Chapter 2
Introduction

Industrial Uses of Agricultural Commodities in the United States

Currently, the United States uses chemicals derived from agricultural commodities for a wide range of industrial applications. Industrial uses, however, represent only a small percent of total U.S. production of agricultural commodities. As an example, industrial uses of vegetable oils use no more than 2 percent of the total U.S. production of vegetable oils (12). Industrially useful compounds derived from renewable resources, including agricultural commodities include:

1. oils and waxes;
2. resins, gums, rubbers, and latexes;
3. fibers;
4. starches and sugars; and
5. proteins.

Oils and Waxes

Lipids (fats and oils) are water-insoluble compounds found in the cells of plants and animals. They serve as structural components of membranes, and as metabolic fuel. Lipids are composed of triglycerides that can be decomposed into fatty acids and glycerol, a chemical that is used in soaps and detergents. Fatty acids consist of carbon chains. The length of the chain, the number of double bonds between the carbons of the chain (the degree of unsaturation), and the type of reactive groups attached (e.g., epoxy and hydroxy groups), determine the characteristics and uses of the various fatty acids. Longer chain (12 or more carbons) fatty acids are used most frequently in detergents. Shorter chain (10 or fewer carbons) fatty acids are used primarily in plastics (1 1). Oilseed crops are a major source of oils and fatty acids used for industrial purposes. Table 2-1 lists the fatty acids most commonly used in industrial applications. Table 2-2 presents total quantities of fats and oils used for industrial purposes in 1987 and 1988. Table 2-3 presents industrial uses of selected oils for May and April 1990.

Waxes are similar to oils, but are generally harder and more brittle (more saturated), and contain esters of longer-chain fatty acids and alcohols. Waxes are used in candles, crayons, and floor polishes among other uses. The United States imports many of the waxes used (table 2-4).

Table 2-1—industrial Fatty Acids

Class	Fatty acid	Most common sources
Saturated	C_{12} (lauric)	Coconut oil
	C_{16} (palmitric)	Palm oil
	C_{18} (stearic)	Tallow, hydrogenated oil
Monounsaturated. .	C_{18} (oleic)	Olive, tall oils
	C_{22} (erucic)	Rapeseed oil
Diunsaturated.	C_{18} (linoleic)	Sunflower, soybean oil
Multiunsaturated . .	C_{18}	Linseed, tung, fish oil
Hydroxy.	C_{18} (ricinoleic)	Castor oil

SOURCE: L.H. Princen and J.A. Rothus, "Development of New Crops for Industrial RawMaterials," *Journal of the American Oil Chemists' Society, vol.* 61, 1984, pp. 281-289.

Table 2-2—Fats and Oils: Use in Selected Industrial Products (million pounds)

	1987	1988
Soap	918	807
Paints/varnish	261	176
Resins/plastics	199	202
Lubricants	109	111
Fatty acids	2,195	2,181
Other	597	501
Total	4,279	3,978

NOTE: Fats and oils include cottonseed, soybean, *corn,* peanut, tall, safflower, palm, coconut, linseed, inedible tallow and grease, tung, castor, palm kernel, rapeseed, edible tallow, lard, sunflower, fish, and other miscellaneous oils.

SOURCE: James Schaub, U.S. Department of Agriculture, Economic Research Service, 1990.

Resins, Gums, Rubbers, and Latexes

Resins, usually obtained from plant secretions, are solid or semisolid organic substances (usually terpenoids) that are soluble in organic solvents and insoluble in water. The most commonly used resins are produced by pine trees. Rosin, a resin mixture extracted from tall oils (a byproduct of chemical wood pulp manufacture) or from dead pine stumps has many uses in the chemical industry (table 2-5).

Many of the gums (e.g., xanthan, dextran, polytran, gullan, and pulludan) currently used are derived from seaweeds and kelps or are produced by microbial bioprocessing. These polysaccharide biopolymers are used primarily as viscosifiers (thicken-

Table 2-3-industrial Uses of Selected Oils, April/May 1990 (thousand pounds)

Oil	Industrial use	April 1990	May 1990
Soybean	Soap	D	D
	Paints/varnish	3,038	3,442
	Resins/plastics	9,599	9,981
	Fatty acids	D	D
	Other[a]	8,020	8,725
	Total[a]	22,819	25,320
Coconut	Soap	13,849	10,255
	Paints/varnish	D	D
	Resins/plastics	175	104
	Lubricants	D	D
	Fatty acids	11,642	12,112
	Other[a]	5,200	5,903
	Total[a]	31,224	28,932
Castor	Soap	D	D
	Paints/varnish	831	410
	Resins/plastics	398	501
	Lubricants	471	418
	Other	D	D
	Total	4,385	4,438
Palm	Total	5,573	5,600
Palm kernel		D	D
Rapeseed		D	D

KEY: (D) Data withheld to avoid disclosing figures for individual companies.
[a]Total and other industrial uses indudes the addition of oil to livestock feed.

SOURCE: James Schaub, U.S. Department of Agriculture, Economic Research Service, 1990.

Table 2-4-1987 U.S. Wax Imports

Beeswax	832 MT
Candelilla wax	352 MT
Carnauba wax	4.015 MT

SOURCE: U.S. Department of Agriculture, Economic Research Service, *Foreign Agricultural/ Trade of the United States, Calendar Year 1987 Supplement* (Washington, DC: U.S. Government Printing Office, June 1988).

ers), flocculating agents (aggregating agents), and lubricants (11).

Natural rubber used in the United States is *Hevea* rubber imported primarily from Malaysia and Indonesia. The United States imports about 800,000 metric ton (MT) of *Hevea* rubber yearly.

Fibers

Fiber can be obtained from trees and other fibrous plants (e.g., hemp, ramie). In the United States, the primary fiber source is the forestry industry. Wood pulp is used in the making of paper and paperboard products (table 2-6).

Table 2-5-industrial Uses of Rosin

Use	Percent total consumption
Rubber and chemicals	35.2
Paper sizing	33.5
Ester gums and synthetic resins	22.7
Paints, varnishes, and lacquers	2.2
Other uses	6.7

SOURCE: Joseph J. Hoffmann and Steven P. Mdaughlin, "Grindelia Camporum: Potential Cash Crop for the Arid Southwest," Economic *Botany* 40(2), April-June 1986, pp. 162-169.

Table 2-6-Use of Pulp in Paper and Paperboard Production

Use	Percent total
Newsprint	8.5
Tissue	7.5
Printing and writing	26.0
Packaging and industrial	8.5
Paperboard	49.5

SOURCE: U.S. Department of Agriculture, Forest Service, "An Analysis of the Timber Situation of the United States, 1989-2040, Part I: The Current Resource and Use Situation," 1989.

Starches and Sugars

Starch is composed of hundreds of glucose (sugar) units bound together in branched or unbranched chains. Starch is the principal carbohydrate storage product of higher plants. Current U.S. production of ethanol requires about 400 million bushels of corn. An additional 4.5 billion pounds of cornstarch are used for other industrial purposes. Of that amount, nearly 3.5 billion pounds are used in the paper, paperboard, and related industries (primarily as adhesives). The remainder is used predominantly in the textile industry (as warp sizers) and as thickeners and stabilizers (3).

Proteins

Industrial uses of proteins include adhesives that help bind pigments to paper. However, proteins are most commonly used for food and feed purposes, rather than as industrial feedstocks.

New Industrial Crops and Uses of Traditional Crops

Chemicals with industrial uses can be derived from crops that are traditionally grown in the United States or from new crops, which must be adapted to U.S. production. New crops can be derived from the domestication of wild species of plants, or introduced from other countries. Cuphea, an oilseed that could replace coconut oil, is an example of an attempt to domesticate a wild species. Industrial rapeseed, an oilseed that produces a chemical used as a slip agent in some plastics, is cultivated in many countries and is now being adapted to U.S. production.

Research and development of new industrial crops in the United States is diverse. Table 2-7 lists some potential new crops that could be developed for U.S. production. The list is not exhaustive, but rather includes new crops that are considered to have high commercial potential based on the types of chemical compounds these plants produce. Four oilseeds *(Crambe,* rapeseed, meadowfoam, and jojoba), one new rubber, guayule, and one new fiber, kenaf, are in relatively advanced stages of development. Each of these potential new industrial crops is discussed in greater detail in *Appendix A: Selected New Industrial Crops.*

New industrial use of crops that U.S. farmers are already producing is also being pursued (table 2-8). Examples include using sunflower seed oil as diesel fuel, or using compounds derived from corn to make a road de-icer that could replace salt. These and a number of other new uses are discussed in *Appendix B: Selected Industrial Uses for Traditional Crops.*

Research is also being conducted to develop new food crops, forage crops, horticultural and ornamental crops, biomedicinal crops, and crops that produce biopesticides among others. New industrial uses of forestry crops and of ligno-cellulose derived from plant wastes are also being explored.

