higher wages will slow employment growth as employers shed excess workers to offset lower profit growth. Tighter credit standards and flat business profits will slow growth in business equipment sales, especially in 1998. Higher interest rates will keep the dollar strong in 1997 and 1998. A strong dollar and modest growth in the economies of our major trading partners, except for Canada, will slow export growth to single-digit levels and keep import growth somewhat higher. On average, the trade deficit should rise modestly for the second half of 1997. The slowdown in investment and export growth will further curtail future manufacturing growth. Government spending will increase very modestly as lower Federal purchases are offset by local governments spending the higher income- and excise-tax revenues resulting from higher wages.

Prospects for Industrial Materials Moderate

As a result of slowing growth in construction, spending on consumer durables and business equipment, and exports, no major manufacturing sector will do as well in the last half of 1997 or 1998 as they did from the second quarter of 1996 to the first quarter of 1997. Nevertheless, the strength of the U.S. economy, even as growth moderates, will increase manufacturing output 4.0 percent for all of 1997. Forces driving the manufacturing sector will spur modest growth in the nine industries using agricultural inputs. However, in

1998, noncomputer manufacturing will grow only 1 percent, making prospects for further growth in the nine industries modest to poor.

Lumber and products output will grow about 2 percent in 1997 and 1 percent in 1998. Construction growth will slow during the rest of this year and next. Lumber prices should fall modestly because of a decline in capacity utilization. Furniture and fixtures output is expected to grow 3 percent in 1997, reflecting many people's desire to fill their relatively new houses with new furniture. The furniture sector is expected to grow 2 percent in 1998, reflecting market maturity. Sluggish demand will bring small price cuts in 1998.

Transportation equipment will grow 5 percent in 1997, reflecting further growth in light truck and bus sales. Prices are expected to rise about 2 percent. The prospects for 1998 are for a mere 1-percent growth in output, triggered by modest price cuts. The generally austere Federal budget will curtail large purchases of fleet buses and subway cars by local transit authorities in 1998.

Output of textile mill products has bounced back from the flat first quarter and should finish 1997 with 3-percent growth because of a rise in spending on household furnishings driven by good personal income growth. The strong dollar will keep price increases at 1 percent in 1997. In 1998, output should rise 5 percent, again due to household furnishings demand. Wholesale textile prices should be up 3 percent in 1998, reflecting strong demand.

Paper and products output should rise 4 percent in 1997 and 3 percent in 1998, reflecting good personal income growth. Prices should increase 4 to 6 percent by the end of 1998, as supplies continue to be tight. Chemical and products output should be up 4 percent in 1997. Most of the rise will be driven by increased sales of drugs and agricultural chemicals. A modest expansion in chemical exports in 1998, due to a rise in foreign economic growth, will boost output 1.5 percent.

Rubber and plastic production will increase 3.6 percent in 1997 because of strong consumer demand and higher production of transportation equipment. In 1998, output growth will slow to about 1.5 percent, reflecting modest gains in consumer demand. Prices should rise about 4 percent by the end of 1998.

The Midterm Prospects for U.S. Manufacturing

The potential for continued growth in U.S. manufacturing is good. The next decade is expected to have moderate GDP growth, slowly rising real oil prices, only a modest increase in inflation from current levels, a dollar not greatly overvalued compared with the relative purchasing power of our trading partners' currencies, and a balanced budget by 2002. However, the manufacturing sector has three interrelated challenges. The sector is highly cyclical, dependent on appropriate adoption of new technology, and exposed to international competition.

Manufacturing demand is driven by consumer demand for durables, business investment in plant and equipment, and exports, all very cyclical parts of GDP. Manufacturing has become increasingly dependent on export markets and is subject to quality and price competition from foreign firms. For example, the very high value of the dollar from 1982 to 1986 severely curtailed manufacturing growth and led to a consolidation within the sector, personnel downsizing, and the bankruptcy of many smaller firms. The manufacturers that survived did so by adopting appropriate technology and using new capital investment. In this process, many jobs were lost and labor productivity rose sharply. The U.S. auto industry went from a declining sector to one that reinvented itself and adopted the inventory practices and niche-market-seeking philosophy of its Japanese competitors. Costs went down and American cars became cost competitive.

The major risks to moderately good manufacturing growth over the next decade are:

- Prolonged or very deep recessions;
- A substantial real oil price shock as large as 1973-74 and lasting for several years, which would increase interest rates and likely slow investment spending;
- A greatly overvalued dollar for several years, as occurred during the mid-1980's; or
- A trade war.

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Ethanol, Citric Acid, and Lactic Acid Use Corn as a Feedstock

Industrial uses of corn in 1996/97 are expected to total 681 million bushels, up from the 642 million used in 1995/96. Ethanol production has rebounded from the low levels experienced in 1995/96. Markets are growing for citric and lactic acids, two organic chemicals usually derived from starch and sugar feedstocks.

Industrial uses of corn in 1996/97 are expected to total 681 million bushels, up from the 642 million used in 1995/96 (table 3). In 1997/98, industrial uses of corn may account for 736 million bushels, a further increase over this crop year. Industrial uses will account for 7 percent of the supply of corn in 1996/97, the same percentage as in 1995/96 when supplies were lower, and a similar proportion is expected in 1997/98.

Corn used to produce ethanol in 1996/97 increased 10 percent from a year earlier. In 1995/96, ethanol producers were caught between higher costs for inputs, moderate increases in coproduct prices, and stable prices for competing products, which limited their ability to raise ethanol prices. Thus, many ethanol producers suspended operations to do maintenance on their plants. Corn used for ethanol production in 1997/98 is expected to increase from 1996/97 as ethanol firms continue production with prices competitive with other oxygenates.

In 1996/97, corn used for manufacturing alcohol was about the same as the previous year. In 1995/96, about 60 million bushels of corn were used for manufacturing alcohol, up from 36 million in 1994/95. Even with tight supplies of corn in 1995/96, higher prices for industrial alcohol relative to fuel alcohol kept corn use strong. In 1997/98, corn used for manufacturing is expected to be about the same as in 1996/97.

Corn used in industrial starch production in 1996/97 will likely be about the same as the 186 million bushels used a year earlier. In 1995/96, corn used for starch production was down 3 percent from the 192 million bushels used in 1994/95. As producers passed along the higher costs of corn in 1995/96, their buyers apparently found alternative products that were less expensive. Corn prices in 1997/98 are expected to be down from a year earlier and corn use for starch production will likely increase. Industrial starch prices and corn use are not highly correlated because starch users and starch producers tend to contract ahead to meet their needs (figure 4).

Ethanol Production Rebounds Somewhat

The financial squeeze ethanol producers experienced in 1995/96 has dissipated as corn prices have dropped and prices of gasoline and methyl tertiary butyl ether (MTBE) have increased. Blending margins for ethanol have greatly improved from last summer when the wholesale price of gasoline was almost 28 cents per gallon less than that for ethanol, excluding the 54-cents-per-gallon ethanol tax incentive. Ethanol prices are strongly influenced by gasoline prices because a large proportion of ethanol is blended into regular gasoline as an octane enhancer and fuel extender. In the spring of 1997, the price difference had narrowed to about 6 cents per gallon. Ethanol also has been competitive with its main rival, MTBE, in oxygenated-fuel-mandated areas because MTBE prices have been on an upward track until recently.

While ethanol production is increasing because of more favorable economics, it has not rebounded to the peak level

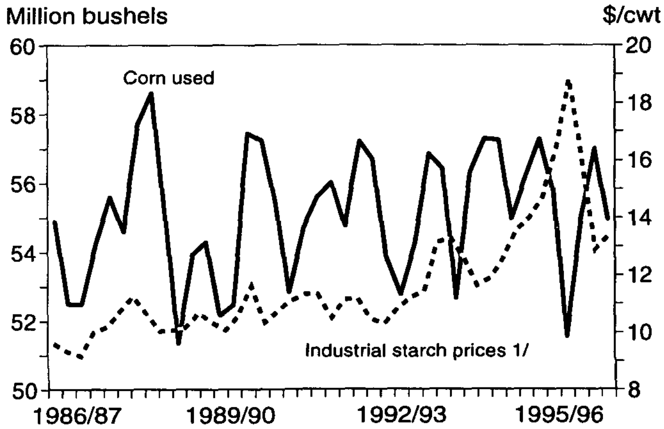
Table 3–Industrial and food uses of corn, 1990/91-1997/98

Marketing year 1/	HFCS 2/	Glucose and dextrose 2/	Cereals and other products	Starch: Food uses	Starch: Industrial uses	Starch: Total 3/	Alcohol: Beverage	Alcohol: Manufacturing	Alcohol: Fuel	Total industrial use 4/
	Million bushels									
1990/91	379	200	114	33	186	219	54	81	349	616
1991/92	392	210	116	34	191	225	58	103	398	692
1992/93	415	214	117	33	185	218	51	80	426	691
1993/94	444	223	118	33	189	223	55	55	458	702
1994/95	465	231	118	34	192	226	64	36	533	761
1995/96	485	235	118	33	186	219	65	60	396	642
1996/97 5/	505	240	120	39	186	225	70	60	435	681
1997/98 6/	530	245	136	39	191	230	73	60	485	736

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

Figure 4

Corn Used in Starch Production and Industrial Starch Prices, Quarterly



1/ Bulk, unmodified.

of 1995 (figure 5). From January to June 1997, ethanol production has averaged 81,000 barrels per day. In comparison, U.S. MTBE production averaged 187,000 barrels per day during the same period. In addition to domestic production, significant amounts of MTBE are imported, particularly to the West Coast. About 435 million bushels of corn are estimated to be used for ethanol production in the 1996/97 crop year. With this amount of corn, plus sorghum and other feedstocks, ethanol production is expected to total 28.6 million barrels in 1996/97, up from 24.8 million barrels in 1995/96.

Ethanol producers are apparently still trying to regain the market share they lost in octane and oxygenated fuel markets when corn prices reached record levels during 1995/96. The loss cannot be overcome immediately, because producers must reestablish long-term contracts with blenders. After last year's extended maintenance shut downs, ethanol producers found many petroleum firms already had committed to MTBE for the winter oxygenate season. In May 1997, stocks of ethanol were 166 percent of a year earlier, suggesting by the winter oxygenate season, petroleum firms will find plentiful supplies of ethanol for blending. Another reason for the slow rebound is that a robust market for beverage exports has diverted production from fuel-grade alcohol.

Demand Is Growing for Citric and Lactic Acids

Many organic chemicals can be derived from starch and sugar feedstocks, including citric and lactic acids. These two organic acids have multiple uses, both food and industrial, and have growing markets. Though both chemicals can be derived synthetically, biobased production methods are the main source of these commodities. Both citric and lactic acid are derived by microbial fermentation of a carbohydrate feedstock. Either crude sugars, such as sucrose or molasses, can be used or the sugar feedstock can be derived from any starch-rich crop, including potatoes, sweet potatoes, wheat, barley, rice, and corn.

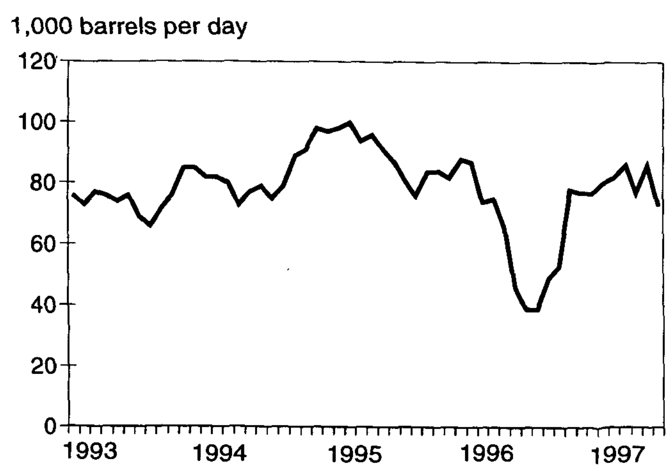
Citric acid is the largest volume organic acid produced by fermentation, accounting for approximately 85 percent of the fermentation-based organic acid market (6). In addition to wide use as an acidulant in the food and beverage industry, it also is used in a variety of industrial and pharmaceutical applications as an acidulant, dispersing agent, sequestering agent, water-conditioning agent, detergent builder, and cleaning agent. In the United States, about 45 percent of citric acid is used in the beverage industry, 23 percent in foods, 20 percent in detergents, 6 percent in pharmaceuticals, and 6 percent in other chemical processing industries.

Output in the three main producing regions of Western Europe, the United States, and China, which together account for about 88 percent of world capacity, was estimated to be over 1.2 billion pounds in 1994 (1). With steady growth rates in citric acid markets in recent years, production in these regions in 1997 could be as high as 1.3 to 1.7 billion pounds. However, another estimate puts the world market at less than 1 billion pounds annually (6). Estimates on the value of the world market also differ, ranging from less than $1 billion to as high as $2 billion annually.

In the United States, citric acid production is estimated to be about 475 million pounds annually, with an industrial capacity of about 490 million pounds (3). U.S. domestic demand for citric acid is assessed to be between 400 and 450 million pounds per year, with a market value of about $340 to $380 million. Continued market expansion is expected due to growth in traditional and new uses. With strong growth, improved product value in specialty applications, and increased production capacities, the market for U.S.-produced citric acid could reach $650 to $750 million by the year 2005.

Figure 5

Monthly Ethanol Production



Source: U.S. Department of Energy, Energy Information Administration.

The three major U.S. producers are Archer Daniels Midland Company (ADM); Cargill, Inc.; and Haarmann and Reimer Corporation (H&R), a subsidiary of Bayer. Currently, most citric acid in the United States is produced via submerged (deep-tank) fermentation of corn-derived glucose or dextrose. Other carbohydrate sources, such as potato, sweet potato, and wheat starch, may be utilized, but on a smaller scale due to their higher cost relative to cornstarch. H&R, the only major producer not vertically integrated back to feedstocks, is looking to sell its citric acid plant. ADM, on the other hand, recently announced plans to build a new bioproducts plant in Cedar Rapids, Iowa, that will produce citric acid, lactic acid, lysine, xanthan gum, and glycerine. In recent years, vertical integration and large facilities, which take advantage of economies of scale, have become very important to the profitable operation of fermentation facilities.

Another organic acid that has the opportunity for expanded use due to developing industrial applications is lactic acid. It is produced by either fermentation of a carbohydrate feedstock or synthetically by hydrolysis of lactonitrile. About 85 percent of lactic acid demand is for food and food-related applications, particularly as a general purpose food additive and to produce emulsifying agents for use in baked goods. Lactic acid also is used in foods and food preparation as an acidulant, flavor enhancer, preservative, texture modifier, antibacterial agent, and preservative for meat carcasses. Some examples of industrial applications, which currently account for about 15 percent of lactic acid use, include use as an ingredient or intermediate in the manufacture of numerous chemicals, a mordant in dyeing wool, a pH balancer in shampoos and soaps, and as the building block for polylactic acid (PLA), a biodegradable polymer (for information on PLA, see the September 1995 issue of this report).

Much of the lactic acid used in the United States has traditionally been imported from Europe, although U.S. production is on the rise. ADM is the largest U.S. producer, followed by several other companies such as Cargill, A.E. Staley Manufacturing Company, and Chronopol, Inc. Total U.S. capacity is estimated to be near 40 million pounds per year, although this will likely rise as companies expand capacity and form joint ventures to build new plants. For example, Cargill has entered a joint venture with the Purac Group, a subsidiary of the Dutch food multinational CSM, to produce lactic acid at a new plant being built in Blair, Nebraska. Purac is the largest producer of lactic acid in the world, with plants in Europe, South America, and the United States.

Although the bulk of the market for lactic acid is fairly mature and slow-growing, newer applications, such as the manufacture of biodegradable polymers, will likely increase lactic acid demand. Current U.S. demand for lactic acid is estimated at about 55 million pounds and total world demand near 150 million pounds (2, 4). Assuming lactic acid is worth an average $1.15 per pound, U.S. and world markets would be valued at approximately $63 million and $173 million, respectively. These values will likely rise as the use of new lactic acid products grows and production technology improves. Conservative estimates have the market growing 3 to 5 percent annually (5), while higher estimates put the range at 8 to 10 percent annually. [Industrial uses of corn: Allen Baker, ERS, (202) 219-0360, albaker@econ.ag.gov. Ethanol: Roger Conway, OENU, (202) 219-1941, rkconway@econ.ag.gov, and James Duffield, OENU, (202) 501-6255, duffield@econ.ag.gov. Citric and lactic acids: Charles Plummer, ERS, (202) 219-0717, cplummer@econ.ag.gov]

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2. "Cargill and Purac Link Up For Major Lactic Acid Plant," Chemical Marketing Reporter, May 27, 1996, p. 5.
3. "Chemical Profile: Citric Acid," *Chemical Marketing Reporter*, April 1, 1996, p. 37.
4. "Ecochem Drops Out of Lactic Acid," *Chemical Marketing Reporter*, November 28, 1994, p. 4.
5. "Lactic Market Is Reshuffling," *Chemical Marketing Reporter*, May 13, 1996, p. 7.
6. Madia, Ashwin, "Organic Acids," *1995 Regulatory Seminar*, Corn Refiners Association, Inc., Washington, DC, pp. 91-99.

Soybean Meal and Oil Make Inroads in New Industrial Applications

Soybean meal is being used to make adhesives and composites. Soybean oil is finding its way into plastics, inks, and solvents. In 1996, 305.2 million pounds of soybean oil were used in inedible applications, accounting for about 2.5 percent of total consumption.

Soybeans contain both meal and oil. Soybean meal is currently the more valuable component obtained from processing soybeans, although this can change when relative prices of commodities change. Over 90 percent of soybean meal is used as a high-protein ingredient in livestock feed. A small portion of soymeal is milled into flour or grits, primarily for edible applications, or used in the preparation of protein concentrates and isolates, which have food and industrial applications.

Soybean oil is the most widely used and least costly domestic vegetable oil, so it is frequently used in industrial applications. It is a source of fatty acids that are used to produce surfactants, emulsifiers, and alkyd resins for paints. One major industrial use is as epoxidized soy oil for a plasticizer in polyvinyl chloride (PVC) and other plastics. In 1996, 305.2 million pounds of soybean oil were used in nonfood applications, such as livestock feed and the manufacture of resins, plastics, paints, inks, and soaps. This constituted roughly 2.5 percent of all soybean oil consumed in 1996, with the remaining 12 billion pounds going into edible uses (table 25).

Soybean oil accounts for about 75 percent of the vegetable oil produced in the United States. Due to the abundance of domestic soybean production, research and development of industrial uses of vegetable oils have tended to concentrate mainly on soybean oil. For example, research on biodiesel has focused on using soybean oil as a major feedstock. Most biodiesel production today is used for testing and demonstration projects, but demand could increase in coming years (see the August 1996 issue of this report for more information on biodiesel).

A variety of public and private research on finding new uses for soybeans is underway. Much of this research is funded by a checkoff program in which farmers pay for promotion, research, and market development through an assessment on the sale of their crop. The United Soybean Board (USB) , which distributes a portion of the earmarked money, has approved more than $6.6 million for new-product research and development from fiscal 1997 funds. The money is being used to fund 34 new projects with 1- and 2-year grants to universities, private companies, and public research facilities. Many of the new applications use soybean oil, but new uses for soybean meal also are being pursued. This article highlights examples of recent market successes and ongoing research projects.

Soy-Based Composites Are on the Market

One of the most successful new soybean-based products recently brought to market is a composite material that looks like granite and works like wood. Environ is comprised of 45-percent soybean flour and 45-percent old newspapers, with inks, oils, and other materials accounting for the remaining 10 percent. It is manufactured by Phenix Biocomposite, Inc., of Mankato, Minnesota, into 3-by-6-foot boards, which are used to make furniture, paneling, flooring, and other wood-like products. The company cites studies that the product has a potential market of $1.8 billion a year by 2000. Construction has begun on a new 150,000-square-foot production facility in Mankato. The $29-million plant should be operational in early 1998.

Commercialization of New Wood Adhesives And Composites Is Imminent

Research on new soybean-based wood adhesives promises performance, economic, and environmental benefits. One product, developed by Kriebich and Associates of Seattle, Washington, is an adhesive specifically developed for use in finger-jointing lumber. The process takes short scrap pieces of lumber and glues them end-to-end to make longer, more marketable lumber. The soy-based adhesive works in tandem with a traditional adhesive. The soy-based adhesive is applied to one piece of wood and the traditional adhesive to the other piece. When the pieces are joined, a strong bond forms in seconds. The water- and boil-proof bond is created without the use of heat, saving energy and time compared with traditional adhesives. The soy-based adhesive has a high tensile strength, which exceeds the minimum standards for finger joints. Using short lengths of lumber to make marketable products supplements scarce supplies of saw logs. Additional mill trials are planned for this year. If the tests are successful, commercial sale of the adhesive is anticipated to begin in 1998.

Other soy-adhesive research has focused on making composites, such as plywood, particleboard, and oriented-strand board (OSB) or chipboard. University of Minnesota researchers are conducting tests to make OSB using soy flour and methylene diphenyl diisocyanate (MDI) adhesive. MDI is commonly used in OSB production. Researchers combine the two adhesives to make a powder that is applied to wood chips. The chips are coated with the adhesive mixture and fed into a press. Heat and pressure bond them to one another to form a high-quality OSB. The soy-based adhesive could replace half of the more expensive MDI, resulting in less expensive OSB. Four other research projects in the wood products area are testing the use of different forms of soy derivatives from whole meal to protein concentrates and isolates.

