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Fuel Alcohol Production and Utilization

This publication was developed to provide answers to some of the most commonly asked questions about alcohol production for liquid fuels—fuel-grade alcohol, gasohol, and diesohol. The information provided is based on the best current knowledge available at Oregon State University and from other sources. The intent of the publication is to assist Oregon farmers in evaluating the potential for ethanol as a liquid energy source and in assessing the on-farm production and utilization of ethanol.

Is the use of alcohol as a fuel for engines a new application?

Use of alcohol as a motor fuel for spark ignition engines has been investigated periodically during the twentieth century. The U.S. Department of Agriculture (USDA) published "Use of Alcohol and Gasoline in Farm Engines" in 1907. Agrol, Alcolene, and Alky-Gas, all ethanol blended fuels, were sold and distributed in several midwestern states during the 1930's.

The modern-day "gasohol" was introduced in 1971 in Nebraska with the passage of Legislative Bill 776, which launched the gasohol program. This program has been supported generously by midwestern corn producers associations, since it offers potential for a sizable and firm market for corn.

How much fuel-grade alcohol can be produced from available agricultural residues, cull crops, and surpluses?

Numerous statements, some optimistic, are made periodically to the effect that ethanol offers the "solution" to our liquid fuel energy shortage. It is important to keep the whole ethanol potential picture in sharp focus and proper perspective.

The United States uses 100 to 120 billion gallons of gasoline yearly. We currently produce about 215 million gallons of various industrial alcohols per year. Approximately 60 million gallons of this is ethanol.

The U.S. Department of Energy (DOE) projects a goal of 300 million gallons per year of ethanol by 1982; 600 million gallons by 1985. This is one-half of 1 percent of gasoline used. Beyond 1985, DOE predicts ethanol use will depend on amount of new conversion capacity built, availability of economically competitive feedstocks, new technology, and relative costs and availability of competing fuels.

On January 11, 1980, President Carter set a target of 500 million gallons of ethanol production for fuel uses during 1981.

USDA projects that by mid-1980's, industry could produce an upper limit of 4.7 billion gallons of ethanol per year. So doing would bring most existing grain land into production and would use all crop surpluses and considerable municipal solid wastes.

What kind of energy balances are involved in making ethanol?

In almost every study and report published on the ethanol issue, there is a different analysis of the "energy efficiency" or "energy balance" of ethanol production. As a practical matter, the alcohol production program must yield more liquid fuel suitable for powering mobile equip-

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ment than the amount of liquid fuel it consumes in feedstock production, feedstock handling and transportation, and conversion to ethanol—in other words, a net gain in liquid fuel suitable for motive power.

Most present-day distilleries are designed for beverage production rather than for fuel alcohol production. They incorporate exotic quality control to insure a minimum of impurities and create specific flavors. They use petroleum-based priority fuels for process heat. Many beverage alcohol plants are old and do not use modern state-of-the-art alcohol conversion technology. They were not designed to conserve fuel nor to minimize priority fuel consumption. They use more priority liquid fuel energy than they produce in ethanol.

Is it possible to produce fuel-grade ethanol with a positive energy balance?

According to reports by USDA, DOE, and others, ethanol for fuel can be produced to yield a net gain in priority liquid fuel, even when some oil and gas are used for processing. New ethanol conversion facilities offer potential for much greater energy efficiency than existing beverage-type plants. Also, industry can design ethanol-making facilities that use coal, wood, agricultural residues, geothermal energy, solar energy, or waste heat from processing or generating plants for much of the process heat. According to these same reports, cost reductions appear possible through:

- Developing an enzyme or chemical method to convert plant cellulose matter into glucose more efficiently.
- Using continuous fermentation processes (some developmental work being done at USDA Western Regional Research Center, Albany, CA 94710).
- Designing energy-efficient vacuum distillation and use of advanced extraction techniques.
- Perfecting the Ames silica adsorption process as an alternative to distillation for separating alcohol from water (work at Iowa State University).
- Coupling conversion facilities with low-cost feedstock supplies.
- Improving feedstock production and collection technology.
- Increasing the use of by-product or stillage protein content, including possible use for human food ingredients.

How much energy is used to make ethanol?

Data based on both potable beverage alcohol and fuel-grade alcohol plants show the following ranges of energy inputs in Btu per gallon of ethanol produced:

	1,000 Btu
Cooking mash	4 to 7
Fermentation	negligible
Distillation to 190-proof	25 to 30
Dehydration from 190 to 200 proof	18 to 23
Recovering stillage	30 to 45
Miscellaneous	5 to 8
Electrical equipment	2 to 5

Several firms designing and constructing fuel alcohol plants are claiming considerably lower energy requirements achievable through heat recovery, improved distillation practices, and reduced attention to control of taste, aroma, color, clarity, and purity in the finished product.

In addition to the processing energy inputs, it is estimated that 27,000 to 30,000 Btu are expended in cultural steps to produce enough corn for 1 gallon of ethanol.

What are the relative heat values of alcohol and gasoline?

The accompanying table summarizes some of the properties of ethanol, gasoline, and #1 diesel fuel.

Fuel Property Comparison

Property	Gasoline	No. 1 Diesel	Ethanol
Heat Value (Btu/Gal)	116,485	133,332	76,152
Octane	85 to 94	10 to 30	106
Cetane*	10 to 20	45	–20 to +8
Air:fuel ratio	14.7:1	15:1	9:1

* Cetane measures ease of self-ignition, a quality required for diesel engines.

Policies

The future of agricultural biomass conversion, and particularly ethanol production, lies at the heart of both agricultural and energy policy concerns. Several major policy options must be evaluated. Further research is needed before definitive conclusions or recommendations can be made.

Diverting biomass from food or feed usages to production of alternate energies involves political, economic, social, and technological issues, as well as international relations, national defense policies, and the balance of trade. We must make political and economic evaluations of producing liquid fuel domestically versus dependency upon foreign governments and their supplies. We must evaluate environmental and soil depletion problems associated with a large-scale program of harvesting crops and crop residues for energy versus returning needed residue to the soil.

Can the public assist in making these policy decisions?

Community, political, industrial, and agricultural leaders must be involved in helping make biomass conversion a viable industry in appropriate locales. The public must become knowledgeable about the potential of biomass as an energy source to understand and support public policy decisions influencing such development.

Would government subsidies be needed?

Major capital expenditures by private enterprise and government (including subsidies, tax rebate programs, and loan guarantees) would be required to finance construction of first-generation demonstration distilling plants and distribution/marketing networks. USDA Secretary Robert Bergland summarized the Department's concern on this matter as follows: "Perhaps the crucial policy question currently posed by the gasohol issue is whether and under what conditions it would constitute good public policy to provide incentives toward a large-scale grain-to-alcohol program, rather than to forego any such commitment for the time being and continue the development and demonstration work to produce liquid fuels from cellulosic (residue) materials, shale oil, coal, or other alternative sources."

Will biomass conversion change farming practices?

Adding an alcohol fuel enterprise to the farm operation is not unlike adding or expanding other enterprises. It requires labor, capital, land, and management. The success or failure of the venture will depend on how well farm producers learn and use technologies to maximize economic returns for producing, managing, and marketing crops and crop residues for biomass conversion. Large-scale use of food or feed materials for alcohol production might distort present balances within the agricultural economy.

Feedstock Data

Feedstock is the raw material (biomass) used to provide the necessary starch or sugar for fermentation to ethanol. Feedstocks can be classified into three groups:

- Sugars: beets, canes, sorghums, ripe fruits;
- Starches: cereal grains, potatoes;
- Celluloses: grass, straw, corn stalks, wood.

How much ethanol can be made from a given amount of feedstock?

The theoretical yield from a 56-pound bushel of most cereal grains is 2.6 gallons of anhydrous ethanol, 18 pounds of distiller's dried grain, and 16 pounds of carbon dioxide. Such yield assumes complete starch conversion under ideal conditions—a situation seldom accomplished in practice. A conversion rate of 1.5 to 2.3 gallons per 56-pound bushel appears more realistic. Achieving these conversions requires the proper types and amounts of enzymes and yeasts and proper management of a correctly designed and constructed fermentation and distillation system.

What are enzymes and why are they needed?

Enzymes are protein molecules that act as catalysts (helpers) to speed up the chemical reactions that occur in breaking down the chain-like starch molecules into two-part sugar molecules (disaccharides) and then splitting these into one-part molecules (monosaccharides) or simple sugars. The enzymes serve only to speed up the reactions—they are not needed for the reaction itself. Each enzyme is highly specific as to the type of reaction catalyzed. Amylase enzymes are used for the first reaction; invertase or saccharifying enzymes are used for the second reaction.

What are yeasts and why are they needed?

Yeasts, which occur abundantly in nature, are one-celled plant-like organisms. The growth requirements of yeast include carbon, nitrogen, water, various minerals, and a mixture of one or more vitamins—all of which are supplied from the fermentation media. The ethanol and carbon dioxide produced by yeast are actually products of yeast growth and metabolism occurring in a closed vessel which excludes air. If done in an open-air vessel, the products are mainly carbon dioxide and water, hence the reason for fermentation under conditions which exclude air.

How much yeast is required to make ethanol?

From 2 to 4 pounds of dry yeast per 1,000 gallons of cereal grain feedstock mash is a commonly used recommendation.

What farm products are good feedstock sources for converting to ethanol?

Many basic agricultural products can be used to make ethanol. They vary in the amount of ethanol they will yield. The accompanying table compares ethanol potential from commonly used feedstocks, based on carbohydrate content.

Ethanol Potential from Various Feedstocks

Feedstock	Ethanol potential (199 proof)		
	Per bushel	Per ton	Per acre-yr
Field crops	*Gallons*	*Gallons*	*Gallons*
Artichokes, Jerusalem	0.6	20.0	200
Barley	2.1	79–88	125
Beets, fodder (Mangels)	0.6	25	
Beets, sugar	0.5	20 to 25	400
Buckwheat	2.0	83.4	50
Carrots	....	9.8	120
Corn	2.6	84 to 94	225
Oats	1.0	63.6	75
Onions	0.4	11–14	
Potatoes, white	0.8	22 to 28	300
Potatoes, sweet	1.2	34.2	140
Rice	2.0	79 to 88	250
Rye	2.2	79 to 88	75
Sorghum, cane	1.7	70.4	500
Sorghum, grain (milo)	2.6	79 to 93	
Turnips	0.5	8 to 11	350
Wheat	2.6	85 to 90	125
Yams	1.0	27.3	100
Orchard crops			
Apples		15 to 22	140
Apricots		13.6	60
Grapes		15.1	90
Pears		11.5	50
Peaches		11.5	84
Plums		10.9	22
Pumpkins/Squash		6 to 10	
Watermelons		10.0	
Other feedstocks (requiring more elaborate hydrolysis)			
Hay		25 to 50	
Newspaper		40 to 50	
Sawmill waste		20 to 35	
Straw, grass or wheat		25 to 50	
Sulfite liquor from paper mill		28 to 40	
Whey, fluids		4 to 7	
Whey solids		75 to 85	
Wood		25 to 50	

Processes

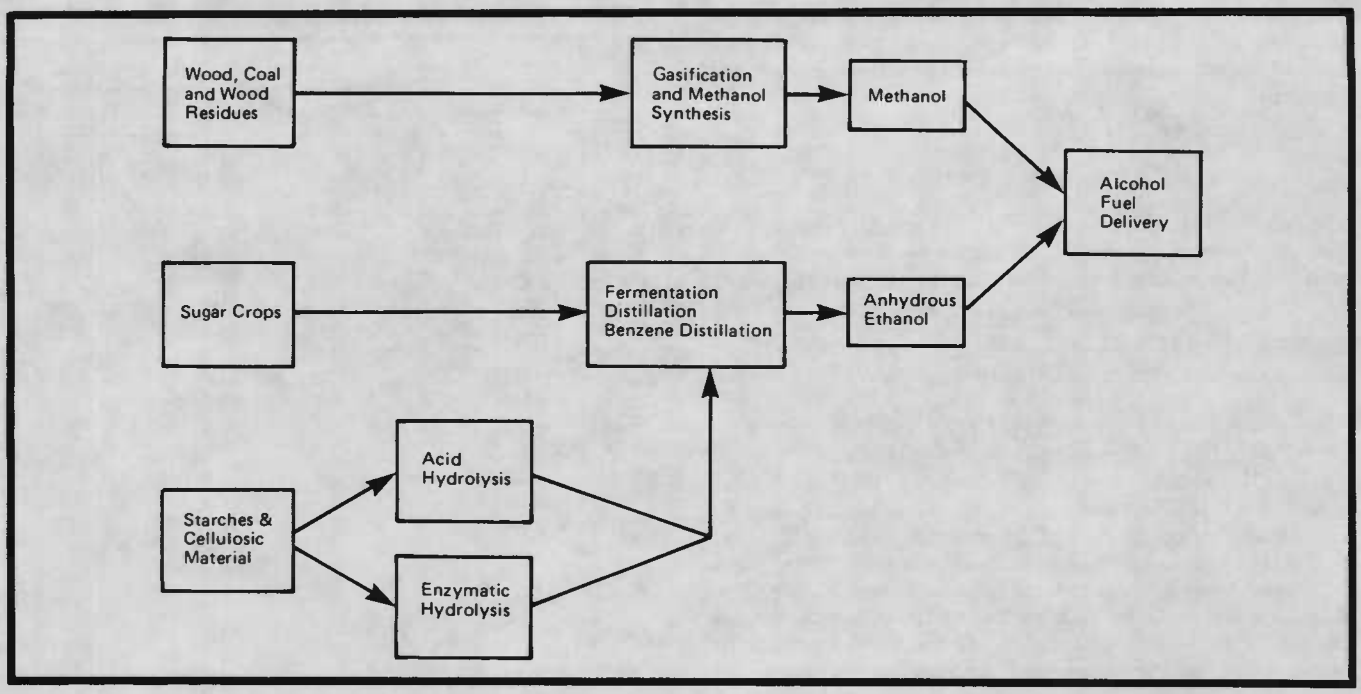
How complicated is the process of making ethanol?

The technology to make ethanol is well-established and details are available in numerous handbooks and other references. However, making fuel-grade ethanol from agricultural crops and crop residues is not the simple, cheap, and easy process many popular press articles outline.

Operation of a still requires knowhow and time-consuming attention. The process of converting biomass to ethanol is fairly complicated, even for the do-everything-yourself specialist. It involves chemistry, steam engineering, microbiology, plumbing, astute economics, meticulous housekeeping, good management, and rigid adherence to government control and regulations. Fortunately, the various steps of ethanol production can be accomplished at atmospheric or very low pressures, making equipment and techniques less complicated.

The following is a simplified outline of the basic steps for making ethanol from cereal grains or potatoes:

- Feedstock preparation—Grind, crush, or shred biomass feedstock into fairly uniform "fine" sizes. A 3/16-inch diameter or 4-mesh per inch hammermill screen works

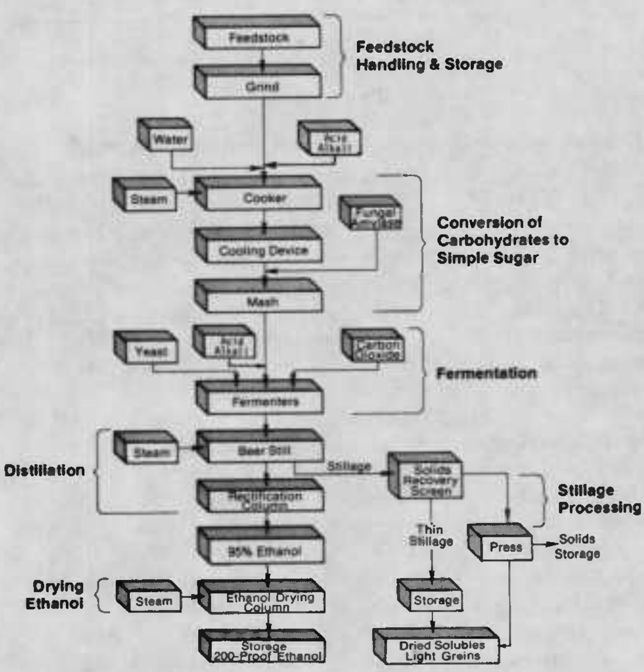


Biomass-to-Alcohol Fuel Routes

well for grains. All kernels must be broken. Too fine a grind increases difficulty of separating out stillage.

• Batch formulation (liquefaction)—Make a slurry by adding water to milled feedstock—for grains, from 10 to 20 gallons per bushel. Bring mash to a 6.0 to 7.0 pH range by adding acids or alkalis to reach the desired balance. Add an enzyme such as alpha amylase to prevent solidifying or gelatinizing.

• Cooking—Cook the mash under constant agitation at 194° F for about 30 minutes and then boil for 10 minutes to convert starches to sugars. Continue cooking at or near boiling for 30 to 60 minutes to gelatinize starch.



Ethanol Production Flow Chart

• Saccharification—Cool quickly to 140° F by adding cool water, reduce pH level to 4.0 to 4.5 range with acid diluted with water, add second enzyme, gluco-amylase, and steep for 30 minutes at 140° F. Agitate slurry continuously throughout formulation, cooking, and steeping.

• Cooling—Thin and cool cooked slurry mash by adding 16 to 18 gallons of cool water per bushel, while constantly stirring, to obtain an 85° to 95° F slurry. Test specific gravity—maintain sugar content of 21 percent or lower (1.08 sp.gr.). Inoculate with a brewer's or baker's yeast culture (*Saccharomyces cerevisiae*). Agitate to mix in yeast.

• Fermentation—Allow to ferment in the absence of free oxygen for 60 to 72 hours at 70° to 90° F, with gentle agitation, to allow yeast to convert starch to an 8- to 12-percent-ethanol liquid or "beer." (Yeast is killed in solutions above 12 percent alcohol.)

• Separation—Screen out by-product or stillage, leaving beer (ethanol and water) mixture. (Some experimenters recommend not separating stillage from beer before distillation.)

• Distillation—Run beer at near-boiling temperatures through an upright, heated distillation column fitted with series of honeycomb baffle plates. Since ethanol vaporizes at 173° F, the vapor rises to top of distillation column. Highest proof ethanol that can be distilled by this method is 190.

• Condensation—Run ethanol vapors through serpentine cooling coils to condense into fluid ethanol. Low-proof (below 140) ethanol should be recirculated through distillation column to reduce its water content.

• Extractive distillation—Add agents such as benzene, cyclohexane, or pentane to break the azeotropic bond between the water and ethanol and remove the last 5 percent water from ethanol mixture to yield 200-proof ethanol. (This step is more complicated, energy-intensive, and precise and is usually done at a larger, centralized commercial plant.)

• Denaturing—Fuel ethanol must be denatured under federal direction and supervision provided by the Bureau of Alcohol, Tobacco, and Firearms, U.S. Treasury Department. (See address under Regulations and Permits.)

NOTE—the fermentation-distillation process specifics may vary from this, depending on equipment and materials used.

Do manufacturing processes vary according to biomass material?

Additional steps are involved in making ethanol from cellulose materials such as straw, wood, or paper. An acid or alkali hydrolysis step, immediately following the milling operation, is needed to break down the cellulose into a sugar. If acid is used, the distiller's residue should not be used as an animal feed; if alkali and enzymes are used, the distiller's residue may be fed to animals.

Equipment and Investments

What capital investment is needed for a farm-size distillation unit?

Several firms have made feasibility studies and some have constructed pilot models of farm-sized stills—stills capable of producing from 15 to as high as 500 or 600 gallons per day. Projected costs of these plants vary from $25,000 to $30,000 for smaller, less automated plants, on upwards for larger capacity, more fully automated units. For efficiency, the plant should operate on a regular schedule—daily if possible. This requires an assured, continuous supply of biomass feedstock material and a means for utilizing or disposing of the wet stillage by-products on a daily basis.

Is the production of ethanol economically feasible?

Ethanol economics involves individual costs and returns. Economic feasibility studies, based primarily on estimated costs and returns, show that the production of ethanol as a fuel, in the past was more expensive than traditional petroleum products. However, the economic situation has changed dramatically because of the cost of petroleum products. This tends to make ethanol-based fuels more competitive.

The feasibility for a particular operation depends largely on the cost elements listed below. The key variables are the cost at which the raw materials can be obtained, the cost of fuel for the distillation process, the revenues obtained from selling any by-products of the fermentation process, the market price for ethanol, and any tax or subsidy incentives that would enhance the competitive position of ethanol.

What are the principal operating costs?

The principal operating costs include:

• Raw materials (feedstocks), including transportation, handling, and storage;

• Processing chemicals—yeasts, enzymes, and acids;

• Energy for fermentation heat, distillation heat, pumping, and handling operations;

• Repairs and maintenance;

• Labor.

In addition, there are fixed costs:

• Depreciation and/or overhead;

• Interest on investment;

• Taxes (personal property or real estate);

• Insurance.

Is there any financial aid available to help finance "pilot model" stills?

Federal, state, and other agencies are formulating and proposing various grant and financial programs. The agencies listed are following this progress and may be able to supply current information on the status of financial aids.

Oregon Dept. of Economic Development
155 Cottage Street NE
Salem, OR 97310
373-1215

Oregon Department of Energy
Labor & Industries Building
Salem, OR 97310
378-4040 or 4998

Oregon Department of Agriculture
635 Capitol Street NE
Salem, OR 97310
378-4666 or 3773

Alcohol Fuels Clearinghouse
Eastern Oregon State College
La Grande, OR 97850
963-2172 Ext. 435
or
(800) 452-8630

Can a farm operation become "fuel self-sufficient" by producing its own ethanol fuel supply?

Many farmers and ranchers are interested in becoming "fuel self-sufficient" by producing and utilizing ethanol on their own premises. To do so, they would need to modify their gasoline-powered engines for operation on ethanol without mixing with gasoline. This involves enlarging carburetor jets, replacing all plastic and elastomer fuel system parts (gaskets, hoses, bushings, floats, filters, pump diaphragms, etc.) with non-plastic parts since ethanol deteriorates plastic, and adding a preheater to the intake manifold for starting at temperatures below 45° to 50° F or operating in sub-freezing conditions. The modified engine cannot be operated on gasoline because the fuel mixture will be too rich, resulting in flooding.

What advantages does a farm-size alcohol plant offer?

The farm ethanol plant, by its nature, is site-oriented. It has a variety of advantages compared to larger, centralized plants.

• Feedstock usually is on hand, on the site. No major transportation is required to move feedstock to plant for processing.

• The feed by-product and liquid fuel do not have to be transported back to the farm from an off-site plant.

• The farm plant is less subjected to cyclical market forces placed on grain or fuel.

• The feed by-product can be fed in a wet form to save energy for drying, although feed handling may require some modification.

• Ethanol in the 160- to 190-proof range can be used directly at the farm level.

• There is the possibility of serving as satellite plants producing 160- to 190-proof ethanol for sale as a farm commodity to a centralized mother plant for further refining to 200 proof.

What makes one plant design better than others?

Plant design can mean success or failure. Design for farm-scale systems should take into account:

• The time, skill and interest available for management.

• Utilization of low-grade or farm-produced fuel for process heat (methane, wood, straw, plant residues, solar, geothermal, etc.).

• Low maintenance, cost-effectiveness.

• Plant construction cost savings—use of on-farm or locally available construction materials.

When buying a system, what shopping tips are suggested?

Before entering into any agreement or contract to design, construct, or purchase, do the following:

• Ask for the location of one of the seller's operating units and visit or inspect it to personally evaluate the system.

• Include in any signed document a written performance guarantee or performance bond and a precisely outlined schedule of committed consulting, maintenance, and servicing programs that are a part of the purchase price.

• Incorporate a provision in the purchase document to withhold partial payment until agreed-upon performance of system is achieved for a specified time period.

Are special storage precautions necessary for ethanol?

Ethanol, like gasoline, is volatile, flammable, and potentially explosive in certain mixtures with air. It should, therefore, be handled and stored with comparable cautions as exercised with gasoline. Since fuel-grade ethanol may be virtually odorless, alcohol fumes will be more difficult to detect than those from gasoline.

How are distiller's grain by-products fed to livestock?

Alcohol production from grain feedstocks yields a residue called stillage or distiller's grain as a principal by-product. When dried, it is called distiller's dried grain with solubles or DDGS. Economic and energy balance studies usually give both economic and energy values to the DDGS produced.

Most of the available data on DDGS is based on the by-product of corn distillation. Little information is available on the feeding value of residues from the fermentation of feedstocks such as potatoes, beets, sugarcane, or other materials. Each bushel of corn yields 16 to 18 pounds of DDGS. Compared with soybean meal, the most common high-protein animal feed supplement, DDGS from corn has about half the ruminant-digestible protein and twice the crude fiber content. The high fiber content of DDGS limits its acceptability for the poultry and swine markets, which account for more than half of total domestic high-protein feed supplement consumption. Most DDGS goes to the dairy and beef finishing markets, where it competes with soybean meal and corn.

Feeding Values Comparisons

Constituent	Corn	DDGS	Soybean Meal
	Percent	*Percent*	*Percent*
Crude protein	8.9	27.0	44.0
Crude fat	3.5	9.0	0.5
Crude fiber	2.9	13.0	7.0
Ruminant digestible protein	5.8	19.3	37.5

Regulations and Permits

Several agencies and regulatory groups must be contacted regarding permits for ethanol production stills. Obtain approvals, permits, or clearances for the following functions from the agency or regulatory group listed:

• General information:
The State Permit Center
155 Cottage Street NE
Salem, OR 97310
378-3732

Provides general information on permits, licenses, certifications, plan reviews, tax incentive programs, etc.

• Alcohol Fuel Producers Permit:
Regional Regulatory Administrator
Bureau of Alcohol, Tobacco & Firearms
Department of the Treasury
525 Market Street—34th Floor
San Francisco, CA 94105
(800) 227-3072
(415) 556-0226

Permit applications for residents of Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, Oregon, Utah, Washington and Guam. (See detailed discussion under "How do you get the Treasury Department permit?")

• Land use: Obtain approval from local governing jurisdiction.

• Building plans: Obtain approval from local governing jurisdiction for building permit, plans review, electrical, mechanical, plumbing, and any other required structural permits.

• Heating boiler:
Building Code Division, Boiler Section
Department of Commerce
2300 SW 6th Street
Portland, OR 97201
229-5755

Permit for installation of boilers or pressure vessels.

• Storage of flammable liquids:
State Fire Marshall
103 Labor & Industries Bldg.
Salem, OR 97310
378-4917

• Water sources:
Department of Water Resources
555 13th Street NE
Salem, OR 97310
378-3739 or 3066

Permit for appropriate ground water, public waters, non-conforming well construction.

• Geothermal sources (State land only):
Division of Lands
1445 State Street
Salem, OR 97310
378-3805

Permit for geothermal exploration, geothermal lease on all state-owned land.

• Geothermal sources (Private land):
Dept. of Geology & Mineral Industries
1069 State Office Building
Portland, OR 97201
229-5580

Permit for drilling geothermal well or test hole.

• Waste disposal:
Department of Environmental Quality
Yeon Building
522 SW Fifth Avenue
P.O. Box 1760
Portland, OR 97207

Permits as applicable for air contaminant discharge (229-6093, Portland); noise (229-5989); solid waste disposal (229-5913); waste discharge into surface waters (229-5325); water pollution control facilities (220-5325).

• Tax credits:
Department of Energy
Labor & Industries Building
Salem, OR 97310
378-4040 for general information

Information on Alternative Energy Device Tax Credit, Tax Credit Certification for Pollution Control Facility (229-6484 Portland), exemption of commercial gasohol plants from property and corporate income taxes (378-3363).

How do you get the Treasury Department permit?

The Department of the Treasury's Bureau of Alcohol, Tobaccco, and Firearms (ATF) is responsible for administering taxing statutes under the Internal Revenue Code of 1954 that relate to distilled spirits or ethanol. These laws were designed primarily for the beverage alcohol industry, but provide the guidelines for all production of ethanol. The main mission of ATF is to collect revenue. However, federal tax is not imposed on ethanol produced for fuel use if it is properly denatured and produced in accordance with existing laws and regulations.

The *Alcohol Fuel Producer's Permit*, as established July 1, 1980, can be obtained by completing ATF Form 5110.74 available from regional ATF offices. ATF classifies alcohol fuel plants into three categories: (a) *Small plants*—up to 10,000 proof gallons per year; (b) *Medium plants*—more than 10,000 but no more than 500,000 proof gallons per year; and (c) *Large plants*—more than 500,000 proof gallons per year. A "proof gallon" is a U.S. gallon of liquid that is 50 percent ethyl alcohol by volume. For example, 2,000 gallons of 190-proof alcohol equals $190 \times 2{,}000 \div 100 = 3{,}800$ proof gallons.

Small plants are exempt from bonding. Bonding to provide the Government-required security against possible loss of distilled-spirits revenue is required for medium and large plants. The bond for a medium plant producing between 10,000 and 20,000 proof gallons per year is $2,000, with an additional $1,000 for each additional 10,000 proof gallons or fraction thereof, to a maximum of $50,000 for 500,000 proof gallons. Bonding for large plants is $50,000, plus $2,000 for each additional 10,000 proof gallons or fraction thereof, to a maximum of $200,000 for plants producing more than 1,240,000 proof gallons per year.

The Alcohol Fuel Producer's Permit is in effect indefinitely, with no renewal required, but is not transferrable. It permits the holder to sell or distribute properly denatured fuel alcohol free of tax. Fuel alcohol is considered denatured or unfit for beverage use when 5 gallons or more of regular or unleaded gasoline, kerosene, deodorized kerosene, rubber hydro-carbon solvent, methyl isobutyl ketone or any combination of the foregoing are added to each 100 gallons of ethanol.

Are experimental distilled spirits plant permits still valid?

ATF has developed a simplified procedure to convert *experimental distilled spirits plant permits* to *alcohol fuel producer's permits.* Any person holding a permit to operate an experimental plant for fuel purposes is still authorized to operate the plant, but should obtain an *alcohol fuel producer's permit* before expiration of the experimental permit.

Research Needs

Current literature reveals many unanswered questions related to ethanol production and use, many of which will require research to resolve and answer. These include:

- Utilization of non-mobile fuels or energies (wood, coal, agricultural residues, geothermal, waste processing heat, solar, etc.) as heat source for fermentation and distillation steps.
- Furnace and heat exchanger designs for using low-grade fuels for processing heat.
- Development of equipment and techniques specifically designed to produce, harvest, transport, store, and handle materials to be used as process heating fuels or as distilling feedstocks.
- Develop and field-test specific crops adaptable to ethanol production. Also, develop and field-test specialty plants with high energy conversion suitable for use as process heat sources.
- Establish criteria for disposal of waste products, including water, to meet existing EPA or other governing environmental regulations.
- Simplify and expedite cellulose hydrolysis with improved chemical processes or additives.
- Refine yeast recovery and recycling techniques in saccharification step of ethanol production.
- Develop additives or techniques to prevent phase separation of gasoline and ethanol to permit direct mixing of 190-proof ethanol with unleaded gasoline.
- Develop a less energy-intensive and simplified technique for separation of water from ethanol in the 190- to 200-proof range.
- Establish more precise information on use of straight ethanol as a fuel for internal combustion engines and its long-term effect on wear and performance.
- Utilization and performance of fuel-grade ethanol or ethanol/diesel blends in diesel engines.

• Criteria and lending formulas for financing of both farm-size and coop- or industrial-size stills through conventional banking institutions, Federal Land Bank, Production Credit Association, Farm Home Administration, etc.

Glossary

Alcohol—a generic name used in chemistry to include numerous carbon compounds in which a hydrogen atom is linked through an oxygen atom to a carbon atom.

Methanol—also called methyl alcohol or wood alcohol, CH_3OH, the simplest primary alcohol, is derived from coal, wood, or organic matter, requires pressurized equipment (750-1,500 psi at 480-520° F) to produce, is very toxic and vile smelling. It contains 63,580 Btu per gallon.

Ethanol—also called ethyl alcohol or grain alcohol, C_2H_5OH, is derived from grains, agricultural crops, and residues containing carbohydrates, is biologically produced at atmospheric or very low pressures, is one of the oldest chemicals known to man, and is the form of alcohol used in the beverage industry. It contains 76,152 Btu per gallon.

Butanol—also called butyl alcohol, $C_4H_{10}O$, is derived from chemically synthesizing certain hydrocarbon gases or fermenting carbohydrates. It contains 104,918 Btu per gallon.

Gasohol—a mixture of unleaded gasoline and denatured ethanol, usually at nine parts gasoline to one part ethanol, used commercially in automotive vehicles.

Diesohol—(sometimes spelled dieselhol)—a term occasionally used to designate a mixture of ethanol with diesel fuel. No standardized mixtures have been generally established to date.

Anhydrous alcohol—ethanol which is free of water, or 200-proof, and has a boiling point of 78.4° C. (An ethanol/water mixture of 95.6 percent alcohol boils at 78.2° C, hence the impossibility of producing anhydrous or 200-proof alcohol by ordinary distillation.)

Denatured alcohol—ethanol which has been rendered unfit for human consumption by addition of a denaturant such as methyl isobutyl ketone, acetaldol, kerosene, or gasoline.

Fuel grade alcohol—alcohol intended for use as a liquid fuel, usually 160-proof or greater.

Industrial alcohol—alcohol that has been denatured and entered in trade channels under the Denatured Alcohol Act of 1906, permitting its tax-free sale for industrial purposes.

Priority liquid fuel—all fuels derived from crude oil, natural gas, coal, or biomass for use in mobile internal combustion engines.

Proof—alcoholic concentration indicated by a number that is twice the percent by volume of alcohol present, i.e., 180-proof is 90% alcohol and 10% water, 200-proof is pure alcohol.

References on Alcohol Production

"Alcohol Fuels," The Energy Consumer, January 1980, U.S. Department of Energy.

"Biomass Alcohol for California," January 18, 1980, Proceedings of Biomass Conference, University of California-Davis.

"Ethanol Production and Utilization for Fuel," January 1980, Cooperative Extension Service, University of Nebraska.

"Fuel From Farms—A Guide to Small Scale Ethanol Production," February 1980, Solar Energy Research Institute, Golden, CO 80401.

"Position Paper on Alcohol Fuels," DOE/US-0001/1, March 1978, U.S. Department of Energy.

"Proceedings of Forum on Alcohol Fuels," February 1980, Kansas State University.

"Report of the Alcohol Fuels Policy Review," DOE/PE 0012, June 1979, U.S. Department of Energy, $7.25.

"Small-Scale Fuel Alcohol Production," USDA-001-000-04124-0, March 1980, $6.00, Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20401.

Associations

National Alcohol Fuel Producers' Association, 1760 Reston Ave., Suite 102, Reston, VA 22090, (703) 471-1611.

National Center for Appropriate Technology, P.O. Box 3838, Butte, MT 59701, (406) 494-4572.

National Gasohol Commission, Inc., Suite 5, 521 S. 14th Street, Lincoln, NE 68508, (402) 475-8044.

NOTE: DOE has a toll-free number for answers to general questions on alcohol production, (800) 525-5555.

Metric Equivalents

Quantity	*US*		*Metric*
Length	1 inch	2.54	centimeters
	1 foot	0.3048	meter
Area	1 square inch	6.5	square centimeters
	1 acre	0.4	hectare
Weight	1 ounce	28.35	grams
	1 pound	0.45	kilogram
	1 ton	907.2	kilograms
Volume	1 quart	0.9463	liter
	1 gallon	3.785	liter
	1 bushel	35.24	liter
Energy	1 Btu	1055.06	joule

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Questions on alcohol fuels can be sent to your county Extension office or to the Extension Agricultural Engineer, OSU, Corvallis 97331.

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