NebGuide

Nebraska Extension

Research-Based Information That You Can Use

G2310 · Index: Crops, Crop Production/Field Crops
Issued November 2018

# Alternative Biomass Materials to Corn for Production of Value-added Products

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*This NebGuide discusses which biomass materials can be an alternative to field corn for production of various value-added products, including sugar, sugar alcohols, ethanol, and other compounds. Research results in terms of comparisons based on solubilization of the biomass materials in the hydrothermal condition are presented and discussed. The technical and scientific content presented in this article is intended for industry technical personnel, university faculty and graduate students, technologists, and other technical professionals related to the topic.*

## Introduction

Producing value-added products using agricultural commodities can contribute utilization of excess agricultural production in various platforms, and this can contribute to economic development. The amount of cropland devoted to growing corn has increased considerably in recent years, and now the United States has excess corn production (US Weekly Corn Update: Ethanol demand weighs on corn futures. Ludtke, Marcus, 2015).

Excess corn can be utilized for many value-added products because of its carbohydrate-rich composition. However, an effective and efficient dissolution process, which combines both liquefaction (conversion of starch to soluble form) and saccharification (conversion of soluble starch to glucose) steps, is necessary to make any conversion process more cost-effective and practical. Currently, liquefaction and saccharification steps in corn-based ethanol production are achieved by heating the slurry in water and use of enzymes that make the process more expensive and time consuming. This NebGuide provides a research update on comparison of dissolution efficiency of various lignocellulosic biomass materials with corn for production of various value-added products, including ethanol.

Nonedible lignocellulosic biomass materials are attracting increasing attention as renewable, economical, and abundant resources to reduce dependency on petroleum resources, minimize energy and material feedstock costs, and reduce petroleum-based energy resources' negative impacts, i.e., greenhouse gas emissions, on the environment.

However, complex and rigid structures of those materials limit their use compared with corn kernels. In many conversion methods, only the carbohydrate fraction of the materials can be utilized for value-added products, and solid forms of these carbohydrate sources are not reactive as their hydrolysates (solubilized fraction).

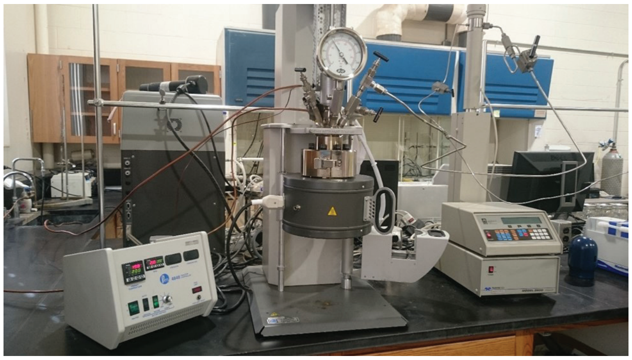

Figure 1. Reactor system used for solubilization experiments

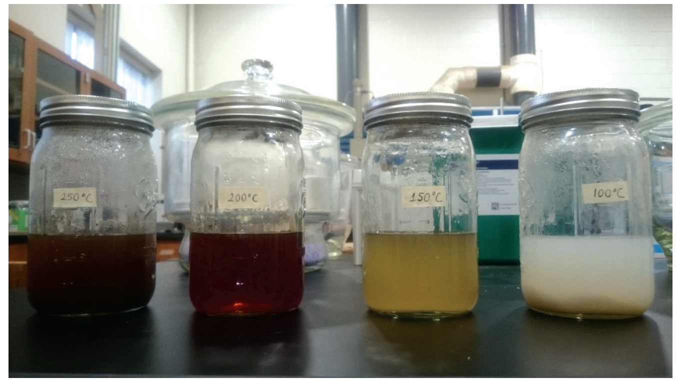


Figure 2. Dissolution of ground corn kernels at different temperatures

Biomass materials and corn kernels must first be broken down into smaller molecular weight soluble components to release the carbohydrates into hydrolysate for their efficient conversion into various products. Hydrolysates from biomass and corn can be used for production of a wide range of value-added products, including biofuels (ethanol, hydrogen, etc.), industrially important chemicals (e.g., solvents), and food products (sugar and sugar alcohols, etc.).

