

# Extraction of Fermentable Carbohydrates from Cellulose

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## Problem Statement

Despite ethanol being a well-known renewable fuel, current methods of mass production of cellulosic ethanol are impractical and inaccessible. Extracting fermentable carbohydrates from cellulosic material is an energy intensive and costly processes. Our goal is to make more effective methods of carbohydrate extraction from widely available sources of cellulosic material to make ethanol fuel production more attractive to industry and more accessible to rural communities.

## Background

- The need for cleaner, renewable fuels is increasing.
- Ethanol, or bioethanol, is a well-known alternative fuel and corn-based ethanol has been observed to reduce emissions by up to 40% on average (1)
- Bioethanol production starts with a biomass feedstock rich in carbohydrates, which is typically pretreated before undergoing alcoholic fermentation to produce ethanol (1).
- The issue with corn ethanol is that corn has high energy and resource requirements to grow, and conflicts exist between its use for fuel production versus food.

### Benefits of cellulosic feedstock over corn:

- Cellulose is found in all plants.
- Low energy and resource requirements to grow high-cellulose materials, like grass.
- Can use plant wastes – eliminate dedicated feedstock
- Cellulosic ethanol has been observed to contain a net energy content three times that of corn-ethanol (2).

### Issues with a cellulosic feedstock:

- Breakdown into fermentable carbohydrates is notoriously difficult.
- Current methods (acid hydrolysis, enzyme hydrolysis) are largely inefficient and materials can be costly.

This project stemmed from ongoing research on PNW's Westville campus, where similar treatments and reactions were carried out in 250 mL flasks. Multiple trials using lawn clippings showed positive results for the production of ethanol.

## Requirements

- Extract fermentable carbohydrates from cellulosic waste materials using **photocatalytic methods**
- **Mechanical pretreatment:** Grind materials as finely as possible
- **Minimal/no chemical pretreatments**
- **TiO<sub>2</sub> catalyst** required for UV light-driven photoreaction
- System must be **automated** and **energy efficient**

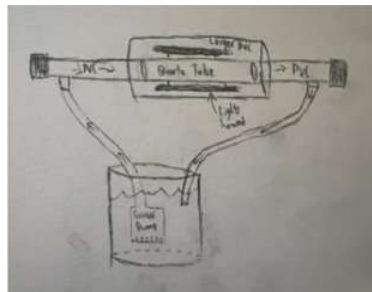


Fig. 2 sketch of design

## Experimentation and Concepts

Experimentation was broken down into two parts:

- 1) Finding a reliable process to breakdown a variety of biomass sources into small particles which can be run through a reactor. The goal is to expose as much cellulose as possible.
- 2) Creating and testing a reactor that could breakdown the cellulose using UV lights and extract fermentable carbohydrates.

In the reactor, the free cellulose (from grinding), TiO<sub>2</sub>, and the UV light must all come together at a single point in an aerated environment. This causes the ether bonds in the cellulose to be cleaved, yielding simple sugars like glucose.

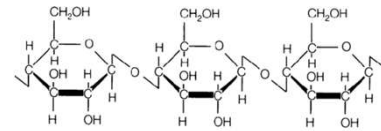


Fig. 1. Chemical structure of cellulose.

## Final Design

- Continuous flow process where a slurry flows through a quartz tube and is exposed to UV light.
- 25 gallon per minute flowrate which mixes the slurry and ensures all biomass is properly exposed to UV light.
- Entirely made of commercial parts except for the slight modification to the acrylic discs.
- Commercially available grain mill (Vevor brand, 2000 W, 28,000 rpm)
- Utilizes a single blade which made it simple and hard to clog
- Results are sorted through a sieve with 1-2 mm openings for the ground material to be passed through

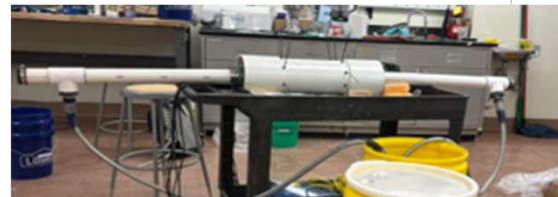


Fig. 3 picture of reactor

## Testing and Results



Fig. 4. Examples of grass at different grinding stages.

- Left shows grass after 30 seconds of grinding
- Middle shows grass after two minutes of grinding
- Right shows grass after three minutes of grinding and being sieved



Fig. 5. Insufficiently ground grass. This example was ground in a blender which was incapable of grinding to the desired size.

Our main method of validating the effectiveness of the reactor is by doing the Benedict's test for reducing sugars, which are the fermentable carbohydrates we are aiming to produce. This is a chemical, colorimetric test.

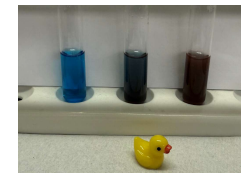


Fig. 6. Benedict's test results from known sugar samples. Samples from left to right are a blank (no sugars), 2% glucose, and filtered soda.

## Conclusions

Using commercially available parts for the grinding process generated the most efficient design, but we do foresee issues with the scalability of our grinding methods. We believe that our reactor design has commercial value due to its simplicity and ability to be scaled up. Although we have not been able to conclusively produce fermentable carbohydrates (or ethanol) using this reactor, we believe the issues lie in our chemical parameters, which can be easily modified over time.

### References

- [1] U.S. Department of Energy. (n.d.). *Ethanol*. Alternative Fuels Data Center: Ethanol. Retrieved February 13, 2026, from <https://afdc.energy.gov/fuels/ethanol>.
- [2] UN Climate Technology Centre & Network. (2017). *Cellulosic ethanol*. <https://www.ctc-n.org/technologies/cellulosic-ethanol>.