Changing demographic patterns in the United States have led to increased demand for many new food items. Imports of Latin and Asian fruits, grains, and vegetables have been steadily rising. Many of these crops could be grown in the United States. Some of these new food crops, like some of the new industrial crops, are drought tolerant and could be grown in areas where water shortages are becoming a problem. Additionally, some new specialty-food crops may face fewer commercialization barriers than new industrial crops (5). Horticultural crops are a rapidly growing, high-value market. Grower cash receipts for horticultural and ornamental crops grew from 5 percent of all crop receipts in 1981 to 11 percent in 1987, with estimated receipts in that year of about $7 billion (10). Examples are discussed briefly in *Appendix C: Selected New Food Crops and Other Uses.* There may also be potential to expand the use of animals and animal products as well.

Table 2-7—Potential New industrial Crops

Crop	Compound of interest	Replacement
OilSeed:		
Buffalo gourd	Oleic acid	Petroleum/soybean oil
Chinese tallow	Tallow	Imported cocoa butter
Crambe	Erucic acid	Imported rapeseed oil
Cuphea	Laurie acid, capric acid	Coconut oil/palm kernel oil
Honesty	Erucic acid	Imported rapeseed oil
Jojoba	Wax esters	Sperm whale oil
Lesquerella	Hydroxy fatty acids	Castor oil
Meadowfoam	Long chain fatty acids	Petroleum derivatives
Rapeseed	Erucic acid	Imported rapeseed oil
Stokes aster	Epoxy fatty acids	Petroleum/soybean oil
Vernonia	Epoxy fatty acids	Petroleum/soybean oil
Gums, resins, etc.:		
Baccharis	Resins	Wood rosins, tall oils
Grindelia	Resins	Wood rosins, tall oils
Guar	Gum	Imported guar
Guayule	Rubber	Imported hevea rubber
Milkweed	Latex	Petroleum derivatives
Fibers:		
Kenaf	Pulp similar to wood	Imported newsprint

SOURCE: Office of Technology Assessment, 1991.

Table 2-8-Potential industrial Uses for Traditional Crops

Use	Crop
Adhesives, matings	Soybeans
Coal *sulfurization	Corn
Diesel fuel	Soybeans, sunflowers
Ethanol	Corn
Degradable plastics	Corn
Ink carrier	Soybeans
Road de-icer	Corn
Super absorbants	Corn

SOURCE: Office of Technology Assessment, 1991.

This report focuses primarily on the potential benefits from, and constraints to, the development and commercialization of new industrial crops and uses of traditional crops, rather than on new food, forage, ornamental crops, etc. It also focuses on production agriculture, rather than on developing new products for the forestry industry. The rationale for focusing on industrial uses and crops is that supplying the industrial market will potentially lead to entirely new markets for agricultural products. Additionally, these industrial markets are potentially high-volume markets that could use excess agricultural capacity. Development of new edible crops is considered more likely to result in the redistribution of market share, than to expand the total market.

Proposed Benefits of Using Agricultural Commodities as Industrial Raw Materials

Proponents of the development of new industrial crops and uses for traditional crops cite many potential benefits that can accrue to society (2,9,17). Those most frequently cited include market diversification and increased farm income, improved agricultural resource utilization, reduced commodity surpluses and support payments, enhanced international competitiveness, reduced negative environmental impacts, revitalized rural economies, a domestic supply of strategic and essential materials, and decreased dependency on petroleum.

Diversification of Agricultural Markets

Currently, U.S. agriculture relies on the production of a limited number of crops, many of which are in surplus production, and are used primarily for human and livestock food. Depressed prices and price variability of these commodities results from domestic surplus production and global competition in their production and marketing, and have resulted in low and variable income for U.S. farmers. The United States has lost market share in the export of many of its major commodities.

As a result of the severe problems facing agriculture in the early 1980s, the Secretary of Agriculture convened a challenge forum in 1984 to explore new directions for agricultural products and markets. The New Farm and Forest Products Task Force was established as a result of this forum. The task force concluded that diversification of agriculture is the only alternative, and should become a national priority. The task force stated that technological innovation can potentially develop high-value products, is key to economic growth, and is necessary to avoid stagnation in mature industries such as agriculture.

Because the agricultural industry represents approximately 18 percent of the U.S. Gross National Product, the report concluded that a stronger agricultural sector will strengthen the U.S. economy. Additionally, agriculture plays a major role in the balance of payments, and development of new products could potentially lead to new export markets and possibly decrease some imports. Because of these possibilities, the task force recommended the development of new agricultural products that would use the equivalent of 150 million acres of production capacity, to be achieved within 25 years (17).

