View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by University of Tennessee, Knoxville: Trace

University of Tennessee, Knoxville
Trace: Tennessee Research and Creative Exchange

Biofuels

UT Extension Publications

5-2008

# SP700-B-Ethanol: A Primer

The University of Tennessee Agricultural Extension Service

Follow this and additional works at: http://trace.tennessee.edu/utk_agexbiof

Recommended Citation
"SP700-B-Ethanol: A Primer," The University of Tennessee Agricultural Extension Service, R12-4110-070-020-08 SP700A-5M-5/08 08-0230, http://trace.tennessee.edu/utk_agexbiof/4

The publications in this collection represent the historical publishing record of the UT Agricultural Experiment Station and do not necessarily reflect current scientific knowledge or recommendations. Current information about UT Ag Research can be found at the UT Ag Research website.
This Bulletin is brought to you for free and open access by the UT Extension Publications at Trace: Tennessee Research and Creative Exchange. It has been accepted for inclusion in Biofuels by an authorized administrator of Trace: Tennessee Research and Creative Exchange. For more information, please contact trace@utk.edu.

UT Biofuels Initiative

# Ethanol: A Primer

*Samuel Jackson, Research Associate*
*Office of Bioenergy Programs*

## Introduction

Ethanol has become a major player in alternative fuels over the last few years. Our nation uses approximately 384 million gallons of gasoline each day. That amounts to more than 140 billion gallons each year. The United States imports approximately 60 percent of the oil it uses. A significant portion of that oil is imported from countries that are not stable and are in volatile parts of the world. Many citizens feel that from a national security standpoint, it is in the nation's best interests to reduce our reliance on foreign sources of energy, such as oil, and move to renewable, domestically produced fuels.

Ethanol is one of these renewable fuels that can be produced within our nation's borders. The feedstocks, conversion and distribution all take place within the country. With recent federal legislation, national goals are to replace 30 percent of our petroleum consumption with biofuels, such as ethanol. Tennessee currently has, installed or under development, about 480 million gallons per year of ethanol production capacity. It is projected that between corn-based ethanol and cellulosic ethanol, Tennessee has the potential to produce at least 1 billion gallons of ethanol each year, replacing 30 percent of its gasoline consumption.

Ethanol is an ethyl alcohol that can be used as a liquid fuel. It is made up of oxygen, hydrogen and carbon ($CH_3CH_2OH$ ). Ethanol is made by fermenting sugars or converted starch into alcohol. The chemical makeup of ethanol is the same, whether it is made from grains or plant materials. It is primarily produced from corn grain, but can also be made from the sugar in cellulosic biomass. Cellulosic biomass is simply plant material from which sugar is extracted. Ethanol can be burned, much like gasoline, to produce energy that powers vehicles and machinery.

Switchgrass is one of the materials that can be used to produce ethanol from cellulose. *Credit: Marie Walsh, University of Tennessee*

## Producing Ethanol from Grain

Traditionally, alcohols, including ethanol, have been produced from corn and other grains. Corn is the primary choice, because a kernel of corn is approximately two-thirds starch, the component that ethanol manufacturers depend upon. In early 2008, production levels of corn ethanol reached 8.1 billion gallons per year at 143 plants in the United States. The type of corn used for ethanol production is called field corn and is not the "sweet" corn used for human consumption.

A general expectation of corn ethanol is that one bushel of corn produces 2.8 gallons of fuel. Two primary methods are used to produce ethanol from corn: wet milling and dry milling. The wet milling process begins when the grain is soaked in a dilute water and acid mixture for one to two days. The soaking begins to break the corn down into the more simple compounds and chemicals of which it is made. The resulting mixture, or slurry, is then passed through a variety of separation procedures to separate out four main parts: corn oil, gluten, fiber and starch. The corn oil, gluten and fiber are often dried and sold as animal feeds. This product is very high in protein content and is in demand by animal producers.

The starch is put into a fermentation process, a step that can take up to 50 hours. Yeast is added to the starchy "mash" – as it was called in the moonshine days – and the mixture is stirred. The yeast metabolizes the starch, in the absence of oxygen, and produces ethanol and carbon dioxide in the process. The resulting liquid is called "beer," and it is transferred to distillation columns where the ethanol is separated from the residual mash. The ethanol is then processed to remove any residual water, and once that is complete, the result is pure ethanol.

In the dry milling process, the corn grain is ground into flour called "meal." The component parts of the grain are not separated out here, as in the wet milling method. The meal is mixed with water and forms the mash. Enzymes, proteins that accelerate chemical reactions, are added to the mixture and convert the starch to dextrose, a simple sugar. The mash is then heated to a high temperature to kill any bacteria prior to fermentation. After heating, the mash is fermented in a similar method to wet milling. In dry milling, the mash left after fermentation is dried and sold as dried distillers grains with solubles (DDGS) as an animal feed. The carbon dioxide from the process can be captured and often used for other purposes, such as carbonating soft drinks.

## Producing Ethanol from Cellulosic Materials

Another source of sugars to manufacture ethanol comes from cellulose, which is found in the walls of plant cells and is one of the most common organic compounds on earth. By using cellulose to create ethanol, a wide variety of new sources of sugar are available for ethanol production, and producers do not have to rely on a specific grain commodity. Materials commonly used for cellulosic ethanol include corn stalks, wood residues and chips, wheat straw, fast-growing trees, native grasses and sugarcane.

Cellulosic ethanol technologies, however, are not as well developed as the grain technologies. The primary difference between the two is that it is difficult to access and free the cellulose in plant cells. Another challenge lies in converting cellulose to simple sugars for fermenting. Two different processes, biochemical conversion and thermochemical conversion, can be used to access cellulose and convert it into simple sugars. Once these processes are complete, the fermentation process is identical to ethanol made from grain.

In the thermochemical process, cellulosic biomass is gasified. Gasification is where the biomass is quickly superheated in a low-oxygen environment. This produces a gas called "syngas" and a residue called "char." Syngas is primarily made up of hydrogen and carbon monoxide. The syngas is then passed through a specially designed reactor, where catalysts turn the gas into ethanol. The char can be used as fertilizer or in other products.

In the biochemical process, living organisms, enzymes, are used to convert cellulosic biomass to ethanol. The biomass is brought into the conversion facility and typically ground or chopped into small pieces. It is then subjected to a high-pressure steam treatment, which starts breaking down the plant cell walls and begins the release of cellulose for ethanol conversion. A dilute acid solution can also be used as a pretreatment.

Next, the biomass goes through a process called enzymatic hydrolysis. This process uses plant enzymes to initiate specific chemical reactions. The pretreatment process allows enzymes to gain access to the cellulose in the plant cells. The reactions caused by the enzymes break the cellulose molecules down to simple sugars. Once this process is complete, the sugars are separated and fermented into ethanol.

Regardless of how the ethanol is produced, a key step at the end of the process is to blend the pure ethanol with about 5 percent denaturant, most often regular gasoline. This blending makes the ethanol undrinkable and not subject to the alcohol tax placed on alcoholic beverages.

## Common Concerns about Ethanol Production

Oftentimes, biofuels are evaluated for how much energy it takes to produce the fuel versus the amount of energy provided by the fuel. This is called the fossil energy ratio. For corn ethanol, the fossil energy ratio is 1.8. For cellulosic ethanol, the ratio is at least 5 and, in some studies, as high as 10. In other words, for every unit of fossil energy it takes to make ethanol, at least 1.8 units of equivalent energy is produced. We get more energy out of ethanol than it takes to produce it. Gasoline has a fossil energy ratio of 0.8, meaning it takes more energy to produce than is provided by the end fuel.

Another common concern related to ethanol production is odor produced in the manufacturing process. The primary source of odor in a corn ethanol plant is the dried distiller's grains with solubles (DDGS). Prior to being sold as animal feed, DDGS are dried. This process produces aldehydes, ketones and lactic acid, all of which combine to produce a foul odor. New technologies allow producers to minimize the impacts of these odors by using scrubbing technologies to neutralize the smell. Cellulosic ethanol facilities do not have this odor problem as they have no DDGS. Another source of odor is from the fermentation procedure, and the exhaust it produces. Both corn and cellulosic ethanol plants must contend with this issue. Scrubber technology is used here as well. The exhaust is passed through the scrubbers, where organic materials responsible for the odor are removed prior to release from the plant.

Water usage in producing ethanol is also an issue. Producing ethanol is a water-intensive process. Making one gallon of gasoline from petroleum takes about 1.5 gallons of water. Ethanol from corn takes about 4 gallons of water for every gallon produced. Current cellulosic ethanol production technology requires 5-9 gallons of water per gallon of ethanol made. However, demand for fresh water can be significantly reduced by recycling it through wastewater treatment prior to reuse in the production process.

Producing ethanol from corn may also have an impact on food and feed prices and availability. As the ethanol industry has developed, more corn has been diverted from traditional markets to ethanol production. More recently, corn commodity prices have sky rocketed to more than $5 per bushel. Many relate this increase in corn prices to ethanol demand. While this demand may have some impact on corn prices and availability, it is important to look at the bigger picture to assess the situation. As petroleum prices increase, so do costs of things depending upon petroleum. Fertilizer, herbicides and pesticides that crop producers depend upon are derived in some way from petroleum. Input costs have gone up dramatically since 2007, with some herbicide and pesticide costs doubling. Fuel costs for planting, harvesting and transporting corn have also increased. Concern has also been raised about the amount of corn exported from the US to other countries. Many nations depend upon our corn for their food supplies. In reality, though, US corn exports have increased, up 6 percent between 2006 and 2007, to their highest levels since 1990.

All of these factors, including demand, have affected corn prices. Higher corn prices may impact food markets, as it will cost more to feed animals and more to buy products derived from field corn. There is a limit to the amount of ethanol that can be produced from corn without significantly impacting food and related markets. This is one reason why cellulosic ethanol, produced from crops with less effect on food commodities, is continuing to be developed.

## Using Ethanol

Ethanol is primarily used as a motor vehicle fuel. Though producing ethanol is similar in cost to producing gasoline, it is less expensive per gallon than gasoline when purchasing E-85 at the pump. The reason is that the federal government currently subsidizes the production of ethanol at 51 cents per gallon, primarily to promote the development of the ethanol industry and to reduce the nation's reliance on foreign oil. New legislation has been proposed to create a different, higher subsidy for cellulosic ethanol.

Ethanol is sold as a blend, meaning what you purchase at the pump is

E-85 dispensers are clearly labeled. You can see the yellow gas cap indicating a flex fuel vehicle in the background. *Credit: Sam Jackson, University of Tennessee*

some ratio of ethanol and gasoline. In most cases, ethanol is sold as E-10 (90 percent gasoline and 10 percent ethanol) or E-85 (85 percent ethanol and 15 percent gasoline). In the US, no road vehicles can use 100 percent ethanol due to the design of current engines. All current vehicle engines are designed to accommodate blends of up to 10 percent ethanol or E-10 in their fuel with no problems. Ethanol is relatively caustic to standard rubber seals, gaskets and hoses in the engine. Although recent studies suggest blends up to 20 percent or E-20 may be suitable for use in standard vehicles, blends greater than 10 percent are not approved by either vehicle manufacturers nor the US EPA, due to possible long-term effects on fuel system components as well as unanswered emission questions.

Automakers now produce vehicles that are called "flex fuel" vehicles. These vehicles have seals, gaskets and hoses that are lined with Teflon™ to prevent deterioration when using high concentrations of ethanol. Traditional vehicles do not have this Teflon™ lining. Other common features that are unique to flex-fuel vehicles are a stainless steel fuel tank and a sensor to measure the ethanol/gasoline ratio to adjust engine performance. If you have or purchase one of these vehicles, you can use a fuel mixture of up to 85 percent ethanol (E-85). If you think you may have a flex-fuel vehicle, check for a sticker or other marking inside your car's fuel filler door and review your vehicle's owner's manual to be certain before filling your tank. There are about 6 million flex fuel vehicles on the road in the US. Only vehicles specifically designed to use higher concentrations of ethanol should use E-85. Using an ethanol concentration of higher than 10 percent in non-flex fuel vehicles may void the manufacturer's warranty and cause long-term problems, such as failing fuel pumps and failure of hoses and gaskets. Check with your manufacturer for details. It is possible to convert a vehicle to meet flex-fuel standards, though it may be cost-prohibitive.


Flex Fuel vehicles are typically labeled with this emblem. It can be found on tailgates or trunks of newer flex fuel vehicles. *Credit: Sam Jackson, University of Tennessee*

A common concern when using ethanol is that vehicles using E-85 get less fuel economy (miles per gallon) than when using regular gasoline. A gallon of ethanol has about two-thirds the energy content of that of a gallon of gasoline. To travel the same distance provided by a gallon of gasoline, it would take 1.03 gallons of E10 and 1.33 gallons of E85. In today's engines, automobiles using E85 typically see a mileage decrease of 10-25 percent, depending upon the vehicle, compared to gasoline. Though mileage may be an issue, ethanol does improve engine performance, as it has a much higher octane rating (113) than regular gasoline (87). The Indy Racing League©, known for the Indianapolis 500, runs all of their cars on 100 percent ethanol for superior engine performance.

Even with the loss in fuel economy, ethanol offers many environmental benefits. Overall, ethanol significantly reduces greenhouse gas (GHG) emissions compared to gasoline, though some, such as acetalhyde, may slightly increase. An E-85 blend of corn-based ethanol reduces GHG emissions by 10-20 percent per mile. An E-85 blend of cellulosic ethanol reduces GHG emissions by at least 60 percent per mile. The largest percent reduction in specific components of GHGs is in carbon monoxide and sulfates.

## Where can I purchase ethanol?

Ethanol is less readily available in the Southeast as compared to the Midwestern US. There are 80 public E-85 stations in the nine Southeastern states. More than half of those, 46, are in South Carolina alone. Most states average 4-5 public stations. In Tennessee, most fuel stations now have E-10 as their standard fuel. The next time you fill up your car's tank, look for a sticker on the pump indicating that the fuel is E-10. This will not hurt your vehicle and will most likely improve engine performance. In fact, most motorboat and lawnmower engines are certified to run on E-10.

In early 2008, Tennessee had only nine public gas stations selling E-85. However, through the Green Island Corridor grant program, at least 22 more public pumps are on the horizon. The program is directed by the Governor's Alternative Fuels Working Group and coordinated by the Tennessee Department of Transportation. To locate the E-85 pump closest to you, visit http://www.eere.energy.gov/afdc/ethanol/ethanol_locations.html.

## For More Information

To learn more about the production and utilization of ethanol, please visit one of these resources.
BioWeb: An online resource for bioenergy and bioproducts – http://bioweb.sungrant.org

Renewable Fuels Association – http://www.ethanolrfa.org/
US Dept. of Energy Alternative

Fuels and Advanced Vehicles Data Center - http://www.eere.energy.gov/afdc/fuels/ethanol.html

THE UNIVERSITY of TENNESSEE UT
Biofuels Initiative

BIOTENN

OAK RIDGE
National Laboratory

Visit the UT Extension Web site at
http://www.utextension.utk.edu/

For more information about the UT Biofuels Initiative, please visit
http://www.UTbioenergy.org

R12-4110-070-020-08 SP700A-5M-5/08 08-0230

Programs in agriculture and natural resources, 4-H youth development, family and consumer sciences, and resource development.
University of Tennessee Institute of Agriculture, U.S. Department of Agriculture and county governments cooperating.
UT Extension provides equal opportunities in programs and employment.