Researchers Attempt To Increase Soy Use In Plastics

In 1996, approximately 121.1 million pounds of soybean oil were used in plastics and resins, the largest category of inedible uses (table 25). Much of this was used to make epoxidized soybean oil, a plasticizer used to modify the properties of PVC and other plastic resins (see the June 1994 issue of this report for more information on vegetable oil-based plasticizers). Soybean oil currently accounts for only 3 percent of the plasticizers used to make PVC pipes and other products. If too much soybean oil is used in the formulation, the oil causes the PVC to become brittle and degrade. Research is being conducted in an attempt to modify soybean oil, enabling manufacturers to use up to 25 percent soybean oil in the plasticizing process. The majority of the plasticizers used in forming PVC resins are petroleum-based or generic phthalic esters, which sell for approximately 56 cents per pound. In comparison, the price of soybean oil has averaged 25 cents per pound during the last 5 years (table 36). Finding practical ways to modify the oil while maintaining its lower price is critical to the success of the project.

Another area of plastics research sponsored by the USB is the use of soybean meal or flour in the manufacture of biodegradable foams and films. Scientists at the University of Missouri at Rolla have developed prototype materials that are being tested for such uses as rigid insulation boards and agricultural mulching films. Planned field testing will help researchers to refine formulations for improved performance.

Inks Now a Large User of Soy Oil

Soybean oil is used in ink formulations as a vehicle, which, as defined by the ink industry, is any media that acts as a solvent, carrier, or binder for pigments to the substrate. Developed by the American Newspaper Publishers Association in response to the oil shocks of the 1970's, soybean oil-based inks were first marketed in 1987. Since then, soybean oil has been incorporated into a number of ink formulations. The amount of soybean oil used varies among manufacturers and types of ink. For an ink manufacturer to claim its product is soy ink, soybean oil must make up a minimum percent of the ink's total formula weight (table 4). Newer formulations have higher amounts of soybean oil; for example, some black news inks contain up to 75 percent soy oil.

Table 4–Percentage of soybean oil in printing inks, by type

Type of ink	Minimum soybean oil content	Maximum current soybean oil usage
	Percent	
Black news ink	40	up to 75
Color news ink	30	up to 50
Sheet-fed ink	20	30
Heat-set ink	7	less than 20
Cold-set ink	30	30
Business-form ink	20	50

The newspaper industry is a large user of soy inks. Soy inks account for more than 90 percent of all colored inks and about one-third of black inks used by U.S. newspapers. Soy inks produce better colors and provide greater clarity with reduced rub-off on readers' hands. The lighter color of soybean oil makes it ideal for color inks because the true color of the pigments can show through. Newspaper pictures are composed of a pattern of dots, which with petroleum-based inks increase in size during the press run, reducing the clarity of the picture. With soy inks, the dots remain relatively the same size, keeping picture clarity constant throughout the press run. Moreover, soy inks can be used for printing newspapers without a change in equipment or printing methods. Soy ink has been found to be a better carrier of pigments, driers, and other agents than other ink vehicles, which can result in less press time, lower cost, and higher quality results.

Color soy inks have taken over much of the market not only because of their superior properties, but also due to their competitive price. Color inks contain less oil, and prices are based primarily on the cost of the pigments. On the other hand, the price of black inks, which are 70 to 80 percent oil, is driven by the cost of the vehicle oil. Currently, the price of refined soybean oil is higher than that for petroleum-based mineral oil, making black soy inks more expensive than their conventional counterparts. (See the June 1993 issue of this report for more information on soy ink development.)

The U.S. Department of Agriculture's (USDA) Agricultural Research Service (ARS) has patented a 100-percent vegetable oil ink that replaces the petroleum-based vehicle and resins used in conventional inks with vegetable oil derivatives. The ARS formulation represents an improvement over most soy oil inks that replaced only the mineral oil carrier with soy oil, but not the resins. USDA issued its first license on the patent in 1992 to Franks Research Laboratories, Inc., of Oklahoma City, Oklahoma, giving the company the right to make ink products for sale in five states. The Department continues to explore other licensing opportunities. ARS scientists also developed sheet-fed and heat-set inks containing up to 60 percent soybean oil by eliminating the petroleum oil and resin. Patents are pending for these technologies.

In addition to their other attributes, soy inks are more environmentally friendly than traditional petroleum-based inks.

Soy inks can help improve air quality since they emit almost no volatile organic compounds (VOC's) into the air. Petroleum inks typically have VOC ratings of 25 to 40 percent, while soy ink manufacturers report VOC ratings under 10 percent, with many soy inks registered at 2 to 4 percent. Soy ink also enhances paper recycling since soy ink is easier to remove from paper pulp than petroleum-based ink, so there is less damage to pulp fibers during deinking. Finally, soy inks are more biodegradable than petroleum-based inks. In a study to test the biodegradability of various inks, ARS scientists found that 90 percent of USDA's 100-percent vegetable oil inks biodegraded, compared with 60 percent for regular soy-based formulations that contain about 30-percent vegetable oil and 20-percent biodegradation for petroleum-based inks. All inks, including the 100-percent vegetable oil formulations, utilize pigments, which are derived from either petrochemicals or metallic oxides, that preclude complete biodegradability.

According to the National Soy Information Center, the use of soybean oil in printing inks grew nearly 27 percent between 1994 and 1995, from 46 million pounds to 58.2 million pounds. However, industry analysts suggest that growth in U.S. vegetable oil-based inks will begin to flatten out, primarily because most of the environmentally proactive users have already switched from petroleum-based inks and demand will stay constant. In contrast, interest is expanding overseas. For example, soy inks are being tested in the Asian market. South Korea's two largest newspapers are using and actively promoting soy ink. Major newspapers in both Japan and Taiwan are considering making the switch to soy.

Soybean Solvents Are Cleaning Up

A new soy-based industrial solvent, now being marketed by several companies, is a direct substitute for petroleum distillate as a cleaner and carrying agent. Soy solvents help cut grease, oil, tar, hydrocarbons, and a variety of oil-based paints and rubber compounds. Other benefits of using soy solvents are that they have no harsh fumes or unpleasant odors, they do not irritate skin, and they are recyclable.

Using USB funding, Cyto Culture International, Inc., of Point Richmond, California, has developed a process that uses methyl soyate to clean up oil spills. The solvent is sprayed on sand and contaminated rocks, and the oil is separated and recovered by conventional skimming technology. In many cases, more than 90 percent of the oil can be removed by the soy solvent. The remaining crude oil then biodegrades more quickly after exposure to the methyl soyate. This new method is far less expensive than older methods of cleaning oil spills that usually require high transport and storage costs of moving the soiled sand to a landfill. In 1997, the U.S. Environmental Protection Agency listed the product and process for use as a surface cleaning agent.

Promising Research in Soy-Based Lubricants

USB is funding research on soy-based lubricants with the goal of commercial use in 3 to 5 years. Soybean oil is biodegradable, which gives it an advantage over petroleum lubricants in instances where the lubricant is lost into the environment and may contaminate water supplies. Soybean oil also protects metal better than petroleum lubricants and costs less than canola or industrial rapeseed oils, which are already being used in lubricant formulations. However, soybean oil has technical and economic barriers to overcome before commercial use is feasible. The oil gels up under pressure and high temperatures. Researchers at the University of Delaware may alleviate these performance problems by using oils from genetically modified soybeans. Also, soybean oil is more expensive than petroleum lubricants, which will relegate soy-based lubricants to niche markets where users would be willing to pay a price premium.

Developing commercially viable soy-based lubricants is primarily focused on hydraulic fluids, crankcase oils, and total-loss lubricants. A niche market for biodegradable hydraulic fluids has already formed in Europe, where many localities ban the use of nondegradable hydraulic fluid to protect water supplies. Industry analysts expect similar requirements to reach the United States sometime in the near future. A prototype biodegradable, soy-based hydraulic fluid has passed year-long development tests at the University of Northern Iowa's Agricultural-Based Industrial Lubricants Research Program and is ready for market introduction.

Scientists at Agro Management Group, Inc., of Colorado Springs, Colorado, are testing soybean oil in conjunction with canola oil in the crankcases of small engines, such as lawnmowers and snowblowers. Renewable Lubricants of Hartville, Ohio, is researching the use of soybean oil as a crankcase lubricant in automobile engines. Soybean oil-based lubricants also can fill a need in situations where oils and greases are routinely lost into sensitive environmental areas. These include uses in railroads and offshore-drilling equipment. Soy lubricants are also safer for workers in industrial situations like metal-working factories where workers are exposed to fumes from quenching and cutting oils. International Lubricants, Inc., of Seattle, Washington, is evaluating soy-based total-loss lubricants. Total-loss lubricants, which include oil for lawnmowers and other machines with two-cycle engines, drop directly to the ground or water through normal use. Omni Tech International of Midland, Michigan, estimates that certain crankcase oils and hydraulic fluids made with soybean oil could be on the market in 2 to 3 years. The company expects soy-based lubricants will eventually capture 10 to 15 percent of the lubricants market.

Creative Efforts of Students Result in New Uses

Professional researchers have not been the only ones in recent years investigating new uses for soybeans. Other innovative uses have been developed by students. Two Purdue University students developed a soy-based fire-starter log. The log is a flat, brownish bar made from sawdust and fully hydrogenated soybean oil under pressure. Two commercial companies have expressed interest in the product.

Other student projects at Purdue have found ways to substitute hydrogenated soybean oil for paraffin, a petroleum-based wax. The first project developed a set of soy-based crayons. The crayons, which are 80-percent soybean oil, are nontoxic and washable. Already in commercial production, soy-based crayons could require the oil from up to 200 tons of soybeans a year. The market for crayons is large, about 2 billion annually. Another group created birthday candles, made with edible wax. The candles are 83-percent hydrogenated soybean oil and come in seven flavors. The candles reportedly drip less and burn an average of 25 seconds longer with a shorter flame than paraffin birthday candles. [Jacqueline Salsgiver, ERS, (202) 501-7107, jsalsgiv@econ.ag.gov]

Straw and Kenaf Make Inroads in Building Materials and Paper

In the United States, composite building materials are being made from straw. Straw bales are being used in the construction of buildings. Researchers are investigating straw as a raw material for paper. Uses of kenaf continue to expand. Numerous companies are producing and selling kenaf-based products.

Straw is the stalk of the plant that remains after the harvest of grains, such as wheat and rice. Most straw is incorporated back into the soil, used for animal bedding, or burned in the field. However, concern about straw burning and high wood prices has prompted interest in alternative uses of straw. Technological improvements in baling, collecting, and transporting straw during the last few decades also have made off-farm uses more economical. For example, modern balers can produce various-sized bales, with the larger sizes weighing up to a ton. A few companies in the United States have begun using straw to make composite building materials. Straw bales also are being used directly in the construction of homes and other structures as walls and insulation. Its use in paper is being investigated in the United States by government and private researchers.

Straw Is Produced in Many U.S. Regions

Numerous types of straw are available throughout the United States as residues of grain production. Most is wheat and rice, but barley, oats, rye, and grass straws also are found in some areas of the country. The amount of straw available for off-farm uses varies. How much can be removed from a field depends on the soil type and field topography. In many instances, some straw must be incorporated back into the soil to maintain soil quality and reduce wind and water erosion. Also, farmers may use some or all of their straw on-farm for livestock bedding or other uses.

Data on straw production or the amount used off-farm are not available. However, researchers have developed techniques to estimate crop residue production, including straw, and, in some instances, the percentage that can be harvested without harming soil productivity. For example, about 78.5 million tons of wheat and rice were produced on average during 1990-96 in the United States (table 5). About 123 million tons of straw was produced annually as a byproduct during the same period. North Dakota, Kansas, Oklahoma, and Washington were the leading wheat growing states, while Arkansas and California were top in rice production. In these and other major growing areas, an estimated 51 million tons out of the 101 million tons of straw produced annually could have been harvested without lasting damage to the soil. These estimates do not take into account on-farm uses, nor whether local production was concentrated enough to make straw collection and transportation feasible.

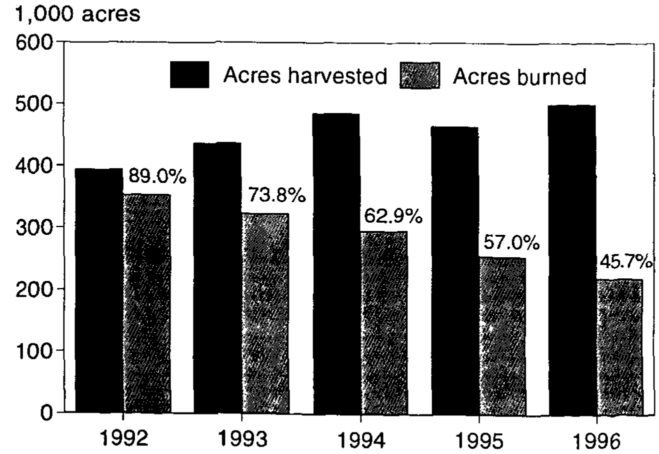
Because straw is bulky, the distance to which straw bales can be economically transported is limited. Companies using straw as a manufacturing input must decide on plant location, collection methods, and type and location of storage facilities, among other business decisions.

In California, finding off-farm uses for rice straw is becoming more important as the mandated phasedown in agricultural burning in the Sacramento Valley continues. Burning has been the standard method for clearing rice fields and disposing of the straw. However, public complaints about the effects of burning on visibility and air quality led to the passage of the Rice Straw Burning Reduction Act of 1991. The law phases down the yearly amount of rice straw that can be burned in the Sacramento Valley Air Basin from 90 percent of planted rice acreage in 1992 to 25 percent in 1998-99. In 1996, farmers burned 45.7 percent of their rice acreage (figure 6), slightly below the 50-percent level mandated by the act. To foster off-farm uses, the California Legislature passed a law in 1996 authorizing a yearly tax credit of up to $400,000 for 11 years for firms using rice straw. Businesses can claim a $15-credit for every ton of rice straw used in products and services.

In 1991, legislators in Oregon also passed a law phasing down field burning of grass-seed and cereal-grain straw in the Willamette Valley from 180,000 acres in 1991 to 40,000

Figure 6

Rice Acreage Harvested and Burned in California's Sacramento Valley



Source: California Rice Industry Association.

Table 5--Estimated availability of wheat and rice straw in leading U.S. production areas

Commodity and state	Average annual production, 1990-96	Grain-to-residue ratio 1/	Estimated crop residue 2/	Harvestable fraction 3/	Estimated availability
	1,000 tons		1,000 tons	Percent	1,000 tons
Winter wheat					
Kansas	10,903	1:1.7	18,535	43	7,970
Oklahoma	4,301	1:1.7	7,312	51	3,729
Washington	3,700	1:1.7	6,290	50	3,145
Texas	2,912	1:1.7	4,950	33	1,634
Colorado	2,446	1:1.7	4,158	13	541
Montana	2,285	1:1.7	3,885	20	777
Nebraska	2,168	1:1.7	3,686	34	1,253
Ohio	1,896	1:1.7	3,223	50	1,612
Illinois	1,832	1:1.7	3,114	50	1,557
Idaho	1,816	1:1.7	3,087	50	1,544
Missouri	1,676	1:1.7	2,849	50	1,425
South Dakota	1,481	1:1.7	2,518	26	655
Arkansas	1,295	1:1.7	2,202	50	1,101
Indiana	1,060	1:1.7	1,802	50	901
U.S. total	49,086	1:1.7	83,446	--	--
Spring wheat 4/					
North Dakota	10,745	1:1.3	13,969	73	10,197
Montana	3,094	1:1.3	4,022	21	845
Minnesota	2,699	1:1.3	3,509	50	1,754
South Dakota	1,789	1:1.3	2,326	36	837
U.S. total	20,930	1:1.3	27,209	--	--
Rice 5/					
Arkansas	3,505	1:1.5	5,258	100	5,258
California	1,746	1:1.5	2,619	100	2,619
Louisiana	1,327	1:1.5	1,991	100	1,991
U.S. total	8,530	1:1.5	12,795	--	--
Total	78,546	--	123,450	--	51,342

-- = Not applicable. 1/ Estimated amount of residue per unit of grain production. For example, production of 1 ton of winter wheat results in 1.7 tons of residue. Source: W.E. Larson, R.F. Holt, and C.W. Carlson, "Residues for Soil Conservation," Crop Residue Management Systems, American Society of Agronomy, Madison, WI, 1978, pp. 1-15. 2/ Grain production multiplied by the appropriate ratio. 3/ Proportion of crop residues that can be removed without significant soil damage from wind and water erosion. For wheat in the Great Plains, the rates are from W.G. Held, Jr., Turning Great Plains Crop Residues and Other Products into Energy, AER-523, USDA, ERS, 1984. For wheat in other states, the rate is assumed to be 50 percent. For rice, 100 percent removal is assumed. 4/ Includes durum wheat. 5/ 1,000 short tons, rough basis.

acres in 1998 and thereafter. The law also authorizes state funds and burning fees be used for research and development to find alternative methods of field sanitization and uses of straw.

Companies Are Making Composite Panels From Straw

A process for producing compressed straw panels was invented in the 1930's and was used to a limited extent in Europe, Canada, and Australia in the intervening decades. Only in the last couple of years have companies in the United States started manufacturing structural and nonstructural panels and composite products made from straw. For example, Agriboard Industries, based in Fairfield, Iowa, and Coppell, Texas, began producing compressed straw panels in February 1997 at its Electra, Texas, manufacturing facility. Farmers bale straw into 1,000-pound bales, which are shipped to the factory and stored for use. The company estimates that it will initially use about 13,000 tons of straw annually and at full capacity, up to 40,000 tons per year.

A 240-foot long linear extrusion mill separates wheat or rice straw into loose strands, compresses it under intense heat, and fuses it into 3½-inch thick strawboard. No chemical binders are added. Straw fibers, when compressed under high temperatures, bond together without any adhesive. For structural applications, the strawboard is then laminated between oriented-strand board to form a stress-skin panel. Stress-skin-panel building systems, usually made with synthetic extruded polystyrene foam or paper as the core material, have become popular in applications where their high insulative properties are desired. Agriboard's panels have undergone testing by the National Association of Homebuilders Research Foundation and other testing agencies to demonstrate their fire resistance, acoustical properties, and structural and thermal performance. The company is supplying panels for several construction projects across the country, including a large retail store in Chicago, Illinois, and 200- and 300-unit apartment complexes in Austin, Texas. The company plans to open plants in California and Ohio within the next 18 months.

Other straw panel manufacturers are due to come on line in 1997. BioFab, LLC, of Redding, California, is now marketing imported prototype strawboard panels, and is planning a full-scale production facility to come on line this fall in California's Sacramento Valley. The panels are formed through an extrusion process under heat and pressure, using 100-percent rice straw and no chemical additives. The company offers two products for interior and nonload-bearing applications:

- A decorative acoustical ceiling/wall panel, which looks like a thatched ceiling, and
- A nonstructural panel covered with recycled-content linerboard, which is sold as a replacement for gypsumboard drywall and wood studs.

Pierce International of Englewood, Colorado, and Stramtech of Rupert, Idaho, are planning to open a production facility in Rupert this fall. Construction is underway. A similar facility in Virginia's eastern shore is scheduled to open in the fall of 1998. Once in operation, these plants will compress straw under heat and pressure in an extrusion process to produce straw panels. Plants in Europe and Australia have been using the same technology to manufacture straw panels since the late 1940's. The panels will be used for interior and nonload-bearing walls and partitions.

Cereal straws are also being used for the production of particleboard and plywood substitutes. For instance, PrimeBoard, Inc., is making an industrial-grade particleboard from wheat straw at its new $15-million plant in Wahpeton, North Dakota, which opened in August 1995. The particleboard is made from wheat straw and a formaldehyde-free binder made from methylene diphenyl diisocyanate (MDI). The absence of urea formaldehyde, a common substance in wood particleboard, is seen as a plus because formaldehyde-containing adhesives give off toxic fumes. PrimeBoard's composite panel has been independently tested and mill certified to meet or exceed all specifications for industrial-grade particleboard and can be used in the same applications as wood particleboard. One of PrimeBoard's primary customers is PrimeWood, Inc., a kitchen cabinet/furniture/architectural millwork component manufacturer also located in Wahpeton. A major impetus for forming PrimeBoard came from PrimeWood's concern about long-term supplies of wood for building materials.

Naturall Fibre Boards, LC, of Minneapolis, Kansas, began manufacturing strawboard on a limited scale in June 1995. The equipment chops up the straw, mixes it with a MDI resin, and presses it into panels. A new press is on order for delivery in 1998 that will increase production eight-fold. The panels are being marketed as floor underlay (a material that is often under carpeting, vinyl flooring, and other floor coverings). According to the company, the panels meet the requirements for fiberboard and particleboard underlay and comply with all building codes.

Eleven farmer cooperatives in central Kansas formed CenKan Enterprises to produce straw-based particleboard. The manufacturing facility in Hutchinson, Kansas, is scheduled to come on line this summer. The production system was purchased from a British firm, which is marketing the technology worldwide. As with similar systems, chopped straw is mixed with a MDI binder and pressed into panels. CenKan has signed a 5-year contract with a Canadian-based distributor to market the straw-based particleboard in ready-to-assemble furniture applications in the United States. These companies are just a few examples of the firms that are using straw or are planning straw-based enterprises in the near future.