Underutilization of Land Resources

In 1989, the United States planted approximately 341 million acres of land to crops. Another 60 million acres were removed from production and enrolled in Federal programs (26 million acres in Acreage Reduction Programs and 34 million acres in Conservation Reserve Programs). Additional acreage that could potentially be used for crop production was planted to pasture (12,14,18). It has been proposed that the development of industrial markets for agricultural commodities might result in the more productive use of cropland that may currently be underutilized.

Reduction of Commodity Surpluses

Reduction of surpluses is expected to occur as new industrial markets are found for surplus crops, or as farmers shift acreage from the production of surplus crops to new crops. In 1989, the U.S. Commodity Credit Corporation had net outlays of approximately $10.5 billion to support farmers and operate Federal commodity programs (13). According to proponents, alternative and more profitable markets for the crops most heavily supported could decrease Federal commodity payments and reduce storage needs.

Enhanced International Competitiveness

In 1989, agricultural exports represented approximately 12 percent of the value of total U.S. exports (13). However, the United States has lost market share in the international trade of several commodities, and is no longer the world's lowest cost producer of many of these commodities. High commodity-support levels encourage production in other countries. Protectionist policies restrict trade. Proponents indicate that development of new uses for traditional crops or new crops could lead to the development of high-value industrial exports to replace some of the low-value bulk commodities that are currently the major U.S. exports. Many of the new crops potentially could reduce U.S. reliance on petroleum and other imports.

Improved Environmental Adaptation

Proponents argue that new industrial crops and uses potentially can offer many environmental benefits. It maybe feasible to develop new crops that are better adapted to certain environments than crops that are traditionally grown (9). Of the new industrial crops discussed in this report, many are well adapted to semiarid climates. These crops have lower water requirements than many crops that are presently being grown. Irrigation may still be required to achieve commercial production levels, but probably not to the extent required for traditional crops. For regions of the Southwestern United States and the Plains States, where competing demands for water use are becoming intense, the need for crops with reduced irrigation needs is becoming more important. An added advantage of some of these drought-tolerant crops is that they are also relatively tolerant of salt. Saline buildup is a major problem in irrigated areas. Examples of potential new industrial crops that are relatively drought tolerant are bladderpod, buffalo gourd, coyote bush, guar, guayule, gumweed, and jojoba.

Potential exists to develop other new crops that are resistant to pests, weeds, and disease; these crops may require fewer chemicals than traditional crops. Additionally, development of plants that can fix nitrogen could reduce fertilizer use. Buffalo gourd and honesty are two potential new industrial crops that are perennials and provide good ground cover. Crops such as these maybe used to help control soil erosion. New crops may also provide more rotation options to farmers, which could potentially decrease erosion and chemical use. Additionally, proponents feel that new uses for traditional crops may offer air quality advantages (less polluting alternative fuels), waste disposal advantages (degradable plastics), and reduce groundwater contamination (chemical delivery systems, road de-icers), among other potential benefits.

Rural Development

Proponents of development of industrial users of agricultural commodities indicate that such development could help to revitalize rura1 economies in two ways. First, the development of new crops and uses can provide more profitable alternatives to farmers, increasing farm income and land values. Increased farm income and land values could improve the tax base of rural communities, which could lead to improved schools, hospitals, infrastructure, etc. Services related to agriculture, such as input supplies will be needed. These services would have a multiplier effect within the economy. Second, the development of new crops and uses might stimulate the construction, expansion, or fuller use of processing and manufacturing plants. This would also create new jobs within some communities.

Strategic Materials

A domestic capacity to produce many strategic and essential materials that the United States currently imports, could reduce U.S. vulnerability to foreign events according to proponents. Strategic materials are those critical to national defense, and include many metals, natural rubber, and castor oil. Essential materials are those required by industry to manufacture products depended on daily, and include many gums, waxes, oils, and resins. The Defense Production Act (DPA) of 1950 (amended in 1980) requires that sufficient stocks of strategic materials be kept for wartime needs; stocks are managed by the Department of Defense. The mandated stockpile level of natural rubber is 850,000 short tons and that of castor oil is 5 million pounds. Since the United States is a large consumer, attempts to purchase the necessary quantities result in large price swings and current stocks are less than the levels mandated (1,8).

U.S. reliance on imports of natural rubber led Congress to pass the Native Latex Commercialization and Economic Act (Public Law 95-592) in 1978. This act was passed with the specific goal to develop a domestic natural rubber industry. In 1984, Congress amended and renamed this act the Critical Agricultural Materials Act (Public Law 98-284), which broadened the goal of the Native Latex Act to develop a domestic capacity to produce critical and essential industrial materials from agricultural commodities.

Summary

Agricultural commodities yield many chemicals that have industrial applications. Proponents feel that commercializing these applications will lead to numerous benefits for society in general, and for the rural economy and agricultural sector in particular. They feel that because of the benefits to be gained, and the lack of USDA responsiveness on this issue, legislation is needed to spur the development of these new technologies. The purpose of this report is to provide information Congress can use to assess the potential benefits of, and constraints to, developing new industrial crops and uses of traditional crops.

The potential benefits of new industrial crops and use development have not been systematically and rigorously analyzed. This report takes a first step at doing so, and presents that analysis in chapter 3. Factors involved in the research, development, and commercialization of these new technologies are discussed in chapter 4. To realize the benefits of new agricultural technology development, new processes must be adopted by manufacturers, and new crops must be adopted by farmers. Factors involved in the adoption of new technologies are discussed in chapter 5. Understanding of the factors involved in the research, development, commercialization, and adoption of new industrial crops and uses of traditional crops can aid in designing policy to achieve maximum benefits. Policy options are presented in chapter 6.

Chapter 2 References

1. Babey, John, U.S. Department of Defense, personal communication, January 1991.
2. Council for Agricultural Science and Technology, *Development of New Crops: Needs, Procedures, Strategies, and Options (Ames, IA),* Report No. 102, October 1984.
3. Deane, William M., "New Industrial Markets for Starch," paper presented at The Second National Corn Utilization Conference, Columbus, OH, Nov. 17-18, 1988.
4. Hoffmann, Joseph J., and McLaughlin, Steven P., "Grindelia Camporum: Potential Cash Crop for the Arid Southwest," *Economic Botany 40(2),* April-June 1986, pp. 162-169.
5. Johnson, Duane, "New Grains and Pseudograins," paper presented at the First National Symposium on New Crops: Research, Development and Economics, Indianapolis, IN, Oct. 23-26, 1988.
6. Princen, L.H., and Rothus, J.A., "Development of New Crops for Industrial Raw Materials," *Journal of the American Oil Chemists' Society,* vol. 61, *1984, pp. 281-289.*
7 Schaub, James, U.S. Department of Agriculture, Economic Research Service, personal communication, July 1990.
8. Tankersley, Howard C., and Wheaton, E. Richard, "Strategic and Essential Industrial Materials From Plants—Thesis and Uncertainties," *Plants: The Potential for Extracting Protein, Medicines, and Other Useful Chemicals—Workshop Proceedings,* OTA-BP-F-23 (Washington, DC: U.S. Congress, Office of Technology Assessment, September 1983), pp. 170-177.
9. Theisen, A. A., Knox, E. G., and Mann, F. L., *Feasibility of Introducing Food Crops Better Adapted to Environmental Stress* (Washington, DC: U.S. Government Printing Office, March 1978).
10. Turner, Steve, and Stegelin, Forrest, Symposia Co-organizers, "Market and Economic Research in Ornamental Horticulture," *American Journal of Agricultural Economics,* vol. 71, No. 5, December 1989, p. 1329.
11. U.S. Congress, Office of Technology Assessment, *Commercial Biotechnology: An International Analysis,* OTA-BA-218 (Washington, DC: U.S. Government Printing Office, January 1984).
12. U.S. Department of Agriculture, *Agricultural Statistics, 1988* (Washington, DC: U.S. Government Printing Office, 1988).
13. U.S. Department of Agriculture, Economic Research Service, *Agricultural Outlook,* AO-170, December 1990.
14. U.S. Department of Agriculture, Economic Research Service, *Agriculutral Resources: Cropland, Water, and Conservation Situation and Outlook Report, AR-19,* September 1990.
15. U.S. Department of Agriculture, Economic Research Service, *Foreign Agricultural Trade of the United States, Calendar Year 1987 Supplement* (Washington, DC: U.S. Government Printing Office, June 1988).
16. U.S. Department of Agriculture, Forest Service, "An Analysis of the Timber Situation of the United States, 1989-2040, Part I: The Current Resource and Use Situation," 1989.
17. U.S. Department of Agriculture, New Farm and Forest Products Task Force, "New Farm and Forest Products: Responses to the Challenges and Opportunities Facing American Agriculture, ' A Report to the Secretary, June 25, 1987.
18. Van Dyne, Donald L., Iannotti, Eugene L., and Mitchell, Roger, "A Systems Approach to Corn Utilization,' paper presented at The Second National Corn Utilization Conference, Columbus, OH, Nov. 17-18, 1988.