Hydrothermal treatment is an alternative way to hydrolyze lignocellulosic biomass and related materials in an environmentally friendly manner by only manipulating temperature and pressure conditions. Significant advantages of this treatment over most commonly used biomass breakdown methods (alkali, acidic, and enzymatic) are that solubilization takes place in a safe solvent (water) and no corrosive, hazardous, or toxic chemicals and expensive enzymes are needed in the process.

The research results from solubilization efficiency of potential renewable feedstocks, biomass materials, and field corn kernels were evaluated in a safe dissolution medium, hydrothermal condition, for production of various value-added products. The selected biomass materials for the study were:

- nonfood energy crops, which usually require low cost and low maintenance to grow compared with other high value/cash crops: switchgrass and miscanthus;
- agricultural biomass residues, which are natural byproducts of the food crops: wheat straw and corn stover; and
- invasive forest biomass, which causes a serious ecological and economic concern because of rapid and widespread expansion of some of the invasive species such as eastern red cedar.

## Hydrothermal Solubilization of the Materials

In this section, some of the procedures involved in the hydrothermal solubilization process are briefly introduced. The biomass materials and corn samples, which had 7.5–8.5 percent and 12.3 percent moisture, respectively, were ground and sieved to pass a 1 mm (0.04 inch) screen before use.

Solubilizations of ground samples were performed in a 500 ml (16.9 oz) stainless steel high-pressure reactor (Parr Model 4520 HP/HT, Parr Instrument Co., Moline, Illinois, USA) equipped with a magnetic drive stirrer and temperature controller system. The 6 g (0.013 lb) ground sample and 350 ml (11.8 oz) of water were placed in the reactor and air in the sealed reactor was purged with carbon dioxide ($CO_2$). The mixture was heated to 200°C (392°F) and the reactor was pressurized with $CO_2$ to 2000 psi (13.79 MPa) pressure using an ISCO 260D pump (Isco Inc., Lincoln, Nebraska, USA). The contents of the reactor were mixed at 200 rounds per minute via the magne-drive for one hour *(Figure 1)*. The hydrolysate solution was collected and the clear solution was analyzed for total organic carbon (TOC) content. The solid residue was dried at 40°C (104°F) and used for calculation of percent hydrolysis.

## Comparison of Solubilization Efficiencies of Biomass Materials with Field Corn Kernels

Because of their structure and composition, field corn kernels are expected to dissolve easily in hydrothermal conditions compared with lignocellulosic biomass. Most of the carbohydrates in corn solely consist of D-glucose. Depending on the solubilization conditions, the carbohydrates released into the hydrolysate can have different molecular weights (starch polysaccharide, D-glucose monosaccharide, etc.). The TOC contents of the hydrolysates correspond to

Table 1. Comparison of solubilization efficiencies of biomass materials with corn

| Material | Hydrolysis (%) | TOC (mg L-1) |
|---|---|---|
| Miscanthus | 51.2 ± 1.2 | 2304 ± 21 |
| Switchgrass | 52.3 ± 1.0 | 2201 ± 23 |
| Corn stover | 57.1 ± 1.4 | 2452 ± 28 |
| Wheat straw | 57.8 ± 1.6 | 2200 ± 21 |
| Eastern red cedar | 62.6 ± 1.3 | 2500 ± 24 |
| Field corn kernel | 91.4 ± 1.0 | 5800 ± 30 |

the combination of soluble form of all these components.

Dissolution of the ground corn kernels at different temperatures resulted in different contents and compositions of the hydrolysates. Undissolved residues left after hydrolysis were also different. The hydrolysates turned dark brown as hydrolysis temperature was increased. *Figure 2* shows visible differences of these hydrolysates.

Hydrolysis over 250°C (482°F) leads to decomposition and gasification reactions of the carbohydrate fractions solubilized and was therefore not included in the study. The best thermal condition for solubilization of corn was found to be 200°C (292°F). The hydrolysates from this temperature had the highest TOC content and left the lowest amount of insoluble residue. Therefore, dissolution of biomass materials was performed at 200°C (292°F) for comparison. The solubilization efficiency of corn was higher than all biomass materials studied (*Table 1*). The nonedible energy crops switchgrass and miscanthus had the lowest hydrolysis percentage while eastern red cedar had the highest values.

## Summary

The hydrothermal solubilization efficