Chapter 2

Industrial Uses for Grains

Man has been harnessing the corn kernel for the value of its parts for several centuries. It has long been a base for the fermentation of alcohol. There is evidence Native Americans used corn to brew beer before Europeans set foot in the Americas.

Current Industrial Uses

And, like today, government played a hand in the first attempts to process corn into something other than hominy or animal feed. The Molasses Act, forced on the American Colonies by the British Parliament in 1733, first encouraged attempts to turn corn into sugar. Later in the 18th century, one of the first national attempts at taxation in the United States was on corn whiskey and led to the young country's first domestic crisis in the Whiskey Rebellion of 1792. Western farmers distilled their corn into whiskey because it was easier to transport. Efforts to process bulk corn into some product more portable, at a time transportation was primitive and expensive, intensified with the whiskey tax.

By the mid-19th century, corn had replaced wheat and potatoes as the principle feedstock for starch production. In the United States, cornstarch was first commercially converted into sugar in 1865 and, long before the automobile was a common form of transportation, corn had been processed into ethyl alcohol, or ethanol. Many of the earliest engine prototypes were designed to run on ethanol. It was the discovery and easy recovery of cheap oil that eliminated ethanol as a competitive fuel 100 years ago.

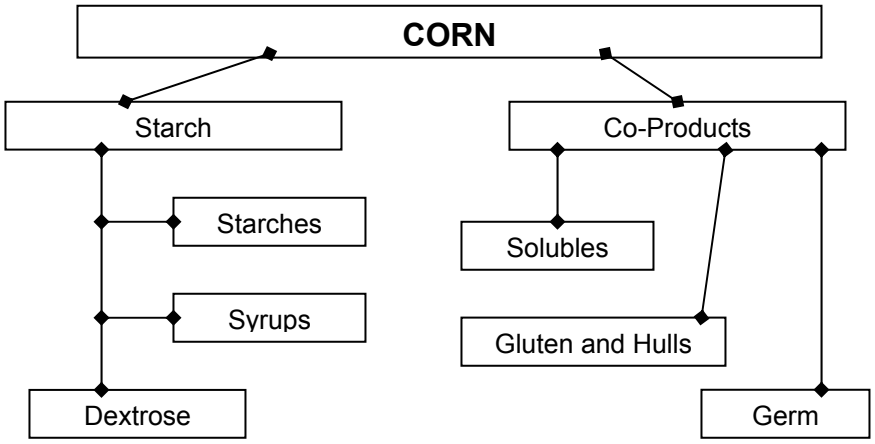
Sweetener and food additive demands were the primary driving force of industrial corn utilization and product innovation until the latter half of the 20th century. Out of 67 kilograms of sweeteners consumed by Americans annually in a variety of products, over one-third of them come from corn or another feed grain.

The versatility, availability and cost of the product pushed chemists to devise uses for corn - and the starch derived from it - in a spectrum of merchandise that proved to be extensive. Even before energy conservation and environmental concerns spurred industrial production into areas of fuel and plastic substitutes, corn use had spread

throughout every aspect of industrial production. Not surprisingly, those who process corn and refine it into these products today have become very efficient at it.

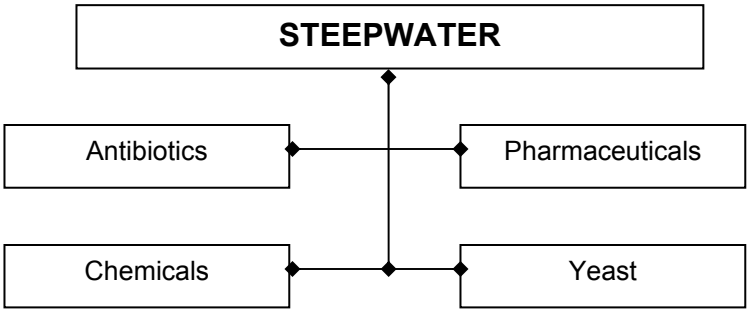
Most people working in the U.S. corn refining business have been at it for some time and have become truly adept at squeezing every drop of value from each kernel's molecular structure.

The Wet Milling Process



Upon arriving at a processing plant, each load of corn passes through a cleaner that removes foreign material and other impurities. Then the corn is soaked for 36 to 48 hours in hot water and sulfur dioxide. This process softens the protein (gluten) within the starch matrix while also toughening the germ.

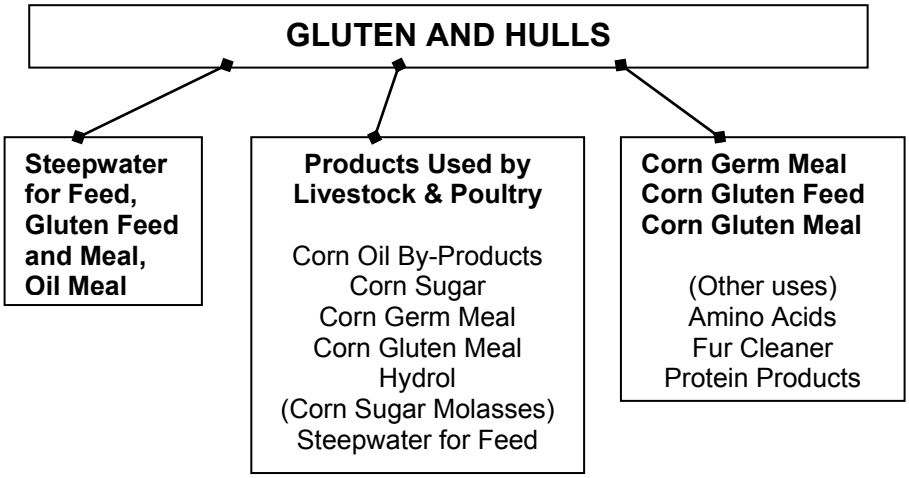
The softened corn kernel moves on to the degerminating mills and the resultant water-based mixture is called steepwater. Steepwater is highly nutritious and can be further processed for various uses. This additional processing consists of dismembering the weakened kernel and separating the bran. Then, the aqueous mixture of parts moves on to floatation tanks where a centrifugal hydrocyclone separates the heavier parts from the lighter germ.



The lighter germ is then crushed for its oil content. After the oil is removed, the remaining material is called, among other names, "corn oil cake," and is ground into meal.

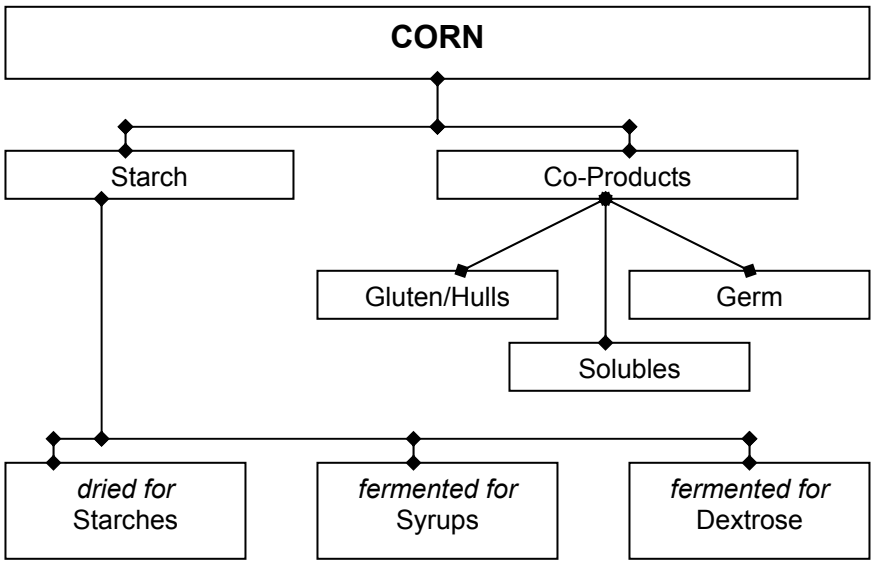
What remains after the germ is removed is first filtered and then returned to a high-speed centrifuge. In the centrifuge, gluten is separated from the mixture and removed. The gluten, as much as 70 percent protein, is mixed with the bran and/or the germ residue to become corn gluten meal or corn gluten feed.

Finally, with the gluten removed, the corn miller is left with the industrial heart of the corn kernel – the starch - or any feed grain that is refined through this process.



The Wonder of Starch

Starch is the feedstock that yields nearly all current industrial feed grains products. From starch comes the vast array of industrial products created over the years by public and private sector research chemists.