According to an analysis of alternative construction materials made from cellulosic wastes (straw, urban wood waste, and recycled paper) by the Institute for Local Self-Reliance, the short-term acceptance of alternative building systems or products depends not only on customer acceptance but also on whether the systems comply with building codes. Construction products made from cellulosic sources will likely have the most success when used with pre-existing construction techniques (8).

Straw Bales Are Used Directly in Construction

In addition to using straw to manufacture building materials, straw bales are being used directly in construction. The bales are used to make the walls of houses, garages, storage sheds, and other structures. Two types of smaller bales are used:

- Two-string bales, which are roughly 35-40 inches long, 18 inches wide, and 14 inches high and tied together with two pieces of polypropylene twine, or
- Three-string bales, which are usually 32-47 inches long, 23-24 inches wide, and 14-17 inches high and tied together with three pieces of polypropylene twine.

Any type of straw can be used. Bale size, density, and the number of strings will vary with the type of straw and the type of baler used.

Bale walls can be built on top of any type of foundation, and can be load-bearing or used as infill with post-and-beam construction. If the walls are load-bearing, which means they are the structural support for the roof, the bales are stacked in staggered courses like big bricks, then rebar (steel reinforcement bars used in concrete structures), bamboo, or wooden dowels are driven down through the bales for vertical reinforcement. Load-bearing structures are usually one-story, square, or rectangular buildings.

With post-and-beam construction, a wood, metal, or masonry structural frame supports the roof, and bales are stacked in between the posts to make the walls. Post-and-beam construction offers greater flexibility than load-bearing designs, allowing for a wider variety of floor plans, roof designs, and building heights. Hybrid systems, with some load-bearing walls and some post and beam, also exist. As one of the final steps in construction, the walls are covered with some sort of finish. Commonly, stucco is applied to the exterior and plaster to the interior, although various other wall finishes have been used.

In the United States, building with bales can be traced to the Sand Hills of Nebraska around the turn of the century. Few trees were available for timber, and the soil was too sandy for sod homes. The advent of baling equipment allowed settlers to use prairie hay as a building material. From about 1890 to 1935, bales were used to build load-bearing homes, farm buildings, churches, schools, offices, and grocery stores.

Recent interest in straw bale construction began in the late 1970's after an article by a Nebraska historian on the bale homes in that state was published in 1974. Using straw bales appeals to future home owners, architects, and builders who are concerned about the impact of traditional building systems on the world's resources. They view straw as an abundant renewable resource. In the southwestern United States, straw bales also were found to be a cheap substitute for labor-intensive double-wall adobe.

One facet of straw bale building often mentioned in the popular press is its affordability. However, walls typically represent only 15 to 20 percent of the overall cost of most houses, and building costs can vary depending on the climate, the characteristics of the site, building-code and permit requirements, and labor and raw-material costs. Using salvaged materials and labor donated by the owner/builder, friends, relatives, and straw bale workshop participants are frequently mentioned as ways owner/builders can reduce construction costs. Structures built by architects and contractors are only marginally less expensive than conventional construction, given that labor accounts for 60 percent of the cost of a contracted home (6). Nevertheless, lower energy and maintenance costs over the life of the structure are often cited as a benefit of straw bale buildings.

Straw Bale Buildings Can Be Found In Many Locations

All types of buildings have been erected with straw—homes, cabins, storage sheds, barns, and other out buildings. Initially, most structures were built in rural areas, where complying with building codes was not a problem. The first straw bale house to have a building permit was constructed in Tesuque, New Mexico, in 1991. This post-and-beam structure was considered a breakthrough by the industry, as it was the first permitted, contractor-built, bank-financed, straw bale house in the United States (4).

The first load-bearing house to receive a building permit was constructed in Tucson, Arizona, in 1993. Approval was made possible as the result of structural tests conducted at the University of Arizona, in cooperation with city and county building officials (5). Since then, load-bearing houses have been approved in other Arizona jurisdictions, California, Colorado, Florida, Maine, Oregon, and Washington State. An estimated 20 states have straw bale structures built with building permits and another 23 have straw bale buildings erected since 1940 (figure 7).

Applying for and receiving building permits is a local process. Unlike Canada and most European countries, the United States does not have a national building code. Building codes are usually adopted as municipal or county ordinances or by state legislatures in the case of statewide codes. These codes often are based on one of three model building codes:

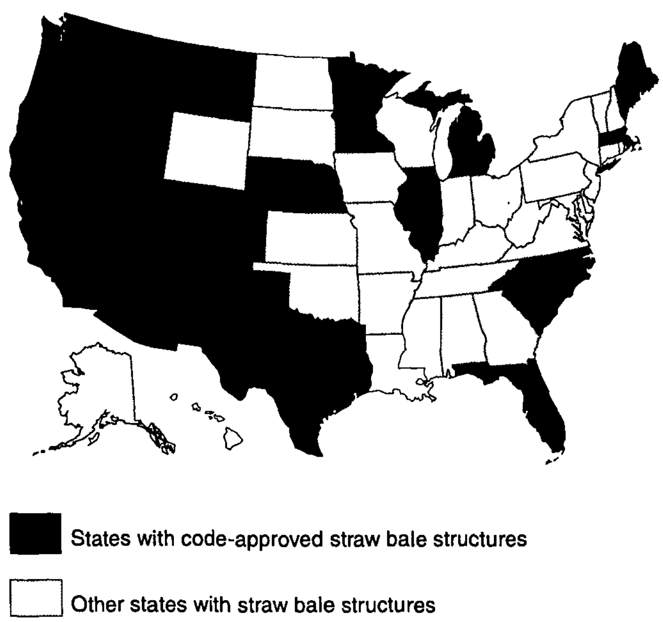
- the Uniform Building Code, which is common west of the Mississippi River,
- the Basic Building Code, which is used primarily in the Northeast and Midwest, and
- the Standard Building Code, which is usually found in the Southeast (3).

All three model codes contain sections that address the use of alternative building materials, such as straw bale, adobe, and rammed earth. Building officials may approve any such alternative, provided that the proposed design of the structure is satisfactory and complies with the provisions of the local code and that the material is, for the purpose intended, at least equivalent to that prescribed in the code in terms of suitability, strength, effectiveness, fire resistance, durability, safety, and sanitation (3).

A few jurisdictions have approved building codes specifically for straw bale construction. In January 1996, New Mexico adopted the post-and-beam code that the state had

Figure 7

Estimated Locations of Straw Bale Structures



been using as guidelines to issue building permits. Also, in January 1996, the City of Tucson and Pima County, Arizona, adopted standards for load-bearing and nonload-bearing straw bale construction.

In the fall of 1995, the California legislature enacted a bill, which became effective January 1, 1996, that amends the state building standards law to establish safety guidelines for the construction of structures that use baled rice straw as a load-bearing or nonload-bearing material. California cities and counties must adopt the guidelines for them to become part of local building codes. Individual jurisdictions may modify the guidelines as deemed necessary. Several counties, including Glenn, Napa, Trinity, and Yolo, have adopted the straw bale guidelines as part of their building codes. Also in 1995, a law was passed in Nevada specifying that local jurisdictions amend their building codes to permit the use of straw and other materials that are renewable or conserve scarce natural resources.

Bale Wall Systems Have Various Attributes

One of the most often cited benefits of building with straw bales is the increased insulation the thick bales provide. Results of two studies conducted in 1993 and 1994 indicate that straw bales have an average R-value (resistance to heat flow) of 2.5 to 3 per inch, compared with 1 for wood, 0.2 for brick, and 3 for fiberglass batts. Thus, depending on the thickness of the bale, R-values can range from 35 to 55. Plaster, stucco, or other finishes also can add to the R-value of completed walls.

While loose straw burns, once it is packed into bales it is remarkably fire resistant. The dense bales limit the oxygen available for combustion. Fire-resistance tests were conducted in December 1993 for New Mexico on test straw bale walls. A 1994 report from the New Mexico State Construction Industries Division on straw bale construction states that the results of the fire-resistance tests demonstrate that a straw bale infill wall assembly is a far greater fire-resistive assembly than a wood frame wall assembly using the same finishes.

Moisture is a concern with straw bale buildings as it is with wood structures. Fungus (dry rot) can occur in straw at humidity levels above 20 percent of the dry weight. However, for significant damage to occur, these humidity levels must be maintained over a period of time. To keep obvious sources of moisture at bay, those familiar with straw bale construction recommend that the bales be elevated above the surrounding soil and a moisture barrier used in areas subject to direct wetting. Historical experience suggests that the best way to avoid sustained high-moisture concentrations is to permit finished bales to transpire any accumulated moisture back into the environment. Common finishes, like lime and adobe plaster and cement stucco, do allow vapor transmission.

More Testing Needed on Straw Bale Construction

For straw bale construction to become more widely accepted, particularly by building code officials, more research and testing is needed on topics such as building methods and parameters and long-term durability in various climates. Some testing has been done in the last few years. For example, structural and thermal tests have been performed in Tucson, Arizona, and fire, wind-loading, and compression tests have been conducted by a certified laboratory in Sante Fe, New Mexico.

In addition, during the early 1990's, the Navajo Nation, in cooperation with the U.S. Department of Energy (DOE) and U.S. Department of Housing and Urban Development, initiated a search for more energy-efficient, affordable housing that could be built on the reservation with local materials and would fit the Navajo lifestyle. The result was a demonstration home, using a combination of adobe walls and load-bearing straw bale walls, constructed near Ganado, Arizona. On behalf of DOE, Lawrence Berkeley Laboratory analyzed the thermal characteristics of the various wall materials and projected energy savings for the prototype home. In its final report, the laboratory concluded that straw bale building offered the best energy performance of any of the new construction types being considered, with a 15-percent improvement in overall building energy efficiency in heating for the climates on the Navajo reservation.

In 1995, the City of Tucson's Community Services Department was awarded a $73,000 grant to measure and evaluate the affordability and energy efficiency of straw bale housing and site/resource utilization. The funding came from DOE and was administered by the Urban Consortium Energy Task Force. In 1996, Habitat for Humanity Tucson and the Tucson Urban League, in conjunction with the city, each built a straw bale house on city-owned land. The buildings were designed for low-energy and resource use and will be monitored for energy use for a minimum of 1 year. The structures, now private homes, are open to the public on a limited basis for 1 year for educational and informational purposes. The information gathered during construction and monitoring of the two houses will be documented and analyzed to determine costs and energy and resource savings.

The nonprofit Aprovecho Research Center of Cottage Grove, Oregon, will soon complete a 2-story straw bale dormitory. The post-and-beam structure complies with Lane County Building Codes and has 350 rye grass straw bales as infill. Part of the funding for the project came from the Oregon Department of Agriculture for construction of a straw-bale home that could be studied for practicality and durability. A portion of the money, from a state fund for finding alternatives to burning straw on Willamette Valley grass-seed fields, goes to the university for monitoring the dormitory with moisture-detecting sensors imbedded in the walls.

Other Countries Are Using Straw For Paper And Paperboard

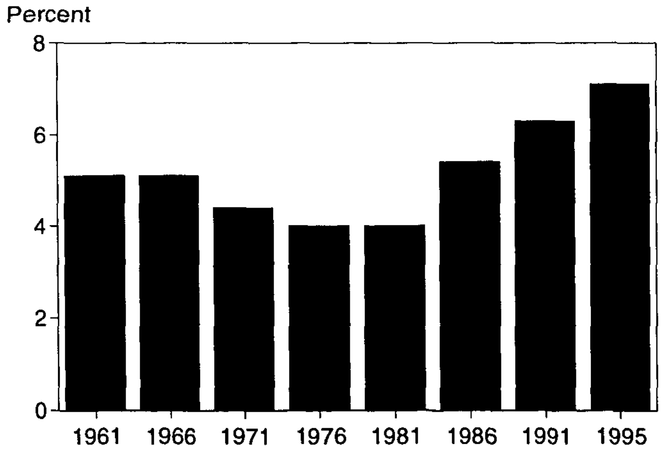
During the 1800's, straw was widely used in the United States and other countries to make paper and paperboard, but the advent of wood pulping technology in the mid-1800's displaced straw from many paper grades. Straw pulping for paperboard continued to expand and peaked in the 1940's. During the next couple of decades, demand for paperboard increased substantially as corrugated cardboard boxes began to displace wooden crates as packing and shipping containers. However, declining economic returns caused many paperboard manufacturers to switch from straw to hardwoods and waste paper. The last U.S. mills stopped using straw in the 1960's.

Nevertheless, cereal straws and other nonwood fibers continue to be important in many countries where supplies of pulpwood are limited. In developing countries, many of which are located in areas with limited forest resources, nonwood fibers accounted for about 35 percent of the raw materials used for pulp production during the 1990's. In contrast, during the 1990's, nonwood fibers made up less than 0.5 percent of pulp production in developed countries, which often have greater forest resources. In 1995, nonwood fibers accounted for 7 percent of total world pulp production, up from roughly 4 percent in the 1970's and early 1980's (figure 8).

Straw, sugar cane bagasse, and bamboo are the leading nonwood fibers countries use for general paper production (table 6). Other nonwood fibers, such as abaca and sisal, have unique characteristics and are used in specialty applications. China and India are major producers of nonwood fibers (table 7). As for straw, China accounted for 88 percent of straw pulp capacity in 1993, with another 22 countries holding the remainder (2).

Figure 8

Nonwood Pulp as a Share of Total World Pulp Production



Source: United Nations, Food and Agricultural Organization.

For straw to again become a raw material for paper and paperboard in the United States, industry experts cite a number of issues that must be addressed:

- Certainty of supply over the long run at a competitive price. For an industry accustomed to using trees, relying on a byproduct of annual grain production raises concerns about availability and price.
- Raw material bulkiness. Straw is bulky, which means collection, transportation, and storage costs will be higher than for wood over similar distances. Pulping procedures also must be adjusted to account for straw's bulkiness.

Table 6—World nonwood-pulp production capacity, by type of raw material

Raw material	Pulp production capacity 1985	1990	1993
	1,000 metric tons		
Straw	6,166	6,787	9,566
Sugar cane bagasse	2,339	2,739	2,984
Bamboo	1,545	987	1,316
Other	3,302	5,049	6,870
Total	13,352	15,562	20,736

Source: Joseph Atchison, "Present Status and Future Prospects for Use of Non-Wood Plant Fibers for Paper Grade Pulps," paper presented at the AF&PA 1994 Pulp and Fiber Fall Seminar, Tucson, AZ, November 14-16, 1994.

Table 7—World production of nonwood pulps, selected years 1/

Country	1961	1971	1981	1991	1995
	1,000 metric tons				
China	1,640.0	2,270.0	3,466.0	12,232.0	17,551.0
India	290.0	660.0	457.0	1,009.0	920.0
United States	400.0	580.0	670.0	240.0	240.0
Pakistan	21.0	42.0	56.0	159.0	160.0
Colombia	16.6	70.0	88.0	101.0	142.0
Thailand	2.6	22.0	37.0	148.0	134.0
Italy	53.6	400.0	215.0	97.0	130.0
Mexico	45.7	165.0	285.0	237.0	117.0
South Africa	25.0	30.0	84.0	99.0	99.0
Argentina	50.0	39.0	44.0	78.0	98.0
Brazil	25.0	56.9	122.0	125.0	75.0
Indonesia	6.0	17.0	65.0	84.0	74.0
Vietnam	0.0	7.0	5.0	69.7	74.0
Venezuela	5.4	23.0	42.0	67.0	66.0
Egypt	2.0	67.0	80.0	47.0	60.0
Cuba	23.0	36.0	31.6	52.0	52.0
North Korea	3.0	30.0	50.0	50.0	50.0
Peru	27.0	78.0	120.0	116.0	48.0
Iran	2.4	24.0	50.0	62.0	45.0
Canada	15.0	40.0	40.0	40.0	40.0
Bangladesh	0.0	20.0	50.5	33.0	38.0
Turkey	6.3	12.3	75.0	87.0	35.0
Denmark	12.6	37.0	45.0	34.0	34.0
Philippines	10.0	33.0	31.0	22.0	27.0
Algeria	23.0	16.0	31.0	21.0	21.0
Hungary	5.5	18.8	22.0	5.0	20.0
Other	1,233.3	1,164.3	841.8	690.8	132.2
World	3,944.0	5,958.3	7,103.9	16,005.5	20,482.2

1/ Includes pulp made from cereal straws, bagasse, bamboo, cotton fibers and linters, flax, abaca, jute, sisal, hemp, reeds, and grasses.

Source: United Nations, Food and Agricultural Organization.

- Extended storage. After harvest, straw must be collected and stored for year-around availability, without significant deterioration of fiber quality.
- Silica content. (Silica is a common mineral; its most familiar form is sand.) Depending on the type, straw can contain 4- to 15-percent silica, which interferes with conventional recovery of pulping chemicals.
- Pulp drainage characteristics. Straw pulp contains high amounts of short fibers (less than 1 millimeter in length) and hemicellulose, which combine to slow the drainage of water from the pulp. Fast drainage is important when using high-speed papermaking machines, which have been key in increasing industry productivity.

A few universities and other organizations are researching the feasibility of using straw for paper and paperboard. For example, Weyerhaeuser Company, Oregon State University, and the Oregon Department of Agriculture initiated a project in 1993 to investigate new technologies for processing ryegrass straw. The project has progressed to tests in a 50-tons-per-day pilot plant using a steam-explosion process. The straw pulp would be used with wood pulp to make linerboard for corrugated containers. Also, the University of Washington and Washington State University are cooperating on a project to assess pulping options for wheat straw and to select wheat varieties with improved fiber properties. The project hopes to receive a grant to assess the feasibility of a straw pulp mill in eastern Washington.

University of Minnesota researchers are working with Blandin Paper Company of Grand Rapids, Minnesota, and local wheat and barley growers to investigate the use of straw for paper. In preliminary tests, researchers found that mixing straw and wood pulps yielded the same type and quality of paper Blandin was making for glossy newspaper inserts. Up to 30 percent of straw pulp could be used without a loss in quality. The group is now planning to conduct a feasibility study of producing straw from farmer-owned mills in the upper Midwest.

One company, Arbokem of Vancouver, Canada, is already producing limited amounts of straw pulp. It's demonstration-scale pulp mill in Vulcan, Alberta, can make up to 2,000 tons of pulp per year using a proprietary potassium-based process. The company plans to build a rice straw-based pulp mill in California's Sacramento Valley. In collaboration with different paper mills, the company has produced various grades of paper for test commercial sale, principally in California. Its white photocopy paper is made from 45-percent wheat straw, 43-percent post-consumer recycled paper, and 12-percent calcium carbonate.

Kenaf Production and Products Continue To Expand

Development and commercialization of kenaf and various kenaf-based products in the United States have been ongoing since the 1940's. Research and development efforts, initiated by the U.S. Department of Agriculture (USDA) when U.S. jute imports were interrupted during World War II, received a boost in the 1950's when researchers identified kenaf as the most promising nonwood fiber for pulp and paper making. More recent USDA research and industry interest was triggered by high newsprint prices in the late 1970's.

Like jute and flax, kenaf stems consist of two distinct fibers. The outer bark of bast fibers comprises 30 to 40 percent of the total dry weight of the stalk. The inner core of short balsa-wood-like fibers accounts for the remainder.

Kenaf can be grown in many parts of the United States and the world, but it generally needs a long growing season to produce the necessary yield to make it a profitable crop. With a long growing season, like that found in the southern United States, kenaf can reach a height of 12 to 18 feet and produce 5 to 10 tons of dry fiber per acre annually. An estimated 8,000 acres of kenaf currently are being grown in the United States (1), up from roughly 4,000 acres in 1992 and 1993 (see the June and December 1993 issues of this report). Primary production areas are Texas, Mississippi, Georgia, Delaware, and Louisiana.

Numerous companies are producing and selling kenaf-based products. Kenaf International, headquartered in McAllen, Texas, has been producing kenaf since 1981 (1). The kenaf is grown in southern Texas and processed locally to separate the bast and core fibers. The fibers are used in moldable fiber mats and oil-absorbent pillows for cleaning up oil spills. The fiber mats, which are made from the bast fibers, are being used in European automobiles as interior door panels. The company also is evaluating other products that can be made from the bast and core fibers. Company President, Charles Taylor, has identified many current and potential types of kenaf-based products, including:

- Pulp, paper, and paperboard produced by wet processing;
- Fiberboard produced by dry processing using moldable fiber mats;
- Absorbing media;
- Packing materials;
- Composite products;
- Livestock forage and feed; and
- Traditional cordage uses.

In February 1997, Canadian-based Kafus Capital Corporation announced that its subsidiary, Kenaf Paper Manufacturing (KPM), had acquired an option to purchase 50 acres of land in Willacy County, Texas, on which the company plans to construct a newsprint mill (7). The facility will be the first commercial pulp mill in North America to use whole-stalk kenaf as its sole fiber source. The announcement indicated that KPM is in the final stages of concluding long-term sales agreements for its newsprint with leading newspaper publishers, primarily in Texas. Newspapers reportedly are interested in newsprint from kenaf because it has the potential to be an additional source of newsprint at a reasonable price. Long-term contracts for supplying kenaf fiber also are expected soon with Kenaf International, which is a minority owner of KPM.

The KPM plant is estimated to cost slightly over $100 million to build and will be capable of producing between 70,000 and 90,000 tons of high-quality newsprint annually. Although this plant is somewhat smaller than most conventional newsprint facilities constructed in North America during the past 10 years, the company claims it is designed to be one of the lowest cost producers of newsprint on the continent.

