Unit 9) Plant-based Renewable Resources

That was Then and This is Now…

Then

"E. T. and his father set the cook stove on the ground near the creek, but what could we burn for fuel? There was not a tree nor even a bush in sight to furnish us with fuel. But 'Grandpa' was elected to supply our needs, so taking a basket and pitchfork he started out and soon returned with a well-filled receptacle of what they called 'Chips.' Well, I thought I could do almost anything other people could do, so I put on my mittens and attempted to make a fire. Then I knew why grandfather needed a pitchfork – his fuel was too wet to burn. But I soon learned by experience how and what to gather to make a fire. 'Chips' were plentiful, as the plains had for years been an open range, first for buffalo and then for cattle in great herds which roamed at will over the prairies. The sod house and cow chips were two great factors in making possible the settlement of this country at so early a date." [1]

Emma Smith, 1879, South Sappa Creek

Now

"This morning I hopped in my car to go to work, but as I started the engine the little orange light flashed at me reminding me that I was almost out of fuel. I pulled into the convenience store. At the pump, I had a few choices, but one suits me the best – a fuel blend that includes 10 percent ethanol. The choice is easy for me because ethanol is a renewable resource – it is made from plants like corn and grain sorghum. Ethanol is also a good choice because it a good way to combat air pollution. This year, a record 13 billion gallons of renewable ethanol will be produced and it appears more will be produced every year. In today's world, where we ship oil from many foreign countries, ethanol makes it possible for us to be a little bit more energy independent."

Holly Martin, 2010, Ford, Kansas

All plants are renewable resources, or resources that can be replaced through natural processes. Kansas farmers provide renewable resources when they grow crops for industrial and consumer uses. These crops are used to make a wide range of products like biofuels, clothing, pharmaceutical products, adhesives, and even paper money. Plant-based materials are also biodegradable, making them environmentally friendly.

Growing Kansas Corn
Credit: Kansas Corn Growers Association

By 2030, a U.S. Congress advisory committee's goal would have biomass supplying 5 percent of the nation's power, 20 percent of the nation's transportation fuels, and 25 percent of the country's chemicals – an amount equivalent to 30 percent of current petroleum consumption by the United States. [2] In the past, crop production focused on providing food, feed, and fiber. Plant-based materials were viewed as alternative sources for other raw materials when

Disposable Diapers Made with Plant Starch
Credit: Keith Weller, USDA ARS

Soy-based Paint
Credit: United Soybean Board/Soybean Checkoff

Biomass – any organic (plant or animal) material, including agricultural crops and plant residues, wood and wood waste products, and animal wastes.

Renewable vs. Nonrenewable

Renewable resource – a resource that can be replaced or regenerated by natural ecological cycles; can be grown like plants or wood or derived from weather or nature like wind or solar energy.

Nonrenewable resource – a resource in limited supply that cannot be replaced through natural processes, at least not for many thousands of years, like a fossil fuel.

used in industrial processing. However, expanded uses of plant-based materials offer additional opportunities to meet the needs of a growing world population without relying as heavily on nonrenewable resources, such as fossil fuels.

Fiber

Plants that produce a natural plant fiber are considered fiber crops. Fiber crops that produce fiber as a result of a single growing season include cotton, flax, hemp, jute, and sisal. These fibers are used as raw materials in the textile and apparel industries, as well as for industrial applications.

Flax and Cotton
Credit: Stephen Ausmus, USDA ARS

Cotton

Today, cotton claims a 36 percent share of the textile fibers market and the world uses more cotton than any other fiber. [3] In fact, cotton is the leading value-added crop in the United States. According to the National Cotton Council of America, the main uses of the U.S. cotton crop are apparel (64 percent), home furnishings (28 percent), and industrial products (8 percent).

Cotton Fabrics
Credit: Scott Bauer, USDA ARS

Cotton Yarn
Credit: Scott Bauer, USDA ARS

Fiber

Fiber – long strands of molecules interwoven to form a linear, string-like structure; may be natural or manmade.

Natural fiber – fiber of plant or animal origin.

Fiber Crops

Fiber crop – plants that produce a natural plant fiber, like cotton, flax, hemp, jute, and sisal. Woody species, like trees, that produce wood pulp fibers are not considered fiber crops.

Linen – fabric made from the fibers produced by flax plants.

Cotton Facts

The world uses more cotton than any other fiber.

The main uses of the U.S. cotton crop are apparel (64 percent), home furnishings (28 percent), and industrial products (8 percent).

Nearly all Kansas cotton is used to produce denim, the thick cotton cloth used to make jeans.

Cotton fibers are divided into lint (long fibers) and linters (short fibers attached to the cottonseed).

One Bale of Cotton Can make:

215 jeans
249 bed sheets
409 men's sport shirts
690 bath towels
765 men's dress shirts
1,217 men's t-shirts
1,256 pillowcases
3,085 diapers
4,321 mid-calf socks
21,960 women's handkerchiefs
313,600 $100 bills

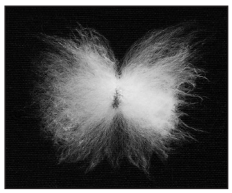
Credit: Scott Bauer, USDA ARS

Source: The National Cotton Council

The fruit of the cotton plant is the boll, a capsule with four to five sections. The cotton boll contains the seed, linters (fuzz attached to the seed), and lint (long fibers). The lint – fibers 1 inch to 1.75 inches long – accounts for about one-third of the harvested crop. The fibers are cleaned, straightened, and spun into yarn for weaving or knitting into fabrics. While cotton is the fiber of choice for apparel and many textile products used in the home, like bed sheets and towels, nearly all Kansas cotton is used to produce denim, the thick cotton cloth used to make jeans.

Cottonseed linters, the short fibers removed from the seed, are used in a wide variety of consumer and industrial products. Cotton linters are used in cotton swabs, cotton balls, and other medical items. Additional uses include carpet yarns, vehicle and furniture cushions, mattresses, and high-grade paper, including the paper used in printing money.

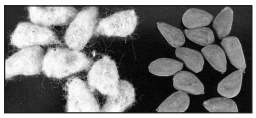
Cotton Boll
Credit: Peggy Greb, USDA ARS



Cotton Fibers
Credit: Stephen Ausmus, USDA ARS

Spooling Cotton Fibers
Credit: Scott Bauer, USDA ARS

Denim Jeans
Credit: Franklin County CD



Linters and Cottonseed
Credit: K-State Research and Extension

Cotton Lint vs. Linters

Lint – long fibers (1 to 1.75 inch long) that are cleaned, straightened, and spun into thread or yarn.

Linters – short fibers (fuzz) attached to the cottonseed; used in a wide variety of consumer and industrial products.

Fuel

In 2010, renewable energy accounted for more than 8 percent of the energy consumed in the United States, according to the U.S. Energy Information Administration. [4] Fuels produced from crops and agriculture-related products can supplement and eventually replace significant amounts of fuel produced from traditional energy sources, like petroleum and coal. Plant-based fuel sources are also friendly to the environment as the plants recycle carbon dioxide and release oxygen during the process of photosynthesis.

Fuel from Corn
Credit: ICM, Inc.

Kansas Corn Car
Credit: Kansas Corn Growers Association

Plant-based liquid transportation fuels such as ethanol and soy biodiesel are considered biofuels. However, biofuel production is not limited to plant-based materials.

Biofuels Pump
Credit: Charles Bensinger, NREL

Bioenergy Words

Biodiesel – a biofuel used in diesel engines that is produced from vegetable oils or fats; may be used as a replacement for diesel fuel or blended with diesel fuel, a petroleum-based fuel.

Bioenergy – renewable energy made from any material directly or indirectly produced by photosynthesis.

Biofuels – liquid transportation fuels that are directly or indirectly plant-based, including, in the case of biodiesel, animal fats.

Plant-based Petroleum

The hydrocarbons in petroleum developed from the energy once captured by plants trapped in fossil layers millions of years ago.

East Kansas Agri-Energy Ethanol Plant, Garnett
Credit: Kansas Corn Growers Association

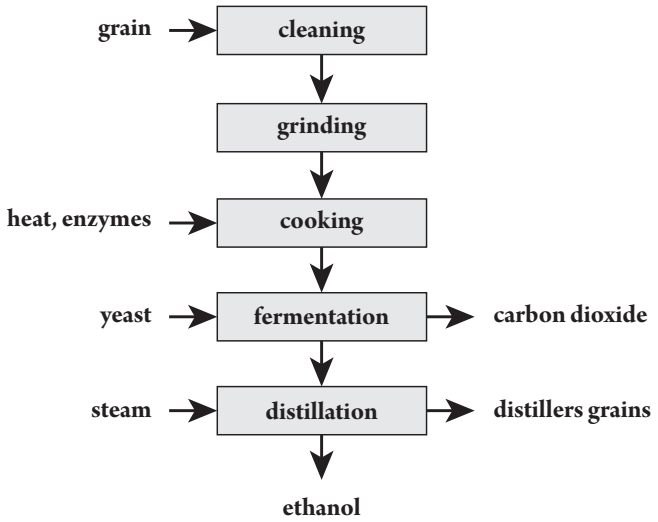
Ethanol

NASCAR Uses Ethanol
Credit: Kansas Corn Growers Association

Ethanol (ethyl alcohol) is produced primarily from carbohydrates (starches, sugars, or cellulose). Grains high in starches, like corn and grain sorghum, are interchangeable in the ethanol making process. Most of the new ethanol production facilities use a "dry milling" process to produce ethanol. The grain is milled into flour before beginning a fermentation process. During the fermentation process, only the starch component of the grain is converted into alcohol. The dry milling process produces three products: alcohol (ethanol), distillers grains, and carbon dioxide. Distillers grains are fed to livestock and the carbon dioxide is used in food processing and bottling as well as the petroleum industry.

Ethanol produced from plant materials (cellulosic biomass) is chemically identical to that produced from grains. However, the carbohydrates found in plant materials (cellulose) are more complex

Grain to Ethanol
(dry mill process)



Source: KFAC

Milling

Find detailed information on flour milling in Unit 6, Machines and Technology.

Receiving Grain by Railcar
Credit: Gerry Harrow, NREL

Fermentation Tanks
Credit: Gerry Harrow, NREL

Distillation Columns
Credit: Gerry Harrow, NREL

Ethanol Storage Tanks
Credit: Gerry Harrow, NREL

Distillers Grains
Credit: Steven Vaughn, USDA ARS

Cellulosic biomass – crops grown specifically for fuel production as well as plant waste products , like wheat straw or sawdust.

than those found in grains (starch), requiring different processes to break the carbohydrates down into simple sugars that can be fermented into ethanol. Cellulosic biomass includes crops grown specifically for fuel production as well as plant wastes, such as wheat straw, sawdust, or paper pulp. Research continues to determine the potential of additional crops, like switchgrass or Jerusalem artichoke, to economically and efficiently produce ethanol.

Transporting Distillers Grains
Credit: Gerry Harrow, NREL

Before it is sold to consumers, ethanol is blended with gasoline. In the United States, a blend of 15 percent ethanol and 85 percent gasoline has been approved for use in model year 2001 and newer cars, light-duty vehicles, and medium passenger vehicles (SUVs). Flexible fuel vehicles are designed to run on any blend up to 15 percent gasoline and 85 percent ethanol. In 2010, ethanol replaced the gasoline refined from 445 million barrels of imported oil, the equivalent of more than the total crude oil that the United State imported from Saudi Arabia that same year. [8]