New Avenues of Research for Industrial Uses

The most promising areas of new research and opportunity for industrial uses lie in expanding the use of feed grains as a substitute for petroleum. There is no molecular hydrocarbon derived from petroleum that cannot be replicated from the starch feedstock.

The best hope for feed grains in quickly supplanting petroleum is plastics:

LDPE: Low density polyethylene
HDPE: High density polyethylene
PVC: Polyvinyl chloride
PP: Polypropylene
PS: Polystyrene

Biopolymers, such as polylactic acid (PLA), have had the most success competing in the LDPE market. Inroads into this market began with the development of a family of biodegradable polymers. Their acceptance has been spurred by growing environmental concerns, though the pace of that acceptance has been uneven and often difficult.

As environmental issues push biopolymers into commercial channels, continued research and development will help bring the cost of production down and broaden the demand beyond environmental niches.

Products made of biopolymers were already common in the field of medical applications without adding their unique environmental benefits. The niche established in the field of food and product packaging will grow as new eco-friendly legislation spurs compliance by manufacturers across many industries. These applications will be concentrated where recycling is either impossible or made impractical by the circumstances of a product's use.

ENCAPSULATION

New Product Examples

Encapsulating products in a biopolymer is a fast growing field of research and application. The process encloses a material - anything from vitamins to fertilizers to toxic poisons - in a feed grain polymer derived from starch that can be designed to remain intact, protecting the encapsulated material, in most environments, and only breaking down and releasing the material when it is demanded.

Encapsulation protects products from contact before use that might lead to deterioration and significant value loss. Biopolymers can also be constructed to allow controlled, gradual release of the encapsulated material, saving repeated applications, time and labor. And, in the case of toxic material, it protects those who must work with it from potential injury or death, thereby reducing liability and creating a safer workplace.

SOLVENTS

The most immediate example of a solvent derived from ethanol is windshield washer solvent. Typically, this product has been made from a methanol feedstock, itself derived from natural gas. Yet this product, which is found in many homes, is extremely toxic if swallowed.

Solvent produced from ethanol is as efficient, safe and price competitive when the social costs of the methanol product are

considered. Although traditional methanol-based washer solvent still holds the bulk of market share, these qualities should soon make the ethanol-based solvent the product of choice in the United States.

CALCIUM MAGNESIUM ACETATE

Road salt is needed to keep roads free of ice and snow build-up during the winter in many areas of the world, but the resulting corrosion is wreaking havoc with bridge and road infrastructure. Estimates of this damage in the United States run as high as $5 billion. Costs from the contamination of drinking water and roadside vegetation are not estimated but they are significant.

Calcium magnesium acetate, or CMA, can also be produced from either a natural gas or feed grains feedstock. CMA is just as effective in ridding roads of dangerous ice and snow. However, it is currently more expensive than road salt before factoring in the societal costs to infrastructure, water quality and environment. Its use is just beginning to catch on with U.S. municipalities faced with the burden of rebuilding their infrastructure.

ABSORBANTS

This is one area where commercial applications are many and already successful. Biopolymers derived from cornstarch were discovered to absorb as much as 1,000 times their own weight more than a decade ago. They quickly found use in disposable diapers, filters and absorbent pads for medical treatments.

Researchers have continued to find new uses for these biopolymers in the area of waste cleanup technology.

CHEMICALS

Considerable time and expense has been put toward deriving high-value industrial chemicals from a starch feedstock. Although the process is still not competitive with petroleum refining, there are firms in the United States making industrial chemicals such as propylene glycol, glycerin and ethylene glycol from starch refined from corn. These chemicals are in turn the feedstock for a whole range of everyday products such as cosmetics, synthetic fats, polyester resins, polymers and antifreeze.

The petroleum industry has been around for nearly a century and has been able to compete with its hundreds of billions of dollars worth of refining infrastructure. However, work on making the process cleaner and cheaper continues to narrow the gap between petroleum chemicals and the corn-based equivalent.

Licensing

How can importers tap into these potential markets at home? While most of the basic refining processes have been part of general industry practice for generations, there are now specific processes that are protected under domestic and international patents.

These include certain fermentation processes to produce ethanol and many of the chemical processes that create individual biopolymers that form the basis for these new products.

It is beyond the scope of this manual to list or describe all those processes that are protected by intellectual property laws in the United States or the international community. There are many resources provided by non-profit industry groups, U.S. government agencies and international organizations that can help importers both keep track of the exciting developments in the field of industrial uses for feed grains and lend direction on how to harness the power of feed grains.

RESOURCES

U.S. Grains Council
1400 K Street, NW
Suite 1200
Washington, DC 20005 U.S.A.
Phone: (202) 789-0789
Fax: (202) 898-0522
Email: grains@grains.org
Website: www.grains.org

The Council was founded in 1960 to develop and promote exports of U.S. feed grains and their co-products. It is one of the few organizations whose membership is truly representative of both producers and agribusiness interests. They have successfully coordinated and unified the efforts of both groups into a policy

promoting the global expansion for the utilization of feed grains and their co-products. This manual is part of that effort.

The Council can be called on by any importer or potential importer for assistance in either developing the technology to process feed grains for industrial uses or in providing information on those products themselves. The Council will direct inquiries to one of their many internal experts on trade and utilization or to one of the 100-plus firms and organizations comprising its membership. The Council also maintains offices in 10 different countries plus consultants in many more to help importers with their feed grains needs.

National Corn Growers Association
632 Cepi Drive
Chesterfield, MO 63005 U.S.A.
Phone: (636) 733-9004
Fax: (636) 733-9005
Email: tolman@ncga.com
Website: www.ncga.com

Founded in 1957, the National Corn Growers Association (NCGA) has nearly 29,000 corn producer members in 47 states. The Association's mission is to enhance corn profitability and utilization while improving the quality of life in a changing world. Among the Association's many programs to further this mission is a strong commitment to developing new markets for corn.

In this role, the NCGA has funded many innovative research projects probing the technological frontier for new industrial feed grains uses. They have, for instance, helped focus the search for new products on ethanol and biodegradable plastics. They continue supporting efforts to make these processes more efficient and competitive with petroleum feedstock and are promoting the development of starch-based substitutes for road salt and window washer fluid.

The Association has a unique network of relationships focusing on the development of new industrial uses, as well as a number of experienced professionals working on their market potential. These professionals can direct inquiries to researchers supported by or familiar with the Association efforts in this area. They can also help direct importers with specific inquiries to refiners or manufacturers in the United States who might hold patents that could be licensed for overseas use by an interested importer.

National Grain Sorghum Producers
4201 N. Interstate 27
Lubbock, TX 79403 U.S.A.
Phone: (806) 749-3478
Fax: (806) 749-9002
Email: tsnyder@sorghumgrowers.com
Website: www.sorghumgrowers.com

This Association represents sorghum grain producers across the United States. They promote alternative uses for sorghum, which include limited use as a feedstock for ethanol production. They do significant work on production efficiencies, including testing on feed efficiencies related to the presence or absence of tannin.

The Association is a resource for potential importers who wish to use grain sorghum as an industrial feedstock and for help in inquiries dealing with the production of ethanol from sorghum.

National Barley Growers Association
2601 Wheat Drive
Red Lake Falls, MN 56750 U.S.A.
Phone: (218) 253-4311
Fax: (218) 253-4320
Email: mzutz@gvtel.com

This Association represents barley grain producers across the United States. They promote alternative uses for barley and do significant work on production efficiencies.
The Association is a resource for potential importers who wish to use grain barley as an industrial feedstock.

Corn Refiners Association, Inc.
1701 Pennsylvania Avenue, NW
Suite 950
Washington, DC 20006 U.S.A.
Phone: (202) 331-1634
Fax: (202) 331-2054
Email: aerickson@corn.org
Website: www.corn.org

The Corn Refiners Association (CRA) represents the wet milling industry in the United States.

The CRA is unabashed in its support of innovative feed grains

utilization, particularly corn. It is the principal source of information on new products from wet milling feedstock and their current use by different industries.

Importers needing statistical information on the U.S. corn wet milling industry should think of the CRA as their first resource. The CRA can also help direct specific inquiries to their refiner members.

North American Millers Association
600 Maryland Avenue, SW
Suite 305 West
Washington, DC 20024 U.S.A.
Phone: (202) 484-2200
Fax: (202) 488-7416
Email: generalinfo@namamillers.org
Website: www.namamillers.org

This organization does for the dry corn milling industry what the CRA does for the wet milling industry.

New Uses Council
Business Office
295 Tanglewood Drive
East Greenwich, RI 02818 U.S.A.
Phone: (401) 885-8177
Fax: (401) 423-0862
Email: info@newuses.com

The New Uses Council was established in 1990 to promote alternative uses for U.S. agricultural products. Its mission is "to develop and promote the use of renewable agricultural and forestry resources in the production of new, nonfood industrial and consumer products." In pursuit of this mission, the New Uses Council has the active support of many diverse producer and industry groups who share the same charge for its specific sponsors: the promotion of new and innovative uses for the agricultural output of the United States.

The New Uses Council has, as its principal resource, the network of its many members. The firms and organizations that comprise the group cover a broad spectrum of industry and producer interests. Consequently, the Council offers a picture of this exciting field that is as complex as it is complete.

Importers can use the New Uses Council as a resource to complement the U.S. Grains Council and producer associations in gaining insight into the latest developments on industrial uses. The New Uses Council would also serve as a reference for identifying potential commercial sources for licenses on individual products and processes.

Renewable Fuels Association
1 Massachusetts Avenue, NW
Suite 820
Washington, DC 20001 U.S.A.
Phone: (202) 289-3835
Fax: (202) 289-7519
Email: info@ethanolrfa.org
Website: www.ethanolrfa.org

This Association was organized during the 1970s. Their mission is to promote the use of renewable fuels. In practice, this has meant a strong voice for ethanol.

U.S. GOVERNMENT

U. S. Department of Agriculture
1400 Independence Ave., SW
Washington, DC 20250 U.S.A.
Phone: (202) 720-3631
Website: www.usda.gov

Within this agency, the two main offices to contact for further information are the Office of New Uses and Energy and the Agriculture Research Service.

National Center of Agricultural Utilization Research, ARS
1815 North University Street
Peoria, IL 61604 U.S.A.
Phone: (309) 685-4011
Fax: (309) 681-6686

The Agricultural Research Service is responsible for spending much of the money the U.S. government puts toward agricultural research. A modest portion of this goes specifically toward new product research; a small share of that portion toward developing new industrial products.

The ARS operates numerous laboratories across the country. The Service is deeply involved in research on a broad spectrum of agricultural questions, including all those raised in the debate over new industrial uses for feed grains. For example, this is the government service responsible for most of the latest developments into starch research. They have made exciting strides in areas of biopolymers and encapsulation. The "super absorbents" that have had such commercial success are a product of these government laboratories.

They are an excellent source for new product avenues, quick and eager to share their ideas. Importers interested in exploring industrial feed grains use should include the ARS on their fact-finding tour.

Office of Technology Transfer
NIH
9000 Rockville Pike
Bethesda, MD 20892 U.S.A.
Phone: (301) 496-7057
Fax: (301) 402-0220
Email: nihott@od.nih.gov
Website: http://ott.od.nih.gov/

One method the U.S. government uses to share the fruits of its research labors is through the Office of Technology Transfer (OTT). Part of the National Patent Program, and a Division of the ARS of the U.S. Department of Agriculture, this office speeds products or processes developed by government scientists into commercial application.

A unique blend of taxpayer-funded support and entrepreneurial incentives, the program rewards individual scientists who work on government projects a share in any patents and licensing revenue that results from commercial application.

It was this office that licensed the super absorbent biopolymers that rank as one of the great successes of feed grains over the competitive petroleum feedstock. The U.S. government holds hundreds of other patents, many of them related to starch research from the National Center of Agricultural Utilization Research in Peoria, Ill.

These patents include new approaches to absorbents, many different encapsulation biopolymers, a variety of films (for example, shrink-wrap biodegradable mulch) and new processes to ferment ethanol from cornstarch.

The Federal Technology Act of 1986 empowered the government, in this case, ARS, to enter into contracts and agreements with both the ARS and individual scientists called Cooperative Research and Development Agreements, or CRADA's.

CRADA's give the cooperator who has entered into an agreement with ARS the right of first refusal to any commercial license opportunities that might arise from the agreed-to project. Under CRADA's, the cooperator may or may not provide funds depending upon the relevance of the proposal to the agency's mission. Information on CRADA's and how they function can be obtained through the OTT.

For help in identifying an opportunity to work with the ARS in CRADA's, inquiries should be directed to ARS Utilization in Peoria, Ill., or their Washington headquarters.

OTT also offers a number of services designed to showcase the government's inventory of agricultural patents. These include:

- TEKTRAN – an electronic system that gives the subscriber direct access to information on new research results and inventions that are available for commercial licensing.

- Agricultural Inventions Catalog – a comprehensive list of the patents held by government jointly with ARS research scientists. The catalog is updated periodically and can be obtained through the OTT.

In addition, detailed help in obtaining licenses for U.S. government-held patents is available through the OTT. They have published several how-to aids that walk the potential licensee through the steps needed to bring the product or process patented to the marketplace.

Alternative Agricultural Research and Commercialization Center
12th & C Streets, SW
Washington, DC 20250 U.S.A.
Phone: (202) 401-4860
Fax: (202) 401-6068

The Alternative Agricultural Research and Commercialization Center, or AARCC, was established by the U.S. Congress in the 1990 Farm Bill. The mission of AARCC is to provide an independent forum for government to aid promising commercial applications of agricultural research.

Under the AARCC charter, proposals are submitted for review and, if accepted, AARCC and the submitting cooperator share in the expense of the project. AARCC's share of the contribution is repaid when the project's commercial applications begin to produce revenue. The funds are then reinvested in another project, theoretically priming the research pump eternally.

The first time AARCC accepted applications for project funding, at least 150 projects totaling nearly $500 million were submitted. Some of the products AARCC is currently funding that involve feed grains include:

- a value-added composting system designed to relieve demand on large-scale landfill operations; the system is based on cornstarch-based polymers and animal materials which yield a product of high nutrient value;
- new pest control products based on cornstarch-encapsulated formulations;
- reopening a mothballed ethanol plant and upgrading the refining processes; sorghum would be the principle feedstock;
- developing an ethanol-based windshield wiper fluid; and

- developing a farmer-based group that aims to accelerate the commercialization of the processes that turn cornstarch into industrial chemicals.

AARCC officials will share information on the projects they are currently funding and direct inquiries on potential licensing opportunities to the respective cooperator involved.

Cooperative State Research, Education & Extension Service
Waterfront Center
800 9th Street, SW
Washington, DC 20004 U.S.A.
Phone: (202) 720-7441
Fax: (202) 401-1782
Website: www.reeusda.gov

The Cooperative State Research Service is another USDA agency charged with the broad task of furthering agricultural growth through the avenue of new industrial uses. The Service is an information network for the many state research activities that take place outside the federal government umbrella. They also serve to coordinate

activities between the different research arms and direct federal funds to promising programs carried on at state laboratories and facilities.

They are an excellent resource for the potential feed grains user, providing a unique overview of the many state-funded programs of research that do not come under federal oversight.

Department of Energy
Office of Alternative Energy
National Biofuels Program
1000 Independence Avenue, SW
Washington, DC 20585 U.S.A.
Phone: (202) 586-9118
Fax: (202) 586-4403

For importers specifically concerned with ethanol and using its energy to supplant unhealthy and environmentally unsound petroleum products, the Department of Energy's Office of Alternative Energy is the first place to turn for advice on government efforts in this important area.

Under an agreement between the departments of agriculture and energy, this office spearheads the joint efforts of these federal agencies to promote biofuel use and fund projects designed to make the refining process more efficient.

The Department of Energy is also responsible for monitoring the implementation of the Clean Air Act which promises to boost ethanol consumption in the United States by up to 33 percent by the turn of the century. The Department of Energy supervises research on ethanol-burning vehicles and the relative environmental benefits of ethanol and other alternative fuels.

Department of Defense
Pentagon
Washington, DC 20301 U.S.A.
Phone: (703) 692-7100

The Department of Defense has a group whose aim is to support domestic sources of energy. Though this is broad enough to cover many renewable energy schemes, the agency is particularly interested in biofuels to replace the imported petroleum products the military relies exclusively on today.

U.S. Patent and Trademark Office
General Information Services Division
Crystal Plaza 3, Room 2CO2
Washington, DC 20231 U.S.A.
Phone: (800) 786-9199
Fax: (703) 305-7786
Email: usptoinfo@uspto.gov
Website: www.uspto.gov

Patent Depository Library
Phone: (703) 308-3924

Both of these agencies can be used as resources to research the patent history of agriculture inventions in the United States. They can provide detailed descriptions of the products and processes protected by U.S. and international patent law and identify the patent holder if an importer is interested in licensing that technology.