First Farm Fibers, a Delaware-based corporation comprised of farmers and investors, and researchers from the University of Delaware have worked with Curtis Paper Mill, a division of James River Paper, in Newark, Delaware, to produce kenaf paper, which can be bleached or unbleached, coated or uncoated. They also have collaborated with Crane Paper Company of Dalton, Massachusetts. Crane, looking for ways to expand market options, has placed an order for 10 tons of kenaf fiber to be used in its fine stationery. In 1996, First Farm Fibers contracted with farmers to produce 250 acres of kenaf in Delaware, and has 750 acres under contract this year.

Another commercial producer of kenaf paper is KP Products of Albuquerque, New Mexico. According to the company, kenaf paper is stronger, whiter, longer lasting, more resistant to yellowing, and has better ink adherence than wood-based paper. The firm has produced about 200 tons of kenaf-based paper since 1992.

Examples of other businesses that sell kenaf-based paper products and the types of items they offer include:

- Acorn Design, stationery sets;
- Dancing Kenafs, kenaf spiral journals;
- Don Mickey Designs, letterhead stationery, envelopes, and business cards;
- Eco Specialties, specialty advertising products;
- Everything Earthly, notepads, writing tablets, and envelope sets;
- Grass Roots Paper Company, soft-covered journal paper;
- Okina Sales, spiral notebooks;
- Simple Thoughts, coloring books and calendars; and
- Soundings of the Planet, cassette tape and compact disk inserts and posters.

Ankal, Inc., based in Atlanta, Georgia, also has developed technology to separate the bast and core fibers. The primary product advertised by the firm is a kenaf-core-based cat litter, which is described as biodegradable, dust free, and environmentally friendly. Other products mentioned in company literature, but not advertised for sale, include kenaf paper, building materials, pressure sensitive labels, and pelletized fiber and feed.

During the early 1990's, the Mississippi Delta Fiber Cooperative of Charleston, Mississippi, attempted to produce 2,000 to 3,000 acres of kenaf annually. However, due to various problems, much of the crop was not harvested and, in 1995, the business was taken over by Lumus Gin Company. About 1,600 acres were grown in 1996. The company hopes to produce about the same volume of kenaf this year on less, but more productive, land.

Kenaf Research Also Continues

While significant progress has been made on commercialization of kenaf, much research and development remains to be accomplished before kenaf becomes a major U.S. crop. The largest and most comprehensive U.S. research effort on kenaf is located at Mississippi State University (MSU). MSU has had over 20 scientists from more than 15 disciplines evaluating various aspects of kenaf, including product development. Much of the financial support was Federal funding provided through USDA's Agricultural Research Service, but this funding is being phased out in 1997. The types of research MSU staff have been conducting include:

- Varietal selection and breeding;
- Evaluating planting date, row spacing, plant density, and other yield determinants;
- Production practices;
- Control of nematodes and other kenaf pests;
- Fertility;
- Weed control;
- Plant desiccation for harvest;
- In-field separation of fibers;
- Economic analysis of fiber separation;
- Using kenaf as bedding for horses, broilers, and laboratory animals;
- Evaluating kenaf as an oil sorbent;
- Kenaf core as a bioremediation enhancer, a feedstock for composite materials, and a component in landscape and greenhouse bedding media; and
- Use as a textile fiber, including processing, fiber characteristics, and product development.

University of Delaware researchers have been evaluating kenaf as an alternative crop for their area. Farmers like to use kenaf in rotation with soybeans because it helps to break the life cycle of the soybean cyst nematode. In addition to on-going kenaf production research, scientists are conducting product development work such as using kenaf fibers in composite materials and kenaf core in cat litter, animal bedding, and as a growing medium for plants. [Straw: Lewrene Glaser, ERS, (202) 219-0091, lkglaser@econ.ag.gov. Kenaf: Donald Van Dyne, University of Missouri, (573) 882-0141, ssvandyn@muccmail.missouri.edu]

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Crambe Production and Processing: A Case Study of the Effects on Rural Areas in North Dakota

by

Jacqueline Salsgiver[1]

Abstract: Crambe is a new industrial oilseed being grown in North Dakota. An input-output model was used in this analysis to estimate the economic effects of crambe production, the construction of an oilseed processing plant to handle the crop, and the crushing of the crop in a 15-county region in central North Dakota. The results indicate that an estimated gain of nearly $10 million in total sales and 42 new wage and salary jobs will be added to the region as a direct result of the increase in the production and processing of the 1997 crambe crop. Through local purchases of supplies and the spending of crambe-related income, the industry will generate an estimated additional $2.8 million in total sales and 46 wage and salary jobs. Building the plant added an estimated 46 temporary construction positions in the region, which generated an estimated increase of $2.2 million in sales and another 40 jobs in various industries as the workers spent their wages.

Keywords: Crambe, North Dakota, industrial crops, oilseed processing, regional development.

Over the last 10 to 15 years, a few new industrial crops have been developed in the United States and are now under commercial production. Kenaf, an annual fiber crop, is being produced in the southern regions of this country. Two new industrial oilseeds, crambe and meadowfoam, are grown in North Dakota and Oregon, respectively.

The development, commercialization, and adoption of new crops can provide farmers with additional cropping options. Crop diversification can minimize the risk of uncertain markets and production problems, such as adverse weather conditions and disease outbreaks. Some new crops may fill a rotational need that has multiyear benefits. For example, farmers in North Dakota prefer to use crambe as a broadleaf crop in rotation with small grains because it does not have the insect problems often seen with canola and sunflowers, yet it is not susceptible to the weeds and diseases plaguing small grains. Another example is meadowfoam, which has given farmers in Oregon's Willamette Valley an alternative crop when grass-seed production is no longer viable due to weed problems or other reasons.

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Potential Rural Impacts of New Industrial Crops

Although these new crops may bring about only marginal changes in farm income and agricultural output at the national level, they may have a greater impact at the local level. The development and commercialization of new industrial crops can affect rural economies in several important ways. First, farm income could rise as a result of new crop opportunities. Second, if farm production increases, the level of inputs, transportation, and storage may increase. Jobs in farm-related industries could be created, such as in processing the raw commodities and producing products. Finally, rural employment also may rise because of the multiplier effects of enhanced farm income, increased demand for agricultural inputs, and the establishment or expansion of processing and manufacturing facilities that use agricultural commodities.

The benefits to rural communities depend in part on the industrial mix of the community. Rural areas with a large agricultural base are likely to experience a greater impact due to changes in farm employment, income, and land values than rural areas that specialize in nonagricultural activities (2). Approximately 24 percent of all nonmetropolitan counties are classified by the Economic Research Service as farming-dependent, deriving at least 20 percent of their total labor and proprietor income from farming. Farming-dependent counties are primarily concentrated in the Great Plains, spanning from North Dakota to the Texas Panhandle.

Even if a new industrial crop is produced in a nonmetropolitan area, not all the potential income and job benefits will be realized. For instance, farm employment may not change with the introduction of a new crop, particularly if it is similar to those currently produced. Also, the higher value-added benefits may not be captured in the area. A firm's decision on where to locate its processing and/or manufacturing facility is based on a region's resource base, transportation costs of the raw commodity relative to the processed product, and the availability of skilled labor. Rural areas generally have a comparative advantage over urban areas in terms of availability of natural resources, lower tax rates, and less expensive land and labor costs. However, some processing plants, particularly for those crops that are less costly to transport and store, are located in metropolitan areas. Also, some industries that use agricultural raw materials, such as the chemical and rubber industries, are located in metropolitan regions because they rely on highly skilled labor and technicians. In these situations, metropolitan areas may receive more benefits from industrial crops and products than nonmetropolitan areas (2).

If the development of new industrial crops is to be used as a rural development strategy, it may be useful to develop criteria for which new crops would likely cause the greatest net gain for a region. A new crop should provide some benefit to farmers by fitting into a crop rotation, having the ability to be grown on otherwise unproductive land, or replacing a lower valued crop. Ideally, the region should also capture some of the frontward linkages of the new agricultural products, such as processing and marketing enterprises. This case study illustrates how a rural area is affected by a new industrial crop. The study looks at crambe production and processing in rural North Dakota, showing a region's success in both producing a new industrial crop and participating in the enhancement of the product.

Crambe Uses and Production In North Dakota

Crambe is an annual oilseed crop first introduced in the United States in 1940. Sustained commercial production began in 1990 in central North Dakota. The crop is grown for its inedible oil, which contains high amounts of erucic acid, a 22-carbon fatty acid. Erucic acid is used to make intermediate chemicals, such as slip and antiblock agents, emollients, and surfactants, that are used in the manufacture of such items as plastic bags, cosmetics, personal-care products, and laundry detergents (1). Crambe oil could potentially be used in paints and coatings, nylon-1313, plastics, and hard waxes (3).

Industrial rapeseed is the traditional source of erucic acid for the world market, but in the United States, crambe has begun to tap into this market. Industrial rapeseed and crambe are the only commercial sources of erucic acid (1). The United States currently imports about 40 million pounds of industrial rapeseed oil, primarily from Canada and Eastern Europe, worth about $10 million annually. A small amount of industrial rapeseed is also grown in the Pacific Northwest.

The American Renewable Oil Association, an association of crambe growers, contracted with 435 producers to grow crambe on 50,000 acres in 1997, an increase of 28,000 acres from the previous year. The number of acres contracted is the estimated amount required to meet the domestic demand for crambe oil. All of the acreage is in North Dakota, with much of the production concentrated in the center of the state. In addition to crambe production, AgGrow Oils, a grower-owned company, has begun construction of an $8-million oilseed-crushing plant in Foster County, North Dakota. The plant is a full-press, mechanical processing facility that is scheduled to begin operation in November 1997 processing this year's crambe crop. The company estimates the plant will be able to handle 200 tons of seed per day at startup. The plant will process other novel oilseeds, such as high-oleic sunflower and safflower, flax, and possibly specialty canolas, as well as crambe. AgGrow Oils plans to add a refining system to the plant in subsequent years.

Using an Input-Output Model To Assess Crambe's Effects

To analyze the regional effects of crambe production and processing, a study area of 15 nonmetropolitan counties was defined. The study area encompasses the major crambe growing areas and the related oilseed crushing plant (figure A-1). Total population in the region is 149,000, with an average income of $40,382 per household (table A-1). Nearly 24 percent of the 86,538 jobs are in the services sector, which accounts for the largest share of the region's employment. Although agricultural employment makes up only 15 percent of regional employment, 8 of the 15 counties are considered farming-dependent. The region produces 30 percent of North Dakota's barley crop and 47 percent of the state's sunflower seeds, which is 11 percent of the Nation's barley crop and more than 26 percent of all domestically grown sunflower seeds (table A-2).

Figure A-1
North Dakota Study Region

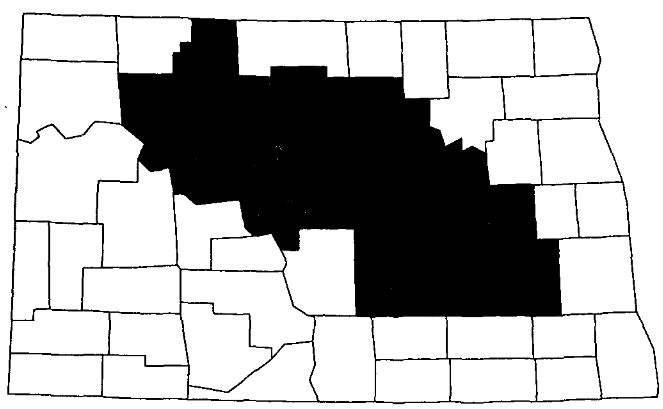

Table A-1--Economic characteristics of the North Dakota study region

Item	15-county study area	Share of North Dakota total
	Number	Percent
Population	149,700	23.5
Income per household 1/	$40,382	N.A.
Total employment	86,538	21.6
Agriculture	12,893	29.2
Mining	446	19.4
Construction	4,287	17.2
Manufacturing	3,414	16.7
Transportation, communication, and public utilities	4,048	20.7
Trade	17,929	20.0
Finance, insurance, and real estate	3,822	18.3
Services	20,741	20.8
Government services	18,636	24.3

N.A. = Not available. 1/ Includes noncash benefits.

Source: IMPLAN Pro Database, Minnesota IMPLAN Group, Stillwater, MN, 1996.

Table A-2--Agricultural characteristics of the North Dakota study region

Item	Regional value	Share of North Dakota total	Share of national total
	1,000 acres	Percent	
Acreage			
Land in farms	11,462	29.1	1.2
Total cropland	8,837	32.2	2.0
Harvested cropland	6,062	31.5	2.1
Irrigated land	37	19.8	0.1
	$1,000		
Value			
Agricultural production	715,074	26.0	0.4
Crops sold	523,719	25.8	0.7
Livestock sold	191,326	26.8	0.2
	1,000 bushels		
Production			
Barley	43,259	30.0	10.9
Corn	2,739	7.3	1/
Wheat	126,631	30.9	5.7
Oats	10,676	31.9	4.3
	1,000 tons		
Hay	992	30.4	0.8
	1,000 pounds		
Sunflowers	589,288	46.8	26.3

1/ Less than 0.1 percent.

Source: 1992 Census of Agriculture, U.S. Department of Commerce, Bureau of the Census, Washington, DC, 1994.

The effects of crambe production and its related enterprises on the overall economy of the central North Dakota study area are estimated using a regional input-output model. Input-output provides a framework in which to collect, categorize, and analyze data on the interindustry structure and interdependencies of a region's economy. Input-output models estimate the direct, indirect, and induced impacts from a final demand change on a region. In this case study, the direct effects are the sales, employment, and value added generated directly by crambe production and the construction and operation of an oilseed processing plant. Indirect impacts are the sales, employment, and value added that result from other firms in the local economy selling to the crambe enterprises, such as the agricultural input industries, agricultural services, and wholesalers. Induced effects or impacts are the sales, employment, and value added generated from the earnings of the workers in the newly created jobs as the earnings are spent in the North Dakota study region.

The analysis is performed within the framework of the 1993 Input-Output Model for Planning and Analysis (IMPLAN) Pro version. This model provides for county-level analysis from 528 industry sectors, similar in detail to the three-digit Standard Industrial Classification codes for most industries. The ability to assess a change in the overall economic activity of a region as a result of some change in one or several economic activities is the appeal of using a model like IMPLAN.

Estimating the Value of Crambe Production And Processing

The first task in estimating the impacts of crambe on the North Dakota study region was to determine the size of the crop, its value to the growers, and the value of the processed oil and meal. First, it is assumed that 90 percent of the 50,000 contracted acres in 1997 will be harvested, i.e., a 10-percent loss will occur due to weather, disease, or other factors, which leaves 45,000 harvested acres. Multiplying 45,000 by the estimated average yield of 1,350 pounds per acre results in a total crambe crop of 60.75 million pounds. Given the contracted price of 10.1 cents per pound, the value of the crambe crop is estimated to be $6.136 million.

Industry sources indicate that an 82.6-percent recovery rate of crambe oil and a 98-percent recovery rate for the meal are reasonable estimates for a mechanical processing facility like the Foster County plant. Crambe seeds contain 35 percent oil (4); therefore, there are 21.263 million pounds of oil in 60.75 million pounds of crambe seed. However, only an estimated 82.6 percent is recovered, or 17.563 million pounds of oil. Subtracting the pounds of extracted oil from the total amount of crambe seed yields 43.187 million pounds of crambe meal. Using the estimated 98-percent recovery rate, the output of crambe meal is about 42.323 million pounds. The total loss rate for crambe processing at this plant is anticipated to be 1.4 percent.

Prices for crambe oil and meal are not available, so price ranges of 28 to 35 cents per pound of oil and $75 to $100 per ton of meal are used as best estimates, based on industry analysts' forecasts. Prices for crambe and industrial rapeseed oil are likely to vary within the range depending on the availability of world supplies. If supplies are adequate, prices may be in the low end of the range. However, if supplies tighten, prices may rise. The price of crambe meal is probably about one-third the price of soybean meal. Crambe meal can only be fed in limited quantities to beef cattle, as per U.S. Food and Drug Administration regulations, and feed formulators may not be familiar with it. However, mechanical processing leaves more residual oil in the meal, giving it a higher feed-energy value than meal from solvent extraction. Given the volumes cited above, the value of the crambe oil is estimated at $4.918 to $6.147 million and the meal at $1.587 to $2.116 million. The value of the two products together is $6.505 to $8.263 million.

Estimating the Impact of Crambe Production

The size of the impact of crambe production on the North Dakota study area is estimated under two different scenarios. The first scenario assumes the 28,000-acre increase in crambe acreage was on land not previously in crop production. The second scenario assumes the increased crambe acreage displaced another crop that would have otherwise been grown on the land. In this case, the income and employment gains from increased crambe production are offset by the loss of the foregone income and employment from the production of the crop that crambe displaced.

The estimated $6.1 million sales of the 1997 crambe crop is up $2.5 million from 1996's $3.6 million crop. This $2.5-million increase was used to estimate the total economic impacts of the expansion of crambe production on the North Dakota study area under the first scenario. The growth in crambe output alone translates into direct economic impacts of $1.2 million value added and the creation of 29 new wage and salary jobs (table A-3). Value added, which includes employee compensation, proprietary income, and indirect business taxes, is a measure of the value of goods and services produced by the crambe growers. When indirect and induced effects are calculated and added onto the direct effects, the total economic impacts of increased crambe production are $3.6 million in total sales, $1.8 million in value added, and 48 new jobs.

Table A-3--Economic impacts of expanded crambe production, 1997-98

Impacts	Sales	Value added	Number of jobs
	Million dollars		
Scenario I			
Direct	2.5	1.2	29
Indirect and induced	1.1	0.6	19
Total	3.6	1.8	48
Scenario II			
Direct	1.3	0.6	15
Indirect and induced	0.5	0.3	9
Total	1.8	0.9	24

Under the second scenario, it is assumed the increased crambe acreage came from canola acreage. Canola was chosen as the displaced crop because it is the most profitable crop after crambe in the north central North Dakota region. The estimated net return of $83.04 per acre from crambe production in 1997 far exceeds the projections for other crops grown in the region (table A-4). Given the $44.21 net returns per acre for canola production, total sales of canola from 28,000 acres are estimated at $1.2 million. An impact analysis on canola reveals that the loss of $1.2 million in sales from canola production would reduce total sales by $1.8 million, with losses of $900,000 in total value added and 24 wage and salary jobs, including induced and indirect effects. Therefore, the gains from crambe production under this scenario are roughly half the size of those under the first scenario. The difference would be even greater if crambe were substituted for a crop less profitable than canola. Aside from crambe's profitability, farmers also benefit by having another crop to put into their crop rotations, an advantage not captured in this analysis.

Assessing the Effects of the Processing Plant

A similar impact analysis was performed to look at the effects on the 15-county study area from the construction of an $8-million oilseed processing plant. Of the $8-million outlay for the plant, an estimated $3.5 million is to be spent on processing machinery, $4 million on construction materials and labor, and $0.5 million on engineering and technical services. The total output effect is estimated at over $10 million and 86 full- and part-time jobs added to the region's economy during construction (table A-5). Because building the plant is a one-time shock to the region, these effects are not expected to be permanent.

Table A-4--Estimated net returns of selected crops in north central North Dakota, 1997

Crop	Returns to land, labor, and management
	Dollars per acre
Crambe	83.04
Canola	44.21
Alfalfa (established)	42.94
Buckwheat	41.16
Sunflower (confectionary)	39.61
Winter wheat	31.12
Barley	15.51
Sunflower (oil)	11.93
Oats	-6.99

Source: Projected 1997 Crop Budgets: North Central North Dakota, North Dakota State University Extension Service, Fargo, ND, 1997.

Table A-5--Economic impacts of constructing a new oilseed crushing plant, 1997-98

Impacts	Sales	Value added	Number of jobs
	Million dollars		
Direct	8.0	1.7	46
Indirect and induced	2.2	1.3	40
Total	10.2	3.0	86

The last phase of the analysis is to examine the impacts associated with the oilseed-crushing plant. In the first year of operation, the plant will process the 1997 crambe crop, which is estimated to be nearly 60.1 million pounds. The value of production from the plant is difficult to determine because prices for crambe oil and meal are proprietary. Nevertheless, the direct output is calculated to be about $7.4 million, the midpoint of the estimated values of oil and meal determined earlier. Including indirect and induced effects, the total value added impact from crambe processing is estimated at $9.1 million, with a possible increase of 40 new jobs (table A-6).

Under the first scenario, the combined direct effect from crambe production, the construction of the processing plant, and the crushing of the 1997 crambe crop is estimated at $17.9 million and an added 88 new jobs in the North Dakota study region (table A-7). Adding the indirect and the induced effects accounts for a nearly $23-million impact on total output and an increase of 174 jobs. Total impacts are not estimated for the second scenario given the uncertainty of the alternative uses of the land used for crambe expansion.

The added jobs come from different economic sectors. Direct job impacts occur in the agricultural, construction, manufacturing, and services sectors (table A-8). The indirect and induced effects show job gains mainly in the trade and services sectors. Most of the new trade jobs are in wholesale trade and eating and drinking establishments, while the model predicts that hospitals account for most of the new service jobs. When total jobs are considered, 24 percent are in services and 22 percent are in construction.

The employment and income impacts from crambe production will be sustainable for the North Dakota study region if the demand for crambe does not fluctuate significantly. Industry sources estimate that about 50,000 acres of crambe would supply market clearing levels of crambe oil. Once the Foster County processing plant reaches full-scale operation of processing other oilseeds in addition to crambe, employment in this value-added industry will likely increase beyond the estimates in this analysis.

Table A-6--Economic impacts of new plant operation, 1997-98

Impacts	Sales	Value added	Number of jobs
	Million dollars		
Direct	7.4	1.2	13
Indirect and induced	1.7	1.0	27
Total	9.1	2.2	40

Table A-7--Combined economic impacts of crambe production and plant construction and operation, 1997-98

Impacts	Sales	Value added	Number of jobs
	Million dollars		
Direct	17.9	4.1	88
Indirect and induced	5.0	2.9	86
Total	22.9	7.0	174

Conclusions

The development of new industrial crops may result in modest rural employment and income growth in agriculturally related industries. Choosing new crops that can attract related industries to a region, such as oilseed crushing, is key to using industrial demand as a tool for rural development.

The results of this study demonstrate the importance of crambe to a farming-dependent region of North Dakota. A full 42 wage and salary jobs were added to the area as a direct result of the increase in the production and processing of crambe. Through local purchases of supplies and the spending of crambe-related income, the industry generates another 46 wage and salary jobs. The region will enjoy the added benefit of the construction activity while the plant is being built, temporarily adding 46 new positions and generating another 40 jobs in various industries as the workers spend their wages.

Table A-8--Combined employment impacts of crambe enterprises, 1997-98

Economic sector	Direct job impacts	Indirect and induced impacts	Total job impacts
		Number	
Agriculture	29	3	32
Mining	0	0	0
Construction	36	2	38
Manufacturing	13	3	16
Transportation, communications, and public utilities	0	8	8
Trade	0	30	30
Finance, insurance, and real estate	0	9	9
Services	10	30	41
Government services	0	1	0
Total	88	86	174
		Percent	
Agriculture	33	4	18
Mining	0	0	0
Construction	41	2	22
Manufacturing	15	4	9
Transportation, communications, and public utilities	0	9	5
Trade	0	35	17
Finance, insurance, and real estate	0	10	5
Services	11	36	24
Government services	0	0	0
Total	100	100	100

The crambe case study also underscores the importance of value-added industries to the economy. The higher wage jobs in such industries provide opportunities for nonmetropolitan residents, thereby aiding in the retention of population in rural areas.

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Comparative Economics of Producing Lesquerella in Various Areas of the Southwestern United States

by

Donald L. Van Dyne[1]

Abstract: Lesquerella is a new oilseed crop under development in Arizona, New Mexico, and Texas. A sensitivity analysis was prepared that estimates net returns per acre given varying combinations of production costs, seed yields, and seed prices. Twenty-one counties in the three states have been identified as areas where lesquerella production would be technically feasible. Estimated net returns of traditional crops in these counties were analyzed to assess lesquerella's chances of being economically competitive with other crops.

Keywords: Lesquerella, alternative crops, net returns, cost of production.

Lesquerella is a new oilseed crop under development in Arizona, New Mexico, and Texas. Efforts to commercialize lesquerella have been underway for less than 10 years (4) and more work needs to be done for it to become commercially viable. However, if commercialization is successful, it would provide southwestern farmers with another source of revenue and an additional crop to use in rotations.

Lesquerella is of interest because of its oil, which has triglycerides that contain hydroxy fatty acids. Currently, the only source of hydroxy fatty acids is castor oil or its derivatives. Imports of castor oil, which is not produced in the United States, have averaged 40,871 metric tons during the last 5 years (table 52).

Researchers and private industry are looking for areas within the three states where lesquerella has the greatest potential so they can focus their research efforts and develop relationships with extension agents and farmers. The purpose of this analysis is to begin that process of identifying areas within the three states where lesquerella production would be technically feasible and economically viable.

Crop and Product Characteristics

Over 100 species of *Lesquerella* have been identified, of which 83 are native to the United States. An extensive germplasm collection from native populations was made by the U.S. Department of Agriculture (USDA), Agricultural Research Service, U.S. Water Conservation Laboratory (USWCL) during 1993 to 1996. Breeding and development work has focused primarily on *L. fendleri*, a species native to the southwestern United States, because of its relatively high seed yields, good seed retention, upright growth habit, and other favorable characteristics needed for commercial crop development. Breeding has focused on increasing the seed oil, gum, and lesquerolic acid content (the hydroxy fatty acid in *L. fendleri* oil); developing self-pollinating plant varieties; increasing average plant heights and plant uniformity; reducing oil pigmentation; and developing varieties with higher seed yield (2).

Agronomic research also is underway to determine the best production practices for lesquerella, such as planting dates and methods, irrigation scheduling, level and timing of fertilizer applications, weed control, and harvesting procedures. Weed control is a particular problem because after lesquerella germinates, it grows very slowly and can be dominated by early season weeds. The research conducted thus far and limited grower experiences have been used to compile a preliminary production guide (3). In the Southwest, lesquerella could fit well in a 2-year, 3-crop rotation of lesquerella, grain sorghum, and cotton (2). Many farmers in the area already own the equipment necessary to plant and harvest lesquerella. It should be seeded when temperatures are moderate, typically August 15 to September 1 in Texas and New Mexico and October 1 to 15 in Arizona. Harvest occurs 8 or 9 months later.

Lesquerella seed is comprised of oil, seed coat gums, protein, and meal. Because the oil and its lesquerolic acid are the focus of commercial interest, researchers are working to increase the content in the seed. In 1996, USWCL made three populations of lesquerella germplasm available to other researchers (1). One population had a seed oil content of 26 percent, while another had a lesquerolic-fatty-acid content in the oil of about 55 percent. Potential exists for the

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seed to contain up to 37 percent oil with a lesquerolic acid content of up to 65 percent.

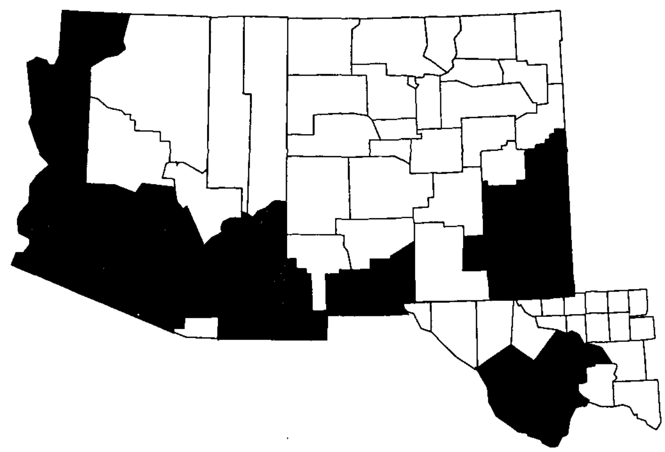
Hydroxy fatty acids are currently used in a variety of products, such as multipurpose lubricating greases, beverage can coatings, toiletries, lipstick and other cosmetics, polishes, and inks. The unique chemical structure of lesquerella oil, although similar to castor oil, holds potential for developing new product applications as well as replacing castor oil in some traditional uses. Recent research on the gums extracted from lesquerella's seed coat indicate they too have significant industrial potential. The meal could be used as a protein supplement in livestock feed. (See the December 1993 issue of this report for additional information on crop and product characteristics).

Potential Lesquerella Production Areas And Net Returns

Agricultural extension personnel, USDA scientists, and representatives from International Flora Technologies, Ltd. (IFT), one of the private firms working to commercialize lesquerella, identified 21 counties in Arizona, New Mexico, and Texas they believe have the best potential for lesquerella production (figure B-1). In 1992, irrigated acreage in these counties totaled almost 1.4 million (table B-1). Scientists working with lesquerella indicate that it could be planted on wheat acreage where farmers are having problems with karnal bunt, a fungal disease of wheat currently a problem in some parts of the area. In 1992, wheat was produced on 321,446 acres in 17 of the 21 counties (5). Lesquerella could also be grown on land used for barley, cotton, hay, and sorghum.

Figure B-1

Counties in Arizona, New Mexico, and Texas That Have the Best Potential for Lesquerella Production



In 1991, using the latest agronomic research results, University of Arizona economists estimated lesquerella production costs at between $307 and $415 per acre (table B-2). The higher value assumed abundant irrigation and weed control, plus generous cost allowances for other inputs (6). The lower value reflected more prudent irrigation and reduced fertilizer and chemical applications. More recently, private sector and government researchers estimated current

Table B-1–Total cropland, irrigated cropland, and acres of selected crops in selected counties in the southwestern United States, 1992

State and county	Total cropland	Irrigated cropland	Crop acreage: Sorghum	Wheat	Barley	Cotton	Hay
				–Acres–			
Arizona							
Cochise	120,472	52,434	N.A.	97	667	9,678	10,484
Graham	54,762	41,219	N.A.	509	590	26,913	2,164
Greenlee	10,210	4,480	N.A.	D	0	D	1,296
La Paz	115,686	95,178	N.A.	8,172	193	44,858	38,282
Maricopa	376,423	273,339	N.A.	19,103	9,513	142,345	52,860
Mohave	23,150	18,638	N.A.	298	0	6,203	10,740
Pima	36,043	27,455	N.A.	2,579	174	15,160	1,137
Pinal	299,656	213,265	N.A.	13,254	7,332	155,393	16,180
Yuma	207,385	189,736	N.A.	35,956	1,352	27,210	45,999
New Mexico							
Chaves	120,517	57,744	447	D	N.A.	8,536	31,291
Curry	454,101	84,377	63,745	150,077	N.A.	D	5,719
Dona Ana	94,405	80,029	64	4,261	N.A.	20,896	14,905
Eddy	D	47,209	317	D	N.A.	9,299	29,869
Hidalgo	D	9,081	761	352	N.A.	2,404	604
Lea	98,045	35,126	5,689	5,177	N.A.	4,589	7,032
Luna	D	29,732	977	1,881	N.A.	3,887	2,730
Roosevelt	378,637	76,365	85,087	79,565	N.A.	2,662	16,858
Texas							
Brewster	3,144	D	0	0	N.A.	0	693
Jeff Davis	1,525	197	0	0	N.A.	0	0
Pecos	64,691	26,716	D	165	N.A.	7,713	8,537
Presidio	17,937	3,584	0	D	N.A.	D	1,425
Total	2,476,789	1,365,904	157,087	321,446	19,821	487,746	298,805

N.A. = Not available. D = Data withheld to avoid disclosing data for individual farms.

Source: 1992 Census of Agriculture, U.S. Department of Commerce, Bureau of the Census, Washington, DC, 1994.

Table B-2--Estimated lesquerella costs of production, Arizona, 1991

Cost	High estimate	Low estimate
	Dollars per acre	
Paid labor	88	65
Seed	42	8
Fertilizer and chemicals	64	42
Farm machinery and hauling	59	59
Irrigation	133	110
Other costs	29	23
Total 1/	415	307

1/ Includes variable costs, but not returns to land or management.

Source: J.C. Wade, P.N. Wilson, and D. McKenon, "Anticipated Production Costs, Revenues, and Commercialization Issues for Lesquerella," report submitted to USDA, Cooperative State Research Service, Office of Agricultural Materials, June 1992.

production costs at $450 to $550 per acre on the limited acreage grown to date. However, with additional research and fine tuning of production practices resulting from commercialization, production costs could drop to $230 to $240 per acre when yields of 1,800 pounds of seed per acre are achieved (3). These estimates include all variable costs, but no land charge or returns to management.

The lesquerella seed produced thus far has been used for planting in subsequent years and for oil-processing studies and product development work. Seed has not been sold in any market.

Since costs are changing rapidly because of advances in lesquerella breeding and production practices and revenues have yet to be determined, a sensitivity analysis was prepared that estimates net returns per acre given varying combinations of production costs, seed yields, and seed prices (table B-3). With production costs of $225 per acre, a yield of 1,500 pounds per acre, and a seed price of 15 cents per pound, farmers would just break even. If costs increase to $250 per acre and yields reach 1,800 pounds per acre and seed prices were 21 cents per pound, the estimated net revenue would be $128 per acre. Higher yields or seed prices might be needed to offset higher production costs or induce farmers to grow a risky new crop.

Costs and Returns of Competing Crops

Not only are lesquerella's net returns important in determining where it could be profitably produced, so are the costs and returns of competing crops. Lesquerella must be able to compete with net returns from other crops before farmers will be interested in growing it. For example, several states, including Iowa and North Dakota, were involved in commercializing crambe, an oilseed with high amounts of erucic acid in its oil. Although yields of crambe were much higher in Iowa, the industry developed in North Dakota primarily because crambe could not compete with corn and soybeans in Iowa, but it could compete with traditional crops in North Dakota. Also, a company in North Dakota involved in oilseed crushing was willing to buy crambe seed and crush it.

The agricultural extension service in most states, including Arizona, New Mexico, and Texas, estimates costs and returns for the coming year for the crops produced in that state on a regional or county basis. These crop budgets are designed to help farmers in their planting decisions for the year. The University of Arizona study evaluated 138 crop budgets for various counties in Arizona, New Mexico, and Texas (6). The estimated costs and returns for 1991 were evaluated for six crops in Cochise County, Arizona, including alfalfa, upland cotton, pima cotton, durum wheat, grain sorghum, and corn. Budgets for traditional crops, excluding vegetables, were examined for the remaining counties in Arizona, plus those in New Mexico and Texas in which lesquerella might be produced.

According to the analysis, wheat had the largest numbers of crop budgets with estimated negative net returns, followed by grain sorghum and barley (table B-4). None of the three crops had estimated net returns in excess of $200 per acre. Federal government payments were not included in the analysis. Estimated net returns for the various crops were also sorted and categorized by state. Arizona had the highest number of profitable crop budgets, and Texas the least. Thus, according to these 1991 estimates, lesquerella might be more competitive with other crops in Texas, followed by New Mexico and Arizona.

Budgets for the 1996 crop year were studied for the same counties in Arizona, New Mexico, and Texas. While overall average returns were estimated to be higher in 1996 than 1991, the relative profitability of the crops remained similar. The most profitable crops in 1996 continued to be alfalfa and upland and pima cotton with estimated net returns of more than $200 per acre in most of the budgets (table B-5). Both corn and wheat were expected to be somewhat more profitable in 1996, with most net returns ranging from $0 to $199, primarily because of higher prices than those in the

Table B-3--Estimated net returns of producing lesquerella with varying production costs, yields, and seed prices

Production costs	Yield	Seed price per pound: 12 cents	15 cents	18 cents	21 cents
Dollars per acre	Pounds per acre	Net returns --Dollars per acre--			
225	1,200	-81	-45	-9	27
	1,500	-45	0	45	315
	1,800	-9	45	99	378
	2,100	27	90	153	441
250	1,200	-106	-70	-34	2
	1,500	-70	-25	20	65
	1,800	-34	20	74	128
	2,100	2	65	128	191
300	1,200	-156	-120	-84	-48
	1,500	-120	-75	-30	15
	1,800	-84	-30	24	78
	2,100	-48	15	78	141

Table B-4--Estimated net returns of selected crops in potential lesquerella production areas in Arizona, New Mexico, and Texas, 1991 1/

Item	Net return (Dollars per acre)			
	Negative	0 to 99	100 to 199	200+
	Frequency by category			
Crop				
Alfalfa	2	3	7	12
Barley	5	2	2	0
Corn	4	9	2	1
Cotton	3	9	8	13
Grain sorghum	6	6	2	0
Oats/oat hay	0	2	0	1
Pasture	2	1	0	0
Peanuts	0	0	1	6
Soybeans	3	0	0	0
Sudan grass	1	0	2	0
Sugar beets	0	0	1	
Sunflowers	1	0	0	0
Wheat	9	7	5	0
Total	36	39	30	33
State				
Arizona	5	12	16	19
New Mexico	18	20	12	12
Texas	13	7	2	2
Total	36	39	30	33

1/ According to State Cooperative Extension Service crop budgets.
Source: J.C. Wade, P.N. Wilson, and D. McKenon, "Anticipated Production Costs, Revenues, and Commercialization Issues for Lesquerella," report submitted to USDA, Cooperative State Research Service, Office of Agricultural Materials, June 1992.

Table B-5--Estimated net returns of selected crops in potential lesquerella production areas in Arizona, New Mexico, and Texas, 1996

Item	Net return (Dollars per acre)			
	Negative	0 to 99	100 to 199	200+
	Frequency by category			
Crop				
Barley	0	2	0	0
Corn	0	2	2	1
Cotton	1	2	3	13
Grain sorghum	1	7	0	0
Oats/oat hay	0	0	0	2
Peanuts	0	0	0	3
Sudan grass	0	0	1	1
Sunflowers and safflower	0	0	0	1
Wheat	1	5	7	0
Total	3	18	13	21
State				
Arizona	2	7	7	12
New Mexico	0	9	6	14
Texas	1	2	0	2
Total	3	18	13	28

Source: Estimated cost of production budgets for 1996 from the State Cooperative Extension Services of Arizona, New Mexico, and Texas, 1996.

1991 budgets. Barley and grain sorghum most frequently had estimated net returns of $0 to $99 per acre. In the possible 2-year, 3-crop rotation of lesquerella, grain sorghum, and cotton mentioned earlier, lesquerella returns could supplement the lower returns received for grain sorghum and provide farmers with a crop rotation sequence as an alternative to continuous cotton.

Conclusions

This analysis of net returns for lesquerella and competing crops gives researchers some parameters to work within as they continue to develop lesquerella as a commercial crop. Initially, lesquerella's net returns will probably need to be higher than those for well-known alternatives to induce farmers to experiment with this new crop and learn how to efficiency grow it. Over the longer term, lesquerella's net returns will need to remain competitive with other crops farmers have the opportunity to produce.

Based on this preliminary analysis of per-acre returns, Texas seems to have the advantage over the other two states as a potential lesquerella site. However, other factors also will influence where commercial production of lesquerella occurs. For example, IFT's oilseed crushing facility is in Arizona. The company will have to balance transportation costs with the price paid to farmers when deciding where to contract for acreage. Thus, New Mexico, with less demands from competing crops than in Arizona and its closer proximity to the processing plant, might be a likely target.

Researchers and private industry point to the lack of sustained extension involvement as one of the key hindrances to lesquerella commercialization. This research on costs and returns may provide extension personnel with basic data and help all parties focus on the areas where lesquerella has the greatest potential to be technically feasible and economically viable.

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List of Tables

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Table 8--Material codes, code descriptions, and the value of agriculturally derived materials (other than wood and paper products) used in manufacturing in 1992

Code	Description	Value
		1,000 dollars
010014	All other fibers (silk, jute, reused wool, waste, etc.)	28,000
011903	Broomcorn	9,100
013101	Raw cotton fibers	3,140,700
019101	Agricultural products (crude), including flowers, grains, seeds, herbs, etc.	705,500
020001	Raw wool, mohair, and other animal fibers (scoured weight)	220,200
021401	Raw wool fibers	d
083100	Natural rubber	40,100
083111	Natural dry rubber	608,900
083113	Natural latex rubber (dry solids content)	313,100
190015	Other fibrous materials, including rags, straw, and bagasse	65,600
190019	Cotton waste	20,100
190047	Cotton linters and cotton waste	12,100
190048	Cotton felt filling materials, purchased, premade	18,100
200101	Processed food and kindred products, including lactose, meat-packing-plant products, yeast, etc.	146,300
201191	Hides, skins, and pelts	1,236,000
204609	Starch	524,900
204610	Starch and dextrin	23,900
207001	Animal and vegetable oils	80,300
207011	Vegetable oil	67,000
207020	Fats, oils, greases, and tallow	430,600
207431	Cotton linters (net weight)	72,100
207619	Vegetable oils	50,900
207711	Grease and inedible tallow	164,200
220010	Yarns and textiles made of cotton, wool, silk, and manmade fibers	35,800
220234	Cotton fabrics	68,800
220305	All other fabrics (except manmade), primary backing	5,100
221101	Cotton broadwoven fabrics (piece goods)	1,015,100
221161	Woven cotton upholstery fabrics, excluding ticking	253,400
228102	Cotton yarns	368,400
228110	Carded cotton yarn	1,024,700
228120	Combed cotton yarn	421,300
228151	Wool yarn	15,500
228301	Spun wool and chiefly wool yarns	29,500
229911	Wool felt	6,700
229961	Jute secondary backing	80,000
229963	Wool tops	90,000
249941	Cork products	53,900
284421	Perfume oil mixtures and blends	610,200
289921	Fatty acids	217,100
289943	Gelatin (pharmaceutical grade) and gelatin capsules	51,200
289951	Essential oils, natural	95,300
311100	Finished leather	465,200
311102	Finished upper leather	142,400
311107	Other finished leather	39,200
311108	All other finished leather	16,900
311111	Finished upper leather	724,800
311112	Finished soling leather	189,900
399991	Dressed hair (including bristle and horsehair)	16,300
999823	Wool noils and waste	8,500
	Total agriculturally derived materials other than wood and paper products	14,022,900

d = Data withheld to avoid disclosing figures for individual companies.

Source: 1992 Census of Manufactures, Bureau of the Census, May 1996.

Table 9—Material codes, code descriptions, and the value of wood and paper products used in manufacturing in 1992

Code	Description	Value
		1,000 dollars
081111	Stumpage cost (cost of timber, excluding land, cut and consumed at same establishment)	3,517,200
190005	Wastepaper, all types	121,900
190006	Mixed wastepaper, except plant's own broke paper	230,000
190007	Mechanical news wastepaper, except plant's own broke paper	194,800
190008	Fly ash	800
190009	High-grade pulp substitutes wastepaper, except plant's own broke paper	276,300
190010	High-grade deinking wastepaper, except plant's own broke paper	245,700
190072	Other mechanical wastepaper, except plant's own broke paper	60,000
190073	Corrugated wastepaper, including kraft, except plant's own broke paper	711,800
240001	Lumber and wood products, except furniture	41,600
240090	Other lumber and wood products, except furniture	11,400
240099	Other wood products (except lumber)	11,300
241101	Spruce and true fir pulpwood bolts and logs	241,800
241102	Hemlock pulpwood bolts and logs	189,100
241104	Southern pine pulpwood bolts and logs	2,068,000
241108	Southern mixed hardwood pulpwood bolts and logs	745,500
241109	Poles, piling, and other round or hewn wood products treated in the same establishment	216,300
241111	Hardwood logs, bolts, and unsliced flitches	1,268,000
241112	Softwood logs, bolts, and unsliced flitches	7,015,300
241113	Logs, bolts, and unsliced flitches	90,300
241135	Other softwood pulpwood bolts and logs, including Douglas fir and Jack pine	253,600
241137	Other hardwood pulpwood bolts and logs	368,300
242011	Chips, slabs, edgings, shavings, sawdust, and other wood waste	22,900
242012	Softwood pulpwood wood chips, slabs, cores, sawdust, bark, and other mill residues	2,224,400
242013	Hardwood pulpwood wood chips, slabs, cores, sawdust, bark, and other mill residues	861,000
242016	Chips, slabs, edgings, sawdust, and other wood waste, except planer shavings	174,500
242017	Planer shavings	139,700
242101	Rough and dressed lumber	354,400
242103	Dressed lumber	941,500
242110	Hardwood rough lumber	1,764,200
242111	Hardwood lumber, rough and dressed	816,400
242117	Hardwood dressed lumber	498,600
242121	Softwood rough lumber	2,219,000
242123	Softwood lumber, rough and dressed	171,900
242128	Softwood dressed lumber	1,560,200
242170	Softwood cut stock, including window and cabinet parts	542,500
242600	Hardwood dimension and parts, including wood furniture frames	411,700
242620	Hardwood dimension and parts, excluding furniture frames	619,000
242628	Hardwood dimension and parts, including furniture frames	55,600
242661	Furniture frames, wood	464,500
243001	Veneer and plywood	127,800
243011	Millwork, wood (including wood doors, window sash, moldings, and cabinets)	58,300
243056	Plywood	208,000
243103	Wood doors and door units	17,300
243105	Wood millwork, including molding, doors, and windows	67,500
243401	Kitchen cabinets, wood	81,100
243510	Hardwood plywood	542,900
243530	Hardwood veneer	189,900
243540	Hardwood veneer	501,100
243601	Softwood plywood	205,800
243640	Softwood veneer	463,800
244021	Wood boxes, pallets, skids, and containers	92,200
244022	Wooden containers, complete (including combination wood and paperboard)	36,200
249300	Reconstituted wood products, including particleboard, oriented-strand board, medium density fiberboard, and hardboard	88,100
249310	Particleboard (wood)	929,100
249322	Oriented-strand board (OSB) and waferboard	64,300
249330	Medium density fiberboard (MDF)	246,100
249340	Hardboard (wood fiberboard)	287,000

Continued--

Table 9–Material codes, code descriptions, and the value of wood and paper products used in manufacturing in 1992––continued

Code	Description	Value
		1,000 dollars
249951	Wood brush handles and backs	30,000
249991	Wood parts, including handles	47,400
251003	Household-type furniture, including tables, sofas, beds, mattresses, etc.	33,000
251011	Cabinets (wood, metal, and plastics)	510,400
260001	Paper and paperboard products, including paperboard boxes, containers, and corrugated paperboard	384,900
260002	Other paper products	21,500
260003	Paper and paperboard, except boxes and containers	17,221,100
260004	Paper and paperboard products (except paperboard boxes, containers, corrugated paperboard, and photographic base papers)	195,600
260012	Paper and paperboard containers, including shipping containers, setup and folding cartons, etc.	566,600
260050	Paper and paperboard products (including album covers, sleeves, etc.)	33,800
260051	Paper and paperboard containers	410,700
260070	Paper and paperboard products, except paperboard boxes, containers, and corrugated paperboard	878,400
260080	Other paper and paperboard products	296,800
260091	Paper and paperboard containers, including shipping sacks and other paper packaging supplies	1,918,100
261102	Woodpulp produced at affiliated or associated mills at other locations	975,200
261104	Woodpulp (purchased market wood pulp)	2,539,100
261105	Woodpulp (air-dry basis)	654,700
261151	Linter pulp	33,300
262100	Paper, all types except light sensitive (including newsprint, book, bond, cover, and coated)	40,600
262101	All other paper, except light sensitive	43,900
262104	Paper (cellulosic wadding)	15,300
262106	Purchased (market) paper	42,600
262108	Paper	6,797,000
262111	Newsprint	186,700
262112	Newsprint	981,800
262113	Newsprint, 30-pound basis weight	3,202,200
262115	Newspaper, other basis weight	629,500
262121	Uncoated paper in sheets	1,269,600
262122	Uncoated paper in rolls	2,530,300
262123	Coated paper in sheets	1,569,000
262124	Coated paper in rolls	2,664,700
262131	Coated paper	1,611,900
262140	Uncoated paper	2,271,000
262163	Carbonless paper	603,300
262164	Carbonizing tissue stock for conversion into one-time carbon paper	16,500
262175	Photographic base papers	308,200
262188	Glassine film	19,300
262190	Building paper and board	59,700
262195	Filter paper	211,100
263105	Paperboard (including news, chip, pasted, tablet, check, binders' board), except for shipping	133,100
263112	Paperboard liners	109,000
264926	Paper (cellulosic wadding)	47,200
265001	Paperboard containers, boxes, and corrugated paperboard	7,709,400
265020	Paper and paperboard boxes and fiber cans, tubes and drums	87,400
265522	Fiber cans, bodies with combinations of fiber and other materials (foil, plastics, etc.) with metal ends	16,500
267000	Bags, except textile, including shipping sacks, multiwall bags, and polyethylene liners	30,500
267004	Other converted paper and paperboard products	38,800
267420	Paper shipping sacks and multiwall bags	58,400
267700	Purchased envelopes	15,900
286101	Wood rosin, turpentine, and other wood chemicals, including tall oil	71,500
286102	Tall oil and rosin	72,800
286104	Wood rosin, turpentine, and other wood chemicals	28,100
286556	Pitch	33,500
289956	Rosin sizing	133,100
	Total wood and paper products	96,337,500

Source: *1992 Census of Manufactures, Bureau of the Census, May 1996.*

Table 10--Material codes, code descriptions, and the value of materials partially derived from agricultural sources used in manufacturing in 1992

Code	Description	Value
		1,000 dollars
190046	Loose-fill insulating materials (mineral fiber, cellulose fiber, and other)	28,600
190049	Insulators, all types, except cotton felt, purchased premade	50,500
190054	Vinyl and paper overlays	86,800
220011	Cloth and nonwoven fabrics for hardbound book covers	61,500
220090	Other textile mill products	d
220100	Textile fabrics	397,700
220101	Cotton and manmade fiber fabrics, broadwoven and narrow woven	178,600
220110	Broadwoven fabrics	287,800
220123	Cotton, wool, manmade fiber fabrics, etc.	131,600
220125	Uncoated broadwoven fabrics for upholstery	387,800
220127	Other broadwoven fabrics (piece goods)	904,700
220129	Broadwoven fabrics (piece goods)	8,242,100
220170	Broadwoven fabrics	265,600
220190	Fabrics, except tire fabrics (including cotton, nylon, polyester, and rayon)	181,700
220200	Woven upholstery fabrics (cotton, nylon, polyester, rayon, etc.), excluding ticking	42,600
220211	Broadwoven fabrics	2,802,400
220308	All other secondary backing (including scrim, solid vinyl, etc.)	47,400
220390	Fabrics, all types	39,000
221141	Ticking (mattress)	186,400
222101	Rayon and acetate broadwoven fabrics (piece goods)	134,300
222103	Other woven upholstery fabrics (rayon, nylon, polyester, etc.), excluding ticking	560,800
224110	Woven narrow tape and webbing	2,100
224111	Narrow fabrics (12 inches or less in width)	902,900
225078	Knit fabrics	5,435,800
227001	Floor coverings, textile	105,600
227002	Carpeting	566,600
228011	All other yarns	512,400
228015	Yarn, all fibers	986,600
228101	Spun yarn, all fibers	2,457,700
228130	Spun rayon and acetate yarn	2,000
228147	All other spun yarns	35,800
229503	Plastics coated, impregnated, or laminated fabrics	531,900
229506	Plastics coated fabrics and shade cloth	92,700
229507	Coated or impregnated woven and nonwoven fabrics, except rubberized	24,200
229508	Coated or laminated fabrics, including vinyl coated	933,900
229710	Nonwoven fabrics	955,100
229801	Cordage	d
229908	Paddings, battings, and fillings, except rubber and plastics foam	137,800
230001	Garments purchased to be printed and resold	347,700
235311	Hat bodies	71,700
239101	Curtains and draperies	39,200
239401	Canvas products	22,300
239621	Automotive trimmings, textile (panels, headliners, etc.)	3,364,600
239901	Seat covers, seat belts, and shoulder harnesses	954,600
267101	Packaging paper and plastics film, coated and laminated	4,000
267102	Packaging paper and plastics film, coated, laminated, printed, etc.	371,100
267231	Pressure-sensitive base stock, self-adhesive, including paper, film, foil, etc.	799,700
270011	Labels, coupons, instructions, and other printed material	424,700
280000	Industrial organic and inorganic chemicals, including acids and alcohols, but excluding fatty acids	14,500
280010	Additives (fire retardants, water repellents, softeners, and antistatics, etc.)	46,400
280012	Other additives, including soaps and detergents	590,400
280021	Tanning materials, dressings, dyes, and finishing agents	281,500
282305	Rayon and acetate staple and tow	355,400
282407	All other filament yarns, except glass	284,700
282412	Filament rayon and acetate yarns	6,600
283011	Blood derivatives and extenders	566,600
283301	Vitamins, natural and synthetic, in bulk, for human and veterinary use	482,700
283302	Vitamins, natural and synthetic, in bulk, for animal feeds	104,200
283306	All other bulk medicinal and botanical uncompounded drugs, except antibiotics and vitamins	4,488,100
283318	Antibiotics, in bulk, for human and veterinary use	1,856,400
283319	Antibiotics, in bulk, for animal feeds	77,900
284141	Glycerin (100 percent)	8,400
284301	Surfactants	62,600
284303	Bulk surface active intermediates (active weight)	339,500
284305	Bulk surface active agents primarily for detergent purposes (active weight), except intermediates	341,500

Continued---

Table 10--Material codes, code descriptions, and the value of materials partially derived from agricultural sources used in manufacturing in 1992 --continued

Code	Description	Value
		1,000 dollars
284306	Other bulk surface active agents (emulsifiers, wetting agents, penetrants, etc.) (active weight), except intermediates	98,300
284307	Bulk surface active agents other than sulfonated oils and fats	170,600
285100	Paints, varnishes, stains, lacquers, shellacs, japans, enamels, and allied products	21,400
285101	Paints, varnishes, lacquers, stains, shellacs, japans, enamels, and allied products	3,830,900
285110	Paints, varnishes, stains, lacquers, shellacs, japans, enamels, and allied products	318,200
286081	Other synthetic organic chemicals (includes acrylonitrile and cellulose acetate)	2,005,600
286099	Other synthetic organic chemicals, not elsewhere classified	3,142,700
286902	Synthetic organic chemicals, except prepared photographic chemicals	141,300
286903	Refrigerant gases and other synthetic organic chemicals	146,000
286906	Other synthetic organic chemicals, including halogenated hydrocarbons	780,800
286907	Alcohol solvents (butyl, ethyl, isopropyl, etc.)	99,200
286920	Alcohols, except ethyl (100-percent basis)	188,900
286931	Perfume materials (synthetic organic)	92,700
286935	Plasticizers	148,300
286952	Alcohol, ethyl (pure and denatured)	272,700
286955	Alcohols	101,400
289100	Adhesives and sealants	126,900
289101	Glues and adhesives	2,268,900
289102	Glues and adhesives, including synthetic resin adhesives	38,200
289147	Adhesives and binders (resins)	103,100
289216	High explosives, including PETN, TNT, azides, and fulminates	14,000
289300	Printing ink	103,200
289301	Printing inks (complete formulations)	2,450,100
289305	Other printing inks, including gravure, flexographic, and screen process	24,300
289311	Letterpress printing inks, including news	33,700
289323	Lithographic (offset) printing inks	114,900
300099	All other rubber and miscellaneous plastics products	33,700
300115	Plastics and natural or synthetic rubber cut stock and findings	58,300
301100	Tires and inner tubes	271,000
301101	Pneumatic tires and inner tubes	2,823,800
301102	Pneumatic tires	145,200
305201	Rubber and plastics hose and belting	845,100
305202	Hydraulic and pneumatic hose (without fittings), rubber and plastics inner tube type, wire or textile reinforced	105,900
305204	Other rubber and plastics hose and belting	6,800
306001	Fabricated rubber products, except gaskets	35,300
306002	Fabricated rubber products, except tires, tubes, hose, belting, and gaskets	31,100
306902	Fabricated rubber products, except tires, tubes, hose, belting, and gaskets	977,100
306903	Reclaimed rubber, excluding "mud" and crumb or ground scrap	32,100
306990	Rubber compounds or mixtures	d
306991	Rubber compounds and mixtures purchased (dry rubber solids content)	609,300
306999	All other fabricated rubber products	158,300
3069E1	Bare rubber thread	51,500
308602	Foam or high-density rubber cushion secondary backing	13,700
313108	Leather and other material cut stock and findings	107,000
356503	Purchased adhesive devices (hot melt and cold glue) for incorporation into complete finished products	10,400
356921	Fluid power filters (hydraulic and pneumatic)	361,500
375115	Seats (saddles), bicycle	28,700
386101	Light-sensitive films and papers	536,900
386155	Light-sensitive films	173,600
386166	Light-sensitive papers (including photographic paper and diffusion transfer paper)	36,400
395523	One-time carbon paper	55,100
399951	Lamp shades	29,800
999825	New and used rags, clips, etc.	24,100
	Total partially agriculturally derived materials	69,406,000

d = Data withheld to avoid disclosing figures for individual companies.

Source: 1992 Census of Manufactures, Bureau of the Census, May 1996.

Table 11--Material codes, code descriptions, and the value of some raw materials used in manufacturing in 1992 that potentially could come from agricultural and forestry products

Code	Description	Value
		1,000 dollars
190089	Other fluid power products (hydraulic and pneumatic)	470,000
190090	Fluid power products	630,400
286002	Other solvents	149,500
286030	Industrial organic and synthetic organic chemicals, including plasticizers (except synthetic dyes, pigments, and toners)	1,690,000
286905	Oxygenated solvents	58,500
286965	Glycols (ethylene, propylene, etc.) (100-percent basis)	413,400
286971	Ketone and ester solvents (methyl ethyl ketone, ethyl acetate, etc.)	176,400
290003	Lubricating and cutting oils	7,800
	Total potentially agriculturally derived materials	3,596,000

Source: 1992 Census of Manufactures, Bureau of the Census, May 1996.

Table 12--Flaxseed: Acreage planted, harvested, yield, production, and value, United States, 1988-97

Year	Planted	Harvested	Yield	Production	Value
	--1,000 acres--		Bushels per acre	1,000 bushels	$1,000
1988	275	226	7.1	1,615	12,200
1989	195	163	7.5	1,215	8,724
1990	260	253	15.1	3,812	20,280
1991	356	342	18.1	6,200	21,845
1992	171	165	19.9	3,288	13,543
1993	206	191	18.2	3,480	14,848
1994	178	171	17.1	2,922	13,590
1995	165	147	15.0	2,211	11,475
1996 1/	96	92	17.4	1,602	10,009
1997 2/	197	189	17.5	3,310	N.A.

N.A. = Not avalalble.

1/ Preliminary. 2/ Forecast.

Table 13--Linseed oil, supply and disappearance, United States, 1988/89-1997/98

Year beginning June 1	Supply: Beginning stocks	Supply: Production	Supply: Total	Disappearance: Exports	Disappearance: Domestic	Disappearance: Total	Ending stocks
			--Million pounds--				
1988/89	41	170	211	12	151	163	48
1989/90	48	165	213	12	164	176	37
1990/91	37	176	213	6	167	173	40
1991/92	40	182	222	12	170	182	40
1992/93	40	172	212	8	150	158	54
1993/94	54	174	228	7	159	166	63
1994/95	63	172	237	24	169	192	45
1995/96	45	180	228	23	155	178	50
1996/97 1/	50	180	230	25	155	180	50
1997/98 2/	50	181	231	20	161	181	50

N.A. = Not available.

1/ Preliminary. 2/ Forecast.

Table 14--Linseed meal, supply and disappearance, United States, 1988/89-1997/98

Year beginning June 1	Supply: Beginning stocks	Production	Imports	Total	Disappearance: Exports	Domestic	Total	Ending stocks
	--1,000 short tons--							
1988/89	3	156	11	170	63	102	165	5
1989/90	5	153	9	167	23	139	162	5
1990/91	5	162	3	170	41	124	165	5
1991/92	5	167	0	172	40	127	167	5
1992/93	5	159	2	166	55	106	161	5
1993/94	5	160	2	167	49	113	162	5
1994/95	5	158	5	168	58	105	163	5
1995/96	5	167	4	176	56	115	171	5
1996/97 1/	5	167	1	173	53	115	168	5
1997/98 2/	5	167	1	173	52	116	168	5

1/ Preliminary. 2/ Forecast.

Table 15--Industrial rapeseed, supply, disappearance, and price, United States, 1988/89-1997/98

Year beginning June 1	Supply: Beginning stocks	Production	Imports	Total	Disappearance: Exports 1/	Domestic	Total	Ending stocks	Price: Minneapolis
	--Million pounds--								Cents/lb.
1988/89	1,107	15,822	0	16,930	0	16,188	16,188	741	11.1
1989/90	741	19,143	0	19,885	0	19,003	19,003	882	10.5
1990/91	882	22,717	0	23,599	0	22,319	22,319	1,279	10.3
1991/92	1,279	16,146	0	17,425	0	17,158	17,158	267	10.1
1992/93	267	14,455	0	14,722	0	14,522	14,522	200	10.0
1993/94	200	7,442	0	7,642	0	7,592	7,592	50	10.2
1994/95	50	12,596	0	12,646	0	12,609	12,609	37	10.3
1995/96	37	3,012	0	3,049	0	2,935	2,935	114	12.0
1996/97 2/	114	3,234	0	3,348	0	3,317	3,317	31	12.7
1997/98 3/	31	1,920	0	1,951	0	1,922	1,922	29	9.9

1/ Trade data do not distinguish between industrial and edible (canola) exports; therefore all exports were allocated to canola. 2/ Preliminary. 3/ Forecast.

Table 16--Industrial rapeseed oil, supply, disappearance, and price, United States, 1988/89-1997/98

Year beginning June 1	Supply: Beginning stocks	Production	Imports	Total	Disappearance: Exports 1/	Domestic	Total	Ending stocks	Price: Minneapolis
	--Million pounds--								Cents/lb.
1988/89	2,522	6,858	35,274	44,654	0	40,188	40,188	4,465	25.6
1989/90	4,465	8,184	29,407	42,057	0	37,851	37,851	4,206	27.8
1990/91	4,206	6,960	20,406	31,571	0	28,414	28,414	3,157	24.5
1991/92	3,157	5,705	8,737	17,599	0	15,839	15,839	1,760	22.6
1992/93	1,760	3,707	11,076	16,543	0	14,889	14,889	1,654	24.4
1993/94	1,654	4,140	6,581	12,375	0	11,138	11,138	1,238	29.0
1994/95	1,238	2,346	10,864	14,448	0	13,003	13,003	1,445	29.7
1995/96	1,445	1,201	9,403	12,049	0	10,844	10,844	1,205	28.3
1996/97 2/	1,205	894	10,153	12,252	0	11,027	11,027	1,225	26.8
1997/98 3/	1,225	821	10,903	12,949	0	11,654	11,654	1,295	26.0

1/ Trade data do not distinguish between industrial and edible (canola) exports; therefore all exports were allocated to canola. 2/ Preliminary. 3/ Forecast.

Table 17--Industrial rapeseed meal, supply, disappearance, and price, United States, 1988/89-1997/98

Year beginning June 1	Supply: Beginning stocks	Supply: Production	Supply: Imports	Supply: Total	Disappearance: Exports	Disappearance: Domestic	Disappearance: Total	Ending stocks	Price: Minneapolis
	--Million pounds--								Dol./ton
1988/89	212	10,738	0	10,951	0	10,736	10,736	215	160
1989/90	215	12,815	0	13,030	0	12,773	12,773	256	135
1990/91	256	10,897	0	11,153	0	10,935	10,935	218	132
1991/92	218	8,933	0	9,151	0	9,017	9,017	134	137
1992/93	134	5,805	0	5,939	0	5,852	5,852	87	141
1993/94	87	6,483	0	6,570	0	6,472	6,472	97	140
1994/95	97	3,674	0	3,771	0	3,716	3,716	55	118
1995/96	55	1,881	0	1,936	0	1,908	1,908	28	171
1996/97 1/	28	1,400	0	1,429	0	1,408	1,408	21	192
1997/98 2/	21	1,286	0	1,307	0	1,288	1,288	19	147

1/ Preliminary. 2/ Forecast.

Table 18--Total fats and oils consumption, with inedible by category, United States, 1988/89-96

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
	--Million pounds--									
1988/89	19,426.7	13,542.0	5,884.7	744.5	180.3	2,079.3	202.3	115.8	2,074.1	488.4
1989/90	20,036.0	14,382.7	5,653.3	792.0	89.5	2,143.5	222.4	157.1	1,944.7	304.1
1991	20,332.1	14,613.0	5,719.1	832.9	106.8	1,974.0	182.6	101.7	2,234.7	286.4
1992	20,751.7	14,847.3	5,904.4	738.8	123.8	2,176.5	165.5	109.4	2,041.2	549.3
1993	21,590.4	15,744.7	5,845.7	748.5	125.2	2,199.5	170.2	116.0	1,897.6	588.7
1994	22,058.7	15,373.8	6,684.9	770.0	115.1	2,272.5	240.7	219.3	2,306.2	761.1
1995	21,157.4	15,056.3	6,101.1	593.8	102.8	2,340.9	210.7	141.9	1,963.6	747.4
1996	20,847.1	14,828.9	6,018.2	468.9	86.6	2,429.5	206.1	124.5	1,920.7	781.9

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 19--Castor oil consumption, with inedible by category, United States, 1988/89-96

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
	--Million pounds--									
1988/89	59.2	0.0	59.2	d	4.8	0.0	4.5	6.2	0.0	43.2
1989/90	51.4	0.0	51.4	d	5.9	0.0	4.0	5.7	0.0	d
1991	46.0	0.0	46.0	d	5.9	0.0	4.0	d	0.0	31.7
1992	41.3	0.0	41.3	d	d	0.0	3.3	3.5	0.0	28.4
1993	54.2	0.0	54.2	d	d	0.0	3.5	2.8	0.0	37.8
1994	61.9	0.0	61.9	d	d	0.0	1.9	2.4	0.0	41.0
1995	62.6	0.0	62.6	d	d	0.0	1.2	2.7	0.0	40.4
1996	59.6	0.0	59.6	d	d	0.0	1.3	2.0	0.0	45.8

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 20--Coconut oil consumption, with inedible by category, United States, 1988/89-96

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1988/89	688.8	211.2	477.6	130.6	1.4	d	14.6	d	121.9	206.6
1989/90	525.2	160.6	364.6	156.9	2.1	0.0	9.7	4.0	134.6	57.3
1991	815.6	153.0	662.6	158.0	d	d	2.4	d	426.7	72.8
1992	875.4	176.3	699.1	121.7	d	0.0	3.2	d	d	d
1993	936.3	218.0	718.3	132.0	d	0.0	3.1	d	d	d
1994	969.2	227.1	742.1	146.1	d	0.0	2.3	d	d	d
1995	676.1	252.2	625.9	92.3	d	0.0	2.3	0.0	d	d
1996	639.5	191.2	448.3	81.8	d	0.0	2.6	d	d	d

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 21--Inedible tallow consumption, with inedible by category, United States, 1988/89-96

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1988/89	3,086.7	0.0	3,086.7	374.9	0.0	1,925.4	0.0	70.3	680.0	36.1
1989/90	3,219.0	0.0	3,219.0	398.4	0.0	1,982.9	0.0	109.0	684.0	44.7
1991	2,949.3	0.0	2,949.3	391.5	0.0	1,748.4	0.0	59.6	700.9	48.9
1992	3,050.1	0.0	3,050.1	334.4	0.0	1,954.4	0.0	63.2	659.0	39.1
1993	3,018.2	0.0	3,018.2	299.6	0.0	1,994.7	0.0	71.5	615.1	37.3
1994	3,189.9	0.0	3,189.9	300.8	0.0	2,101.9	0.0	81.8	634.0	71.4
1995	3,222.8	0.0	3,222.8	263.9	0.0	2,166.5	0.0	89.7	656.9	45.8
1996	3,288.7	0.0	3,288.7	245.2	0.0	2,252.8	0.0	89.2	629.4	72.1

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 22--Lard consumption, with inedible by category, United States, 1988/89-96

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1988/89	389.9	324.5	65.4	0.0	0.0	d	0.0	d	d	d
1989/90	369.3	303.8	65.5	d	0.0	d	0.0	9.1	d	d
1991	393.1	313.8	79.3	0.0	0.0	d	0.0	5.7	d	4.1
1992	479.7	345.0	134.6	0.0	0.0	d	0.0	10.9	d	13.5
1993	473.3	324.6	149.7	0.0	0.0	d	0.0	8.6	d	28.7
1994	451.9	324.7	127.2	0.0	0.0	0.0	0.0	8.9	0.0	118.3
1995	488.7	364.3	124.4	0.0	0.0	0.0	0.0	27.2	0.0	97.2
1996	447.9	309.7	138.2	0.0	0.0	0.0	0.0	16.9	0.0	121.3

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 23--Linseed oil consumption, with inedible by category, United States, 1988/89-96

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					--Million pounds--					
1988/89	154.9	0.0	154.9	0.0	101.6	0.0	23.1	d	d	28.2
1989/90	110.5	0.0	110.5	0.0	30.3	d	52.5	d	d	23.8
1991	95.8	0.0	95.8	0.0	40.7	0.0	41.6	d	d	12.7
1992	154.4	0.0	154.4	0.0	69.0	0.0	31.3	d	d	d
1993	125.8	0.0	125.8	0.0	66.9	0.0	25.4	d	d	d
1994	124.3	0.0	124.3	0.0	33.0	0.0	50.9	d	d	40.4
1995	112.8	0.0	112.8	0.0	30.2	0.0	51.4	0.0	0.0	31.2
1996	98.6	0.0	98.6	0.0	18.3	0.0	47.4	0.0	d	d

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 24–Rapeseed oil consumption, with inedible by category, United States, 1989/90-96 1/

Year 2/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 3/	Fatty acids	Other products
					–Million pounds–					
1989/90	d	265.0	d	0.0	d	d	d	d	d	d
1991	d	285.1	d	0.0	0.0	d	0.0	d	d	d
1992	d	360.5	d	0.0	0.0	d	0.0	d	d	d
1993	d	362.5	d	0.0	0.0	0.0	0.0	d	d	d
1994	d	446.3	d	0.0	0.0	0.0	0.0	d	d	d
1995	d	315.8	d	0.0	0.0	0.0	0.0	0.0	0.0	d
1996	d	317.9	d	0.0	0.0	0.0	0.0	0.0	d	0.0

d = Data withheld to avoid disclosing figures for individual companies.

1/ Includes both canola and industrial rapeseed. 2/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 3/ Includes similar oils.

Source: Bureau of Census.

Table 25–Soybean oil consumption, with inedible by category, United States, 1988/89-96

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					–Million pounds–					
1988/89	9,917.6	9,635.8	281.8	1.5	34.9	d	123.7	d	d	68.2
1989/90	10,808.3	10,536.7	271.6	d	38.2	d	112.4	d	d	52.4
1991	11,267.7	10,966.7	301.0	d	49.2	d	104.7	d	d	40.4
1992	11,471.6	11,168.7	302.8	d	43.5	22.3	94.0	5.9	d	69.8
1993	12,495.6	12,200.9	294.7	d	38.7	23.7	98.1	5.8	d	65.8
1994	12,474.1	12,157.8	316.3	d	47.6	d	119.6	d	d	91.9
1995	12,354.0	12,049.3	304.7	d	47.0	d	122.4	0.0	d	99.6
1996	12,322.3	12,017.1	305.2	d	50.5	d	121.1	0.0	d	98.0

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 26–Tall oil consumption, with inedible by category, United States, 1988/89-96

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					–Million pounds–					
1988/89	1,234.3	0.0	1,234.3	8.3	31.8	0.0	18.0	8.1	1,157.3	10.8
1989/90	1,024.7	0.0	1,024.7	8.4	7.4	0.0	21.7	7.1	969.9	10.2
1991	940.0	0.0	940.0	3.5	5.4	0.0	11.6	4.0	906.5	9.0
1992	883.5	0.0	883.5	d	d	0.0	19.4	7.0	841.8	11.4
1993	891.8	0.0	891.8	d	d	0.0	23.0	6.3	806.9	d
1994	1,362.5	0.0	1,362.5	d	d	0.0	48.4	6.1	1,025.0	d
1995	1,357.7	0.0	1,357.7	d	d	0.0	16.0	7.9	908.5	d
1996	1,179.4	0.0	1,179.4	d	d	0.0	18.6	6.6	930.3	d

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 27–Tung oil consumption, with inedible by category, United States, 1988/89-96

Year 1/	Total consumption	Total edible	Total inedible	Soap	Paint or varnish	Feed	Resins and plastics	Lubricants 2/	Fatty acids	Other products
					–Million pounds–					
1988/89	7.7	0.0	7.7	0.0	3.5	0.0	1.8	0.0	0.0	2.4
1989/90	8.9	0.0	8.9	0.0	2.7	0.0	3.8	0.0	0.0	2.4
1991	6.4	0.0	6.4	0.0	d	d	2.9	0.0	0.0	1.6
1992	7.3	0.0	41.3	d	d	0.0	3.3	3.5	0.0	28.4
1993	11.2	0.0	11.2	d	1.0	0.0	8.6	0.0	0.0	1.6
1994	9.3	0.0	9.3	d	1.2	0.0	6.6	2.4	0.0	1.5
1995	20.2	0.0	20.2	0.0	d	0.0	d	0.0	0.0	12.1
1996	21.3	0.0	21.3	0.0	2.6	0.0	d	0.0	0.0	d

d = Data withheld to avoid disclosing figures for individual companies.

1/ Crop year runs from October 1 to September 30. Annual totals reported on a calendar year basis beginning in 1991. 2/ Includes similar oils.

Source: Bureau of Census.

Table 28--Castor oil prices, raw No. 1, tanks, Brazilian, 1991-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Cents/pound --						
1991	39.30	36.00	36.75	37.00	37.00	36.50	35.50	35.00	35.00	35.40	35.00	37.50
1992	37.50	37.50	37.50	36.00	34.50	34.50	34.50	34.50	34.00	34.00	34.00	34.00
1993	34.00	32.00	32.00	32.00	37.00	37.00	37.00	37.00	38.50	44.00	44.00	44.00
1994	44.00	41.75	41.00	41.00	46.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00
1995	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00	45.00
1996	43.50	41.50	41.50	41.50	41.50	41.50	41.50	41.50	41.50	41.50	41.50	41.50
1997	41.50	41.50	41.50	41.50	41.50	41.50						

Source: Chemical Marketing Reporter.

Table 29--Coconut oil prices, crude, tanks, f.o.b. New York, 1991-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Cents/pound --						
1991	20.22	20.31	20.50	19.38	19.69	21.69	26.19	25.63	25.63	28.50	31.50	32.38
1992	39.33	36.00	34.57	34.75	33.56	32.13	29.63	27.31	27.88	26.94	27.00	25.50
1993	24.94	24.33	23.65	23.25	24.13	24.95	25.35	25.61	24.44	23.88	25.62	33.06
1994	30.30	30.94	29.56	30.19	29.45	30.25	29.56	30.35	30.63	30.60	34.19	33.69
1995	32.50	32.00	31.13	31.00	30.50	35.00	37.90	35.63	35.00	36.00	37.88	33.69
1996	35.80	36.63	36.75	38.75	39.50	42.25	41.80	42.80	47.20	48.00	49.50	50.00
1997	44.20	44.00	42.88	42.50	42.50	35.00						

Source: Chemical Marketing Reporter.

Table 30--Flaxseed, average price received by farmers, United States, 1991-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/bushel --						
1991	5.12	4.80	4.90	4.66	4.33	3.98	3.91	3.69	3.55	3.40	3.31	3.46
1992	3.39	3.43	3.52	3.53	3.61	3.67	3.70	3.71	4.12	4.09	4.10	4.21
1993	4.12	4.47	4.54	4.41	4.35	4.44	4.29	3.80	4.25	4.09	4.05	4.18
1994	4.38	4.61	4.64	4.60	4.43	4.25	4.28	4.52	4.54	4.49	4.51	4.71
1995	4.75	4.94	5.15	5.10	4.93	4.25	5.10	4.52	5.11	5.20	5.13	5.03
1996	5.20	5.18	5.28	5.40	6.03	6.06	6.19	5.91	5.89	6.51	6.50	6.68
1997	6.42	6.30	6.66	6.59	6.50	6.27						

Source: USDA, National Agricultural Statistical Service.

Table 31--Industrial rapeseed oil prices, refined, tanks, New York, 1991-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Cents/pound --						
1991	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25
1992	82.25	82.25	82.25	82.25	82.25	82.25	82.25	82.25	67.25	62.25	62.25	62.25
1993	62.25	62.25	62.25	62.25	55.88	53.75	53.75	53.75	53.75	53.75	53.75	53.75
1994	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75	53.75
1995	53.75	53.75	53.75	53.75	53.15	50.75	50.75	50.75	50.75	50.75	50.75	50.75
1996	50.75	50.75	50.75	50.75	50.75	50.75	50.75	50.75	50.75	60.56	90.00	90.00
1997	90.00	90.00	90.00	90.00	90.00	90.00						

Source: Chemical Marketing Reporter.

Table 32--Inedible tallow prices, Chicago, 1991-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Cents/pound --						
1991	14.53	12.91	13.63	13.57	12.25	12.36	12.96	14.00	13.50	13.68	13.08	12.50
1992	12.25	12.63	12.68	13.25	13.75	13.98	14.75	15.42	15.25	15.73	16.75	13.52
1993	15.36	14.69	15.24	15.94	15.00	15.11	14.95	14.58	14.54	14.68	14.50	14.94
1994	15.00	15.00	15.22	19.00	15.25	15.63	16.67	18.64	19.50	19.78	20.38	22.48
1995	21.75	18.86	18.00	17.75	17.50	17.89	19.61	19.81	19.53	19.46	19.75	20.08
1996	19.45	17.00	17.03	17.54	19.37	19.50	20.98	22.40	25.98	21.05	19.65	21.63
1997	23.40	22.88	19.35	17.39	18.09	19.64						

Source: Grain and Feed Marketing News.

Table 33–Jojoba oil prices, 1 metric ton or more, f.o.b. Arizona, 1991-97 1/

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						– Dollars/pound –						
1991	10.89	10.89	10.89	10.89	10.89	10.89	10.89	10.89	9.53	7.03	7.03	7.03
1992	7.03	7.03	7.03	7.03	7.03	7.03	7.03	6.12	6.12	5.45	5.45	5.45
1993	5.45	5.45	5.45	5.45	5.45	5.45	5.45	5.45	4.55	4.55	4.55	4.55
1994	4.55	4.55	4.55	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09	3.85
1995	3.85	3.85	3.85	3.85	3.85	3.85	3.85	3.85	4.75	4.75	4.75	4.75
1996	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75	3.75
1997	3.75	3.75	3.75	3.75	3.75	3.75						

1/ Price quotes are the low end of a range.

Source: Chemical Marketing Reporter.

Table 34–Linseed oil prices, tanks, Minneapolis, 1991-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						– Cents/pound –						
1991	36.00	36.00	36.00	36.00	36.50	36.00	36.00	36.00	36.00	30.00	30.00	30.00
1992	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	32.00	32.00	32.00	32.00
1993	32.00	32.00	32.00	32.00	32.00	28.50	32.00	32.00	32.00	32.00	32.00	32.00
1994	32.00	32.00	32.00	32.00	32.00	32.00	30.31	32.00	32.00	33.50	35.00	35.00
1995	35.00	35.00	35.00	35.00	35.00	35.00	35.00	35.50	37.00	37.00	37.00	37.00
1996	37.00	37.00	37.00	37.00	37.00	37.00	37.00	37.20	37.50	37.00	33.95	32.19
1997	36.00	36.00	36.00	36.00	36.00	36.00						

Source: Grain and Feed Marketing News.

Table 35–Linseed meal prices, bulk, 34-percent protein, Minneapolis, 1991-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						– Dollars/ton –						
1991	131.00	131.25	120.00	121.00	126.25	134.25	133.00	131.25	116.25	128.00	113.75	127.80
1992	122.00	124.00	115.00	117.50	120.00	125.00	123.50	126.25	131.00	141.25	152.50	137.40
1993	136.70	142.50	135.40	125.50	125.00	123.20	133.75	150.00	148.75	147.50	161.80	140.00
1994	140.00	130.00	126.00	125.00	125.00	111.40	114.90	111.60	N.A.	122.50	110.00	95.60
1995	82.40	85.25	90.00	94.40	85.00	85.00	92.50	95.00	112.50	131.00	151.67	143.75
1996	142.00	143.75	155.00	174.00	176.25	178.75	174.00	170.00	167.50	167.50	168.30	170.00
1997	165.00	156.25	163.30	168.00	188.30	171.25						

N.A. = Not available.

Source: Grain and Feed Marketing News.

Table 36–Soybean oil prices, crude, tanks, f.o.b. Decatur, 1991-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						– Cents/pound –						
1991	21.56	21.66	22.21	21.50	20.23	19.65	19.05	20.23	20.46	19.57	18.78	18.99
1992	18.77	18.88	19.74	19.00	20.15	20.71	18.82	17.87	18.28	18.36	20.10	20.52
1993	21.23	20.72	21.00	21.24	21.15	21.30	24.13	23.46	20.93	23.61	22.98	24.22
1994	29.91	28.85	29.03	27.94	29.48	29.43	27.20	25.02	24.87	24.73	24.75	24.75
1995	29.04	28.15	28.33	26.30	26.00	26.78	27.60	26.56	26.26	26.56	25.48	24.76
1996	23.69	23.65	23.60	25.82	26.54	23.81	24.16	24.03	24.01	22.06	21.99	21.72
1997	22.57	22.60	22.79	23.31	23.85	23.14						

Source: The Wall Street Journal.

Table 37–Tung oil prices, imported, f.o.b. New York, 1991-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						– Cents/pound –						
1991	70.00	63.00	61.50	63.00	63.00	61.50	61.00	61.00	61.00	61.00	61.00	70.00
1992	70.00	70.00	70.00	76.00	82.00	130.00	130.00	130.00	132.00	131.50	130.00	130.00
1993	130.00	130.00	130.00	130.00	117.00	130.00	130.00	130.00	107.50	100.00	94.75	93.00
1994	93.00	79.25	78.00	78.00	78.00	78.00	78.00	78.00	78.00	74.40	60.00	60.00
1995	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	60.00	48.00
1996	60.00	60.00	64.00	64.00	64.00	64.00	64.00	64.00	64.00	64.00	64.00	64.00
1997	74.00	92.00	92.00	92.00	103.00	103.00						

Source: Chemical Marketing Reporter.

Table 38--Cedarwood oil prices, drums or cans, 1993-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
Chinese												
1993	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
1994	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
1995	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70	1.70
1996	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78
1997	1.78	1.78	1.00	0.95	0.95	0.95	0.95					
Texas												
1993	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
1994	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.70
1995	3.70	3.70	3.70	3.70	3.70	3.70	3.70	4.15	4.15	4.15	4.15	4.15
1996	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15
1997	4.15	4.15	4.15	4.15	4.15	4.15	4.15					
Virginia												
1993	5.80	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
1994	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
1995	6.50	6.70	6.70	6.70	6.70	6.90	6.90	6.90	6.90	6.90	6.90	6.90
1996	6.90	6.90	6.90	6.90	6.90	6.90	6.90	6.90	6.90	6.90	6.90	6.90
1997	6.90	6.90	6.90	6.90	6.90	6.90	6.90					

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 39--Citronella oil prices, drums, 1993-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
Java 1/												
1993	2.53	2.53	2.53	2.53	2.53	3.10	3.10	3.10	3.10	3.60	3.80	4.00
1994	4.00	4.30	4.30	4.15	4.15	4.15	4.15	4.75	4.75	5.00	5.50	6.00
1995	6.00	7.90	8.43	8.43	8.43	8.60	8.60	7.00	6.75	6.00	6.00	6.00
1996	5.00	4.85	4.85	4.13	4.13	4.00	4.00	3.60	3.60	3.60	3.60	3.60
1997	3.10	3.10	3.10	3.10	3.10	3.30	3.30					
Chinese												
1993	2.20	2.25	2.35	2.35	2.35	3.13	3.13	3.13	3.13	3.25	3.50	4.00
1994	4.00	4.20	4.20	4.05	4.05	4.05	4.05	4.40	4.40	5.00	5.40	6.10
1995	7.00	7.90	8.35	8.35	8.35	8.60	8.60	7.90	6.80	6.30	5.90	5.90
1996	5.90	5.50	5.50	4.60	4.30	4.15	4.00	3.60	3.60	3.60	3.60	3.60
1997	3.20	2.90	2.90	2.90	2.90	2.90	2.90					

N.A. = Not available. 1/ Beginning August 1995, Sri Lanka, ordinary.

Source: Chemical Marketing Reporter.

Table 40--Eucalyptus oil prices, Chinese, 80 percent, 1993-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
1993	2.88	2.88	2.88	2.88	2.88	2.63	2.63	2.63	2.63	2.63	2.63	2.63
1994	2.63	2.63	2.63	1.90	1.90	1.90	1.90	2.00	2.00	2.00	2.00	2.15
1995	2.38	2.50	2.50	2.80	3.00	3.20	3.20	3.20	2.90	2.90	2.90	2.90
1996	3.00	2.90	2.90	2.70	2.50	2.50	2.50	2.50	2.30	2.30	2.30	2.30
1997	2.40	2.40	2.40	2.40	2.40	2.40	2.25					

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 41--Grapefruit oil prices, drums, 1993-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
Florida												
1993	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
1994	6.00	6.00	6.00	6.75	6.75	6.75	7.50	8.25	8.25	8.25	8.25	8.25
1995	8.25	8.25	8.25	11.25	11.25	11.25	11.25	11.25	15.75	15.75	15.75	17.00
1996	17.00	17.00	17.00	17.00	17.50	17.50	17.50	17.50	17.50	17.50	17.50	17.50
1997	15.25	14.00	14.00	14.00	14.00	12.00	12.00					
Israeli												
1993	N.A.	N.A.	N.A.	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63
1994	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63
1995	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	4.63	13.50
1996	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50
1997	13.50	13.50	13.50	13.50	13.50	13.50	13.50					

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 42--Lemon oil prices, 1993-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						– Dollars/pound –						
Argentinean												
1993	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25
1994	10.25	11.00	11.00	11.00	11.00	11.00	11.50	11.50	11.50	11.50	11.50	12.25
1995	12.25	12.25	12.25	12.25	12.25	12.25	12.25	12.65	12.65	12.65	12.65	12.65
1996	12.65	12.65	12.65	12.65	12.65	12.65	12.65	12.65	12.65	12.65	12.65	12.65
1997	12.65	12.65	12.65	12.65	12.65	12.65	12.65					
California, U.S. Pharmacopeia, drums												
1993	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	10.50	9.50
1994	9.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50
1995	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	8.50	9.00
1996	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.75	9.75	9.75
1997	9.75	9.75	9.75	9.75	9.75	9.75	9.75					
Italian												
1993	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
1994	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00
1995	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	15.00
1996	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
1997	15.00	15.00	15.00	15.00	15.00	15.00	15.00					

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 43--Lime oil prices, distilled, Mexican, drums, 1993-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						– Dollars/pound –						
1993	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.25
1994	10.25	10.25	10.25	10.25	10.25	10.25	10.25	10.75	10.75	10.75	10.75	10.75
1995	10.75	10.75	10.75	10.75	10.75	10.75	12.00	13.50	13.50	13.50	13.50	13.50
1996	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50
1997	10.90	10.90	10.90	10.90	10.90	10.90	10.90					

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 44--d-Limonene prices, drums, 1993-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						– Dollars/pound –						
1993	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
1994	0.78	0.78	0.78	0.83	0.83	0.83	0.83	0.83	0.83	1.05	2.00	2.00
1995	2.00	2.00	2.35	2.35	3.00	3.00	3.00	2.50	2.50	2.50	2.50	2.35
1996	2.10	1.80	1.80	1.50	1.40	1.30	1.25	0.95	0.95	0.80	0.80	0.80
1997	0.65	0.62	0.65	0.65	0.60	0.60	0.60					

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 45--Menthol prices, natural, Chinese, drums, 1993-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						– Dollars/pound –						
1993	6.35	5.68	5.68	5.10	5.10	5.10	5.10	5.10	5.10	5.00	5.00	5.00
1994	5.00	4.80	4.80	4.80	4.80	4.80	4.80	4.80	4.80	9.50	11.50	12.00
1995	12.00	12.50	11.00	9.75	9.75	9.00	9.00	9.00	9.80	10.63	12.00	12.00
1996	12.00	12.00	12.75	13.00	13.00	13.00	13.00	15.50	17.00	19.00	19.00	19.00
1997	19.00	49.00	49.00	49.00	49.00	49.00	49.00					

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 46--Orange oil prices, 1993-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
California, distilled, cans, f.o.b. plant												
1993	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25
1994	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	2.00	2.00
1995	2.00	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.88
1996	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.00	1.50	1.50	1.50
1997	1.50	1.50	1.50	1.50	1.50	1.50	1.50					
Florida, drums 1/												
1993	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
1994	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	1.10	2.00	2.00
1995	2.00	2.25	2.50	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75	2.75
1996	2.38	2.13	2.13	1.85	1.70	1.70	1.80	1.05	1.00	0.90	0.90	0.90
1997	0.80	0.80	0.68	0.68	0.68	0.65	0.65					
Brazilian 2/												
1993	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
1994	0.75	0.75	0.75	0.78	0.78	0.78	0.78	0.78	0.78	1.10	2.00	2.00
1995	2.00	2.40	2.40	2.55	2.70	2.70	2.70	2.43	2.63	2.63	2.63	2.63
1996	2.25	2.00	2.00	1.60	1.45	1.45	1.40	1.10	1.00	0.90	0.90	0.90
1997	0.80	0.72	0.75	0.75	0.75	0.75	0.75					

N.A. = Not available.

1/ Florida, midseason, drums beginning in February 1994. 2/ Pera Brazil, drums, f.o.b. plant beginning in February 1994.

Source: Chemical Marketing Reporter.

Table 47--Peppermint oil prices, 1993-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
Midwest U.S.												
1993	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.35	13.50	13.50	13.50
1994	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50
1995	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50
1996	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50	13.50
1997	13.50	13.50	13.50	13.50	13.50	13.50	13.50					
Yakima U.S.												
1993	12.30	12.30	12.30	12.30	12.30	12.30	12.30	12.30	12.30	15.00	15.00	15.00
1994	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
1995	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
1996	13.00	13.00	13.00	13.00	13.00	12.50	15.00	15.00	15.00	15.00	15.00	15.00
1997	15.00	15.00	15.00	15.00	15.00	15.00	15.00					
Syntetic, drums, f.o.b. works												
1993	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	10.00	10.00	10.00	10.00
1994	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
1995	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
1996	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
1997	10.00	10.00	10.00	10.00	10.00	10.00	10.00					

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 48--Spearmint oil prices, 1993-97

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
						-- Dollars/pound --						
Far West, native												
1993	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	11.00	11.00	11.00
1994	11.00	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50
1995	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50
1996	13.70	13.70	13.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70	14.70
1997	14.70	14.70	14.70	14.70	14.70	14.70	14.70					
Far West, Scotch												
1993	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	12.50	12.50	12.50
1994	12.50	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
1995	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
1996	16.50	16.50	16.50	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00
1997	19.00	19.00	19.00	19.00	19.00	19.00	19.00					
Chinese, 80 percent												
1993	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50	7.50
1994	7.50	7.50	7.50	7.50	7.50	5.75	5.75	5.75	5.75	5.75	5.50	6.00
1995	6.00	6.70	6.70	6.70	7.00	7.00	7.00	7.50	8.50	8.50	9.25	9.25
1996	9.25	9.25	9.25	9.25	9.25	9.25	10.15	11.60	13.70	13.10	13.10	13.10
1997	14.50	14.50	14.50	14.50	14.50	14.50	15.20					

N.A. = Not available.

Source: Chemical Marketing Reporter.

Table 49--Selected prices for biobased chemicals and derivatives, 1991-97 1/

Item	Unit	Average annual price 2/						
		1991	1992	1993	1994	1995	1996	1997 3/
Starches, sugars, and gums								
Arabic gum, National Formulary, powdered, barrels	Dollars/pound	1.85	2.67	3.44	4.00	4.00	1.25	1.00
Denatured alcohol, ethyl (ethanol), CD18, CD19, tanks, delivered east	Dollars/gallon	2.08	2.02	2.02	2.26	2.46	2.68	2.70
Dextrin, corn, canary dark, paper bags, carload, works	Cents/pound	32.00	32.00	32.00	32.00	32.00	32.00	32.00
Dextrose, hydrated, commercial, bags, carload, delivered New York	Cents/pound	25.50	25.50	25.50	25.50	25.50	25.50	25.50
Furfural, tanks, f.o.b. plant	Cents/pound	79.00	79.00	79.00	79.00	79.00	79.00	79.00
Guar gum, industrial, high viscosity, bags, carload, f.o.b. shipping point	Cents/pound	35.00	35.00	35.00	39.92	53.33	77.50	85.00
Karaya gum, No. 1, powdered, drums	Dollars/pound	3.25	3.25	3.25	3.25	3.25	3.25	3.25
Locust bean gum, powdered, bags	Dollars/pound	4.75	4.75	4.63	4.71	10.00	16.00	16.00
Pectin, high methoxyl	Dollars/pound	3.30	4.03	4.75	4.75	4.67	4.50	4.50
Sorbitol, U.S. Pharmacopeia, regular, 70-percent aqueous, drums, carload, f.o.b. shipping point	Cents/pound	33.29	33.00	33.00	33.00	33.00	26.25	32.57
Sucrose acetate isobutyrate, 90-percent, drums, truckload, delivered	Dollars/pound	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Sucrose octa-acetate, denaturing grade, 100-pound drums, f.o.b. works	Dollars/kilogram	12.50	12.50	12.50	12.50	12.50	12.50	12.50
Tragacanth gum, No. 1, ribbons, 100-pound drums	Dollars/pound	36.00	36.00	36.83	41.00	41.00	41.00	41.00
Xanthan gum, food grade, 100-pound drums, f.o.b. works	Dollars/pound	5.65	5.65	5.74	6.20	6.20	6.20	6.20
Fats, oils, and waxes								
Beeswax, refined, bleached, white bricks, 100-pound cartons	Dollars/pound	3.10	3.12	3.35	3.33	3.31	3.28	2.40
Butyl stearate, technical, tanks, f.o.b. works	Cents/pound	55.00	55.00	54.75	54.00	54.00	54.00	54.00
Capryl alcohol, secondary, 98-percent, tanks, f.o.b. works	Cents/pound	48.00	48.00	48.00	66.33	68.00	68.00	68.00
Caprylic acid, commercial, pure, tanks	Dollars/pound	0.83	0.91	1.02	1.02	1.02	1.04	1.29
Carnauba wax, Parnahyba, No. 1, yellow, bags, ton lots	Dollars/pound	2.88	3.23	3.50	3.50	4.88	4.25	4.25
Glycerine, natural, refined, U.S. Pharmacopeia, 99.7-percent, tanks, delivered	Dollars/pound	0.64	0.57	0.64	1.01	1.08	1.00	0.94
Lecithin, unbleached, bulk, less carload, works	Cents/pound	29.00	28.00	25.75	25.00	25.00	25.00	25.00
Magnesium lauryl sulfate, tanks, f.o.b.	Cents/pound	43.00	43.00	47.75	57.25	57.25	57.25	57.25
Magnesium stearate, bulk	Dollars/pound	1.16	1.16	1.20	1.20	1.20	1.20	1.20
Menhaden oil, bulk, Gulf ports	Cents/pound	13.13	15.83	16.54	16.50	16.50	16.50	16.50
Myristic acid, commercial, pure, truckload 4/	Dollars/pound	0.67	1.10	1.25	1.17	1.15	4/	0.85
Oleic acid, double distilled (white), tanks	Cents/pound	54.00	54.00	60.42	61.00	61.00	61.00	61.00
Sebacic acid, chemically pure, bags, carload, works	Dollars/pound	2.05	2.05	2.05	2.05	2.05	2.05	2.05
Sodium lauryl sulfate, 30-percent, drums, truckload, f.o.b. works	Cents/pound	43.00	43.00	47.75	57.25	57.25	57.25	57.25
Tallow fatty acids, technical, tanks, delivered	Cents/pound	24.88	23.50	23.50	23.50	23.50	23.50	23.50
Animal products								
Casein, acid precipitated, ground, 30-mesh, edible, imported, truckload, c.i.f.	Dollars/pound	2.50	2.52	2.55	2.55	2.55	2.55	2.55
Gelatin, edible, 100 AOAC test, drums, less truckload, delivered	Dollars/pound	1.54	1.68	1.70	1.70	1.70	2.08	2.60
Glue, bone, extracted, green, 85 jellygrams, bags, carload	Cents/pound	95.00	94.00	89.00	89.00	89.00	89.00	89.00
Lanolin, anhydrous, pharmaceutical, 400-pound drums, works	Dollars/pound	1.00	1.25	1.25	1.25	1.25	1.25	1.25
Forest products								
a-Pinene prices, technical grade 5/	Dollars/pound	0.43	0.43	0.53	0.60	0.60	5/	2.50
b-Pinene 6/	Dollars/pound	0.55	0.55	6/	1.14	1.14	1.86	2.90
Cellulose acetate, powdered, bags, truckload, delivered east	Dollars/pound	1.62	1.94	2.12	2.12	2.12	2.12	2.12
Tall oil, crude, Southeast, tanks, freight equaled	Dollars/ton	159.17	150.83	119.17	121.25	156.67	155.00	150.00
Turpentine prices, crude sulfate, tanks, f.o.b. Southeast	Dollars/gallon	1.36	0.88	0.68	0.50	0.63	1.12	1.36

See next page for footnotes and definitions.

1/ Spot and/or list prices from the Chemical Marketing Reporter for selected chemicals and related materials on a New York or other indicated basis. These prices do not represent bid, asked, or actual transaction prices. Variations from these prices may occur for differences in quantity, quality, and location. 2/ Some prices are from the low end of range. 3/ January to July. 4/ The unit of quantity changed from bags to bulk in December 1996. 5/ Price changed from technical grade to 99-percent perfume and flavor grade in September 1996. 6/ Price changed from technical grade to 97-percent perfume and flavor grade in October 1993.

Chemical definitions:

Arabic gum is a dried, water-soluble exudate from the stems of Acacia senegal and related species that is used in pharmaceuticals, adhesives, inks, textile printing, cosmetics, and confectionery and food products.

Denatured ethyl alcohol is made by yeast fermentation of carbohydrates or by hydrolysis of ethylene for solvents, cosmetics, and as an oxygenated gasoline additive.

Dextrin is obtained by heating acidified dry starch for adhesives and paper products.

Dextrose is obtained from cornstarch hydrolysis for use in foods and as a fermentation substrate.

Furfural is obtained by steam distillation of acidified plant materials for polymers and foundry binders.

Guar gum is a water-dispersible hydrocolloid from the seeds of the guar plant that is used in foods and industrial applications such as oil-well fracturing fluids.

Karaya gum is a hydrophilic polysaccharide from Indian trees of the genus Sterculia for use in pharmaceuticals, textile coatings, ice cream and other food products, and adhesives.

Locust bean gum is a polysaccharide plant mucilage from seeds of Ceratonia siliqua used in cosmetics, textiles sizings and finishes, and drilling fluids, and in foods as a stabilizer, thickener, and emulsifier.

Pectin is obtained from citrus fruit rinds for use in jellies, foods, cosmetics, and drugs.

Sorbitol is obtained by hydrogenation of glucose for foods, cosmetics, and polyester polymers.

Sucrose acetate isobutyrate is made by controlled esterification of sucrose with acetic and isobutyric anhydrides for hot-melt coating formulations and extrudable plastics.

Sucrose octa-acetate is used as a plasticizer for cellulose esters and plastics, and in adhesive and coating compounds.

Tragacanth gum is polysaccharides from Astragalus bushes for use in pharmaceutical emulsions, adhesives, leather dressing, textile printing and sizing, dyes, and printing inks.

Xanthan gum is a synthetic, water-soluble polymer made by fermentation of carbohydrates for use in drilling fluids, ore floatation, foods, and pharmaceuticals.

Beeswax is a byproduct of honey production used for cosmetics and candles.

Butyl stearate is obtained by alcoholysis of stearin or esterification of stearic acid with butanol for use in polishes, special lubricants, and coatings and as a plasticizer and emollient in cosmetics and pharmaceuticals.

Capryl alcohol is obtained by distilling sodium ricinoleate, a castor oil derivative, with an excess of sodium hydroxide for solvents, plasticizers, wetting agents, and petroleum additives.

Caprylic acid is a fatty acid obtained from coconut oil for use in synthesizing dyes, drugs, perfumes, antiseptics, and fungicides.

Carnauba wax is a hard commercial wax obtained from leaves of Copernica cerifera for shoe, furniture, and floor polishes; leather finishes; varnishes; electric-insulating compounds; and carbon paper.

Glycerine is a byproduct of splitting or saponification of fats and oils, or made by petrochemical synthesis for cosmetics, food, drugs, and polyurethane polymers.

Lecithin is a byproduct of soy oil extraction used as an emulsifying agent and antioxidant in foods.

Magnesium lauryl sulfate is a surfactant derived from fatty acids for use in plastics, plasticizers, textile applications, and consumer end-product manufacturing.

Magnesium stearate is a surfactant made from tropical oil fatty acids and inorganic materials for use in lubricant, adhesive, and detergent manufacturing.

Menhaden oil is obtained from menhaden fish for soaps, rubber compounding, printing inks, animal feed, and leather-dressing lubricants.

Myristic acid is obtained by fractional distillation of coconut and other vegetable oils for soaps, cosmetics, and synthesis of esters for flavors and perfumes.

Oleic acid is obtained by fractional crystallization from mixed fatty acids for candles, soaps, and synthesis of other surfactants.

Sebacic acid is made by high-temperature cleavage of castor oil for use as an intermediate chemical in the manufacture of polymers and plasticizers.

Sodium lauryl sulfate is synthesized from fatty acids for use in toothpaste and as a food additive and wetting agent for textiles.

Tallow fatty acids are made from splitting tallow for direct use as lubricants or in greases, and for separation into pure fatty acids.

Casein is a coagulated and dried milk protein for adhesives and plastics.

Gelatin is water extracted from bones and hides for photographic emulsions and food.

Glue (bone) is obtained by steam treatment and water extraction of bones for glue and mineral flotation processes.

Lanolin is extracted from wool for cosmetics, leather dressing, and lubricants.

a-Pinene and b-Pinene are chemical intermediates fractionated from turpentine that are converted to pine oil (a-Pinene), terpene resins (b-Pinene), and specialty chemicals.

Cellulose acetate is made by reacting cellulose from wood with acetic acid for rayon textiles and cigarette filters.

Tall oil (crude) is a byproduct of paper production (chemical pulping) that is refined into rosin and fatty acids.

Turpentine (crude sulfate) is obtained by steam distillation of pine gum recovered from pulping softwoods (for paper production), which is used for a- and b-pinene.

Table 50--U.S. imports of nonwood fibers, yarns, twine, and cordage, 1992-97

	Unit	1992	1993	1994	1995	1996	Jan-May 1997
Flax, raw or processed, not spun	Metric tons	48,166	47,030	55,059	66,092	81,182	36,818
Jute, raw or processed, not spun	Metric tons	6,246	7,326	7,026	5,876	4,218	730
Flax yarn	Kilograms	690,248	888,656	1,113,918	1,185,977	723,521	445,099
Jute yarn	Kilograms	5,380,531	5,046,250	4,312,393	7,888,502	6,970,594	2,872,173
Abaca, twine, and cordage	Kilograms	5,623,279	6,930,999	7,652,898	6,268,102	5,579,141	2,385,826
Jute, twine, and cordage	Kilograms	6,623,013	7,606,930	15,403,623	11,957,283	5,504,137	1,886,477
Sisal, twine, and cordage	Kilograms	73,056,843	71,595,465	78,704,800	84,234,676	57,740,754	50,553,881

Source: Department of Commerce, Bureau of the Census.

Table 51--U.S. exports of nonwood fibers, yarns, twine, and cordage, 1992-97

Item	Unit	1992	1993	1994	1995	1996	Jan-May 1997
Flax, raw or processed, not spun	Metric tons	3,687	121	92	302	174	49
Jute, raw or processed, not spun	Metric tons	1,534	1,202	2,353	2,554	1,386	323
Flax yarn	Kilograms	209,218	363,084	112,330	44,078	106,928	15,521
Jute yarn	Kilograms	591,864	575,383	236,225	101,924	122,841	63,490
Jute, twine, and cordage	Kilograms	305,873	297,794	462,136	530,599	537,077	240,886
Sisal, twine, and cordage	Kilograms	1,366,504	1,150,473	519,285	928,515	1,153,697	436,397

Source: Department of Commerce, Bureau of the Census.

Table 52--U.S. imports of selected vegetable oils, 1992-97

Item	Unit	1992	1993	1994	1995	1996	Jan-May 1997
Castor oil, crude and refined	Metric tons	34,018	42,214	44,094	44,093	39,938	12,509
Coconut oil, crude and refined	Metric tons	501,466	443,496	441,332	490,650	423,189	227,035
Linseed oil, crude and refined	Metric tons	351	159	426	1,729	2,699	1,111
Jojoba oil and its fractions	Metric tons	235	142	198	332	289	91
Tung oil and its fractions	Metric tons	4,995	4,272	5,404	4,427	3,943	2,924

Source: Department of Commerce, Bureau of the Census.

Table 53--U.S. exports of selected vegetable oils, 1992-97

Item	Unit	1992	1993	1994	1995	1996	Jan-May 1997
Coconut oil, crude and refined	Metric tons	9,448	6,364	8,494	9,089	3,987	2,157
Linseed oil, crude and refined	Metric tons	3,940	3,804	5,402	15,422	14,892	18,130
Jojoba oil and its fractions	Metric tons	209	351	287	151	149	65
Tung oil and its fractions	Metric tons	329	297	176	516	1,190	1,080

Source: Department of Commerce, Bureau of the Census.

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