Corn Plant
Credit: Kansas Corn Growers Association

Corn Stover
Credit: Patrick Corkery, NREL

Switchgrass
Credit: Brett Hampton, USDA ARS

Ethanol Facts

According to the U.S. Department of Energy, each gallon of ethanol delivers one-third or more of the energy used to produce it. [5]

The production of ethanol in the United States has increased 800 percent in the last decade. [6]

In 2010, ethanol production in the United States replaced the gasoline refined from more than 445 million barrels of imported oil. [7]

Biodiesel

Biodiesel is a biofuel produced from fat or oil. It is the fastest growing alternative fuel in America, according to the U.S. Energy Information Center. Although it can be blended with petroleum diesel at any level, biodiesel itself does not contain any petroleum. Biodiesel can be made from vegetable oils, animal fats, or recycled cooking oil.

To produce biodiesel, oilseeds are first processed into vegetable oil. Then, through a chemical process called "transesterification," the vegetable oil is separated into two products – methyl esters (biodiesel) and glycerin. The glycerin is used in soap, lotion, and other consumer products.

Soybean oil is a common source for the oil processed into biodiesel. One bushel of soybeans (60 pounds) yields 1.5 gallons of biodiesel, according to the American Soybean Association. Since biodiesel production uses only the oil portion of the soybean, soybean meal – the protein portion of the seed – is still available for food and livestock feed uses.

Biodiesel Pickup
Credit: Minnesota Soybean

Biodiesel Bus
Credit: Patrick Corkery, NREL

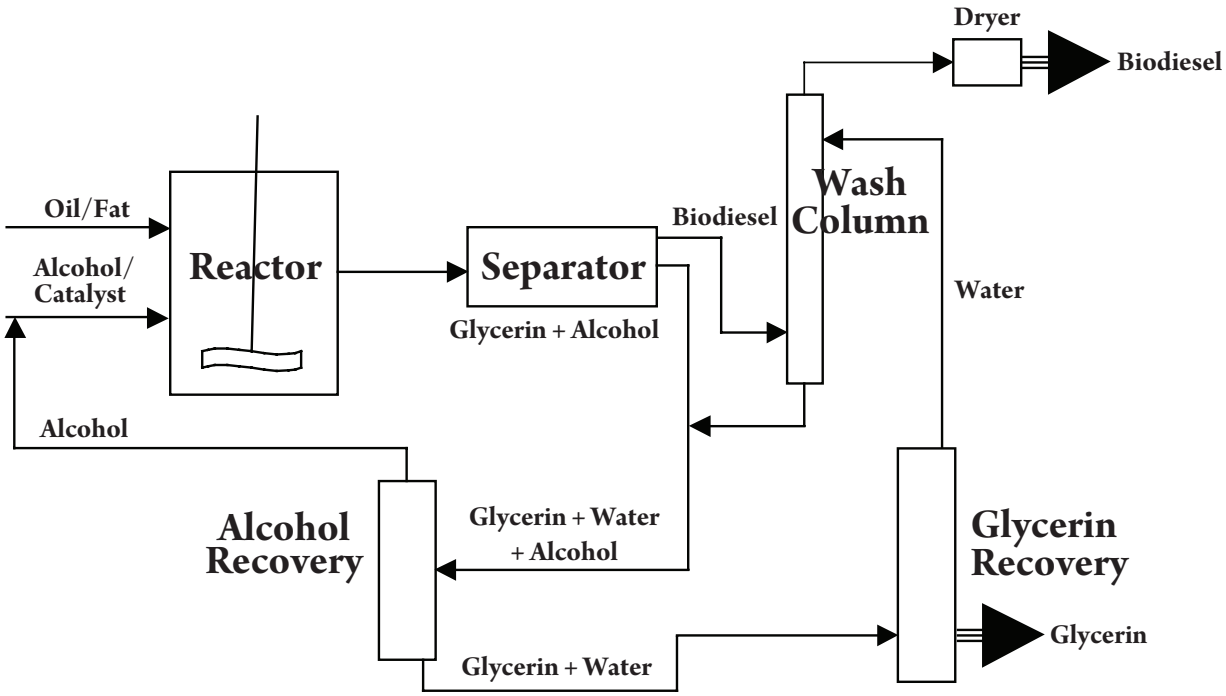
Biodiesel Fuel Tank
Credit: Minnesota Soybean

Chicken Eating Soybean Meal
Credit: United Soybean Board/Soybean Checkoff

Processing Oilseeds

Find detailed information on processing oilseeds into vegetable oil in Unit 6, Machines and Technology.

