

Bioethanol

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Biodiesel reactor at NC State



Fuel from biomass

- Plant material consists of
 - Cellulose
 - Hemicelluloses
 - Lignin
 - Sugars are bound up in the cellulose and hemicelluloses
- Starches are polymers of sugars

Ethanol – what is it?

- An organic compound
- An alcohol

How do you use ethanol as fuel?

- Directly in spark-ignition engines
- In reaction to make biodiesel (alternative to methanol)

How do you make ethanol?

- Chemical process from other hydrocarbons
- Fermentation of sugars, followed by distillation to purify
- Overall reaction is



Glucose

Ethanol

Carbon dioxide

What's so great about ethanol?

- Can be made easily from local, renewable sources
- Reasonably non-toxic to humans
- A good fuel for spark engines
- A good reactant to make biodiesel

What's not so great about ethanol?

- Some bad combustion products—easily remedied
- Low energy density compared to gasoline
- Distillation is energy-intensive
- More expensive than methanol
- More ethanol required than methanol to make biodiesel
- Making ethyl esters is tricky!!!

Batch production of ethanol

- Mashing (saccharification)
- Fermentation
- Distillation

Mashing

- Converts other plant materials to sugars
- For us, this means converting starches to sugars
- Dissolve starches in hot water
- Convert starches to sugar using enzymes

Fermentation

- Converts sugars to ethanol
- Yeast is the most common method
- Bacteria can also be used
- Anaerobic process is best (seal the container)
- Ethanol is toxic to yeast (it's a waste product)
- When ethanol concentration gets high enough, yeast die (~14%)

Distillation

- A method of separating two or more liquids, by changing the equilibrium balance between them
- Takes advantage of differing boiling, condensation points
- Requires heat or vacuum, or both
- Distillation column results in much higher purity

Distillation columns

- Theoretical maximum purity for distillation of alcohol and water: 96%
- Using a pot distiller, you have to re-distill several times to approach this purity
- Using a distillation column, you can get high purity in one pass! (~94%)

Drawbacks of batch production

- Alcohol kills the yeast
- Batch distillation is inefficient

Inefficiencies of batch distillation

- You have to heat the whole batch to boiling before anything comes out
- Alcohol content of batch decreases over time. At end of process:
 - Higher boiling temperature
 - Lower yield per energy input
 - Lower purity

Can we improve on this? Yes!

- Simultaneous mashing and fermentation
- Semi-continuous fermentation
- Continuous distillation
- Solar thermal + vacuum

Solar thermal and vacuum

- Use solar collector to heat the mixture to 140 – 150 F
- Use vacuum pump to lower the system pressure so that the mixture boils at the current temperature

Modifying gas engines to run on ethanol

- Enlarge injector nozzle openings or carburetor jets
- Get a bigger fuel pump
- Advance the spark timing
- Replace rubber fuel lines, gaskets, etc.

Batch production of ethyl esters (ethyl biodiesel)

- Use 30% ethanol instead of 20% methanol
- Reaction proceeds more slowly (react longer or add heat)
- Reaction is sensitive to water content (dry WVO first)
- Reaction tends to form soap (use two-stage process)
- Reaction products don't want to separate! (use acid, water, glycerin)

Proposed ethyl ester recipe

- ✓ Settle and dry the WVO
- ✓ First stage: acid-catalyzed esterification
- ✓ Second stage: base catalyzed transesterification
- Ethanol recovery by distillation
- Separation
- ✓ Washing

The big picture

- Small-scale biofuel production facility
- Make ethanol from crops
- Get WVO from restaurants, food processors
- Get VO from ...
- Use ethanol as fuel, or to make biodiesel

Small biofuel production

- Inputs
 - Sugar crops
 - Oils
- Outputs
 - Ethanol
 - Biodiesel
- Glycerin derivatives

Demonstration

- Distillation (re-distillation of previous batch)
- Mashing, fermentation, and straining of corn batch

Corn recipe

www.homedistiller.org

- Mix your grain bill together and weigh it out. For every 3 pounds of grain (1344 grams) you will need one gallon (4 liters) of water.
- Put the grain-I use 15 pounds (6.75 Kilos) per 5 gallon (20L) batch- into your fermentor (sanitized, 20+liter buckets are best), pour in 10 liters of room temperature water, and mix it with the grain. Make sure there are no lumps or clumps, and that all the grain has been wetted down (no dry spots are allowed). The first water mixed with the grain **MUST NOT BE HEATED!!** If it is, the grain will clump together, leaving dry spots in the middle of the clumps, leading to an infection.
- Take the next 10 Liters of water and bring it to a boil in a pot on the stove. Once it's boiling, pour it into the bucket with the pre-wetted grain, and stir it up to prevent any clumping. This will liquify the starch, and sanitize the batch (the precooling effects of the grain/water in the bucket will prevent the bucket from warping/melting). Leave the hot water/grain filled bucket overnight.
- When cool, add your yeast and your enzyme, and let it ferment. Depending on the grain, when you add the yeast, the mash may be as thick as oatmeal- don't add any more water, it will thin out in a day or so, during the ferment.
- Wait until all foaming and bubbling has stopped, and all the grain settles to the bottom (3 days to 2 weeks, depending on temperature), filter this through a layer or two of cheesecloth, and distill it.

Web Sites

- www.journeytoforever.org
- www.homedistiller.org/
- www.brewhaus.com/
- www.nrel.gov/