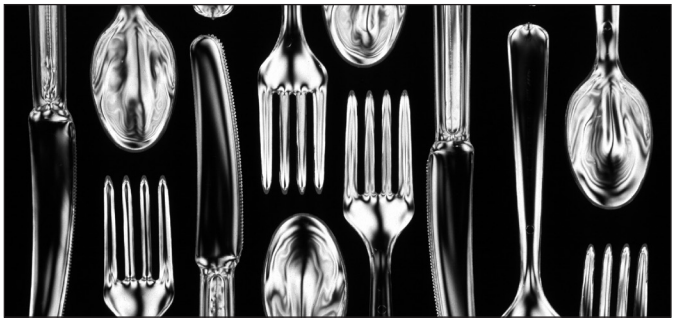
Converting Vegetable Oil to Biodiesel



Source: Oklahoma Cooperative Extension Service, Oklahoma State University

Other Products from Kansas Plants

At the present time, plant-based materials only account for a small percentage of the world's manufacturing inputs. Industrial uses of plants include chemical and biological processes that utilize whole plants, as well as the portions of the plant not used for food or feed production. Many products currently on the market utilize Kansas crops to supplement or replace nonrenewable resources like petroleum.



Biodegradable Silverware
Credit: Scott Bauer, USDA ARS

Look for the Logo!

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Soy Ink
Credit: United Soybean Board/ Soybean Checkoff

Soy Ink (left) vs. Petroleum-based Ink Formula
Credit: Keith Weller, USDA ARS

Naturally occurring chemicals extracted from plants are the major sources for some chemicals, including sorbitol, cellulose, citric acid, natural rubber, many amino acids, and proteins. While those chemicals are used in their original molecular state, other plant components are broken down to provide products from specific molecules. For example, the refining process for ethanol involves fermenting the starch from a corn kernel, which results in alcohol that can be separated from carbon dioxide and other coproducts. The alcohol is used for ethanol while the carbon dioxide is sold for other uses, like adding carbonation to beverages.

Extracts and essential oils are used in food and consumer products to create flavors and aromas or add coloring.

Extracting Flavonoids from Raspberries, Blueberries, and Strawberries
Credit: Keith Weller, USDA ARS

Flavonoids

Flavonoids are compounds naturally produced by plants and categorized according to chemical structure.

More than 4,000 flavonoids have been identified and are being examined for potential health benefits for people and animals.

Depending on the plant, the seeds, bark, leaves, roots, or fruit may be the resource processed. Specific components may be physically isolated for uses based on their properties or produced by enzymatic transformation or fermentation.

Oilseeds

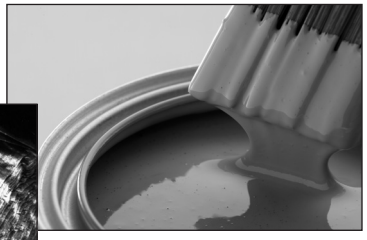
Oilseeds are plants that produce seeds rich in oil. The oil is primarily extracted from the seeds, rather than other plant parts. Oilseeds include soybeans, sunflowers, canola, peanuts, cotton, and flax. In some crops, like corn, cotton, and flax, the oil produced by the seeds may be a coproduct of processing the seeds for other uses. Seed oils often contain high amounts of fatty acids with individual characteristics, such as those associated with specific aromas. The molecular structure of these fatty acids makes them useful in various formulations for many industrial and consumer products.

Soybeans
Credit: Warren Gretz, NREL

Sunflowers
Credit: National Sunflower Association

At the present time, soybeans account for 90 percent of the oilseeds produced in the United States. Nearly all the soybeans produced in the United States are "crushed," which is the process of separating and extracting the oil. Between 18 to 19 percent of the weight of the whole soybean is oil. Industrial applications for soy oil consume 13 percent of the soy oil produced in the United States. [9] Soy oil is used in plastics, printing inks, lubricants, solvents, crayons, textiles, and biodiesel.

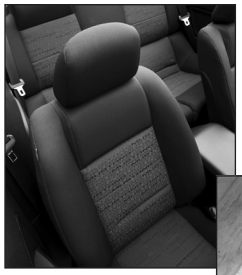
Crayons
Credit: Minnesota Soybean



Soy-based Paint
Credit: United Soybean Board/ Soybean Checkoff

Carpet Backing
Credit: United Soybean Board/ Soybean Checkoff

Foam Insulation
Credit: United Soybean Board/ Soybean Checkoff



Foam Car Seats
Credit: United Soybean Board/Soybean Checkoff

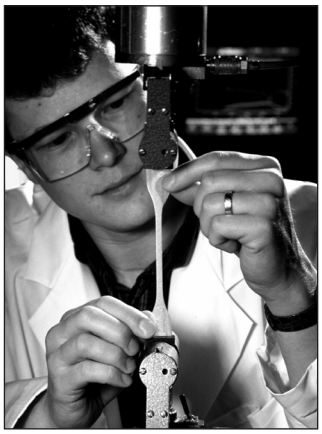
Adhesive for Plywood
Credit: Keith Weller, USDA ARS

Grains

Grains are crops that produce a small, hard seed. Cereal grains, such as wheat, corn, grain sorghum, and rice, produce seeds that are used as food for people or as feed for livestock. Nonfood uses of grains make up a small, but increasing, percentage of grain usage. Industrial processing typically starts by milling the grain, following steps similar to those used to produce flour. The key step in making grains into industrial and consumer products is the conversion of carbohydrates to usable chemicals or fibers. Biological catalysts, such as enzymes or microorganisms, are commonly used to stimulate or accelerate these chemical reactions. For example, high fructose corn syrup originates as a starch in the corn kernel, which is broken down to glucose. During the refining process, enzymes convert the glucose into fructose. The final product is a blend of fructose and other sugars, primarily glucose. Scientists are developing new ways to convert carbohydrates into usable chemicals through the use of inorganic (non-living) catalysts.

Corn Kernels
Credit: Warren Gretz, NREL

Cornstarch Products
Credit: Scott Bauer, USDA ARS



Testing Strength of Starch-based Plastics
Credit: Keith Weller, USDA ARS

The largest industrial use of grain in the United States is the production of ethanol. After feed uses, ethanol is the second largest use of corn in the United States, using 4.65 billion bushels of corn in 2010. In 2010, the amount of livestock feed generated by the ethanol industry nearly matched the total amount of grain fed to cattle in the nation's feedlots. [10] In addition to ethanol, nearly 4,000 other consumer products from toothpaste to windshield washer fluid use corn or corn components. Products made from cornstarch are used in pharmaceutical and pet products, corn-based plastics and textiles, and food packaging materials.

Biodegradable Cornstarch-based Products
Credit: Scott Bauer, USDA ARS

The Facts: Fuel vs. Food

About 1 percent of the corn produced in the United States is sweet corn.

Less than 10 percent of the U.S. field corn crop is used for direct human consumption in corn-based foods like corn flakes, cornmeal, and cornstarch.

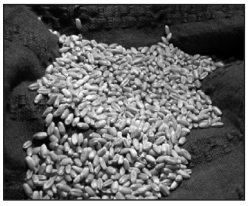
In general, retail food prices tend to rise by a fraction of any change in farm prices – less than 10 percent in the case of corn-based foods.

Using $2.28 (the 20-year average) as the farm price for a bushel of corn, the approximate value of corn in a box of corn flakes is 3.3 cents and the value of the high fructose corn syrup in a 2-liter bottle of soda is 3.8 cents. [11]

Ethanol also represents a growing market for grain sorghum. According to the United Sorghum Checkoff Program, 30 to 35 percent of the grain sorghum produced by U.S. farmers is used to produce grain-based ethanol. [12] Grain sorghum and corn are interchangeable in the ethanol-making process. Historically, in Kansas, more grain sorghum than corn was used in ethanol plants.

Grain Sorghum
Credit: Kansas Grain Sorghum Producers Association

Wheat can also be used to produce ethanol but food products represent the largest use of wheat in the United States and around the world. Even so, nonfood and industrial applications represent a growing market for U.S. wheat producers. The unique elastic qualities of wheat gluten, which make wheat ideal for making breads or other food products, make wheat useful in the production of adhesives, biodegradable packaging materials, and construction materials. Wheat gluten is also used by the pharmaceutical industry to manufacture pill capsules and by the papermaking industry in paper coatings. In addition to wheat gluten, wheat starch is used in cosmetic products and adhesives, like those found on postage stamps.



Wheat Kernels
Credit: Mary Anne Stoskopf

Biodegradable Containers
Credit: Peggy Greb, USDA ARS

Wheat Products
Credit: Bill Spiegel, Kansas Wheat

Wild Phlox
Credit: Kirsten Bosnak, Kansas Biological Survey

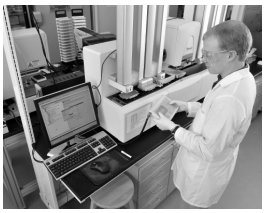
Native Plants

In the future, Kansas farmers may add native plants to the mix of crops grown in Kansas for industrial and consumer uses. Native prairie plants hold great promise for the development of products that could benefit human health. The Native Medicinal Plant Research Program at the University of Kansas is targeting plants that have been used by American Indians for medicinal purposes, focusing on plants from the Great Plains region. The program is a collaborative project of the University of Kansas' Department of Medicinal Chemistry and the Kansas Biological Survey.

Plants are identified and collected, usually from public lands. Once the plant material has dried, it is ground in a laboratory mill until it is about the consistency of oregano spice found on the grocery store shelf. From there, the plant material is tested for its chemical makeup and screened for biological properties.

Drying Plant Materials
Credit: Quinn Long, Kansas Biological Survey

In order to grow and reproduce, plants produce large quantities of specific chemical compounds. In addition, plants make other chemicals in much smaller quantities, particularly when stressed. Those secondary compounds may help the plant fight off disease or predator insects, survive in a drought, or reproduce under less than ideal situations. Once thought to have little or no value, scientists have discovered that these secondary compounds have great potential for food, cosmetic, veterinary, health,



High-throughput Screening Laboratory
Credit: KU University Relations

Prescription Medicines

Secondary compounds from plants or synthetic compounds modeled on plant molecules are the source of 25 percent of the prescription medicines dispensed in the United States today.

Source: Kansas Native Medicinal Plant Research Program

and pharmaceutical products. In fact, secondary compounds from plants or synthetic compounds modeled on plant molecules are the source of 25 percent of the prescription medicines dispensed in the United States today, according to Barbara Timmerman, chair of medicinal chemistry at the University of Kansas. [13]

The Native Medicinal Plant Research Program began collecting plant specimens for testing in 2010. In addition to testing the plant materials, the program maintains the Native Medicinal Plant Research Garden north of Lawrence and is building a Prairie Ethnobotany Database, which has identified American Indian uses of more than 900 unique plant species. Although the program is relatively new, early research results are promising, showcasing opportunities to develop new products from native Kansas plants.

Collecting Licorice Root
Credit: Kansas Biological Survey

Forestry Products

More than 5,000 products come from trees. In addition to paper, lumber, and other wood products, tree extracts and tree fibers are used in many products, ranging from toothpaste and deodorant to carpets and fabrics like silk and rayon. Advanced technologies have developed products so that almost 100 percent of a tree can be used when it is harvested. Even the hull (shell) of the black walnut is used – for polishing, to clean jet engines, as filler in dynamite, as a filtration medium, and as an ingredient in cosmetic and dental products. Charcoal is also a forestry product. At one time, there was a large charcoal plant in southeastern Kansas that produced briquettes for outdoor cooking from coproducts from sawmills.

Tree Nursery
Credit: Peggy Greb, USDA ARS

Growing Trees
Credit: Lynn Betts, USDA NRCS

Measuring Tree Circumference
Credit: Stephen Ausmus, USDA ARS

Harvested Logs
Credit: Lynn Betts, USDA NRCS

Sawmill
Credit: Kansas Forest Service

Lumber
Credit: Lynn Betts, USDA NRCS

Wood Products
Credit: Keith Weller, USDA ARS

One of the more recent developments in Kansas is the use of wood waste (sawdust or ground wood) as fuel. According to the Kansas Department of Health and Environment, several facilities in Kansas are using wood wastes to supply their energy needs. For example, wood waste from Custom Wood Products in St. Marys is being used to dry alfalfa before it is made into pellets at the alfalfa mills of Bert and Wetta Sales, Inc. near Abilene. [14] The Kansas Department of Health and Environment also reports that at least one sawmill in southeast Kansas is exploring the possibility of using anaerobic digestion to process sawdust, using the resulting biogas to generate electricity.

Oils from Wood
Credit: Warren Gretz, NREL

The Carbohydrate Economy

The term "carbohydrate economy" describes opportunities to expand the use of plant-based materials. In the future, biorefineries and new processing systems based on using plant materials in specific ways for specific uses will be more common, rather than plant materials just serving as alternative sources for existing processes. Bioprocessing will improve the utilization of coproducts from the waste streams of processing systems with the use of microbes and enzymes.

Biotechnology is important to increasing crop yields and protecting plant production. Advances in biotechnology allow scientists to modify plant components to align crops with the needs of processing systems like raising or lowering oil, starch, or protein content. Crop producers will continue to choose which crops to produce and select specific varieties based on intended

Sunflower Growers
Credit: National Sunflower Association

Starch-based Biodegradable Resins and Silverware
Credit: Robert Barclay, USDA ARS

Bioprocessing Words

Bioprocessing – manufacturing products using microorganisms, cells in culture, or enzymes. Cheese, yeast breads, and fermented beverages are examples of products that have been produced for thousands of years through bioprocessing.

Biorefinery – an industrial facility that converts biomass (as opposed to fossil fuels like petroleum, coal, or natural gas) into one or more fuel, energy, or chemical products.

Biotechnology – technologies based on biological processes, using living cells and materials produced by cells to make new products (pharmaceutical, diagnostic, agricultural, environmental, etc.) or altering genetic information in animals and plants.

Plant DNA in a Tube

Wheat Growers Holding Plant DNA

Credit: National Association of Wheat Growers

end uses. Expanded choices might be between food or feed uses, feed uses or feedstocks (raw materials for industrial uses), oil or starch production, fiber or sugar production, or pharmaceutical or polymer uses. To address environmental concerns, crop producers might even grow plants based on their ability to store carbon in their roots, bark, or other plant parts.

Petroleum-based plastics increased 400 percent between 1970 and 1990, gradually replacing glass, metal, and paper products. [15] While that type of rapid growth is not expected in nonfood uses of plant-based materials, opportunities for additional uses of these renewable resources continue to grow.

Packing Peanuts

Credit: Keith Weller, USDA ARS

Endnotes

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Teacher's Resources

The Kansas Foundation for Agriculture in the Classroom (KFAC) offers lesson plans and other educational resources on the KFAC website: **www.ksagclassroom.org**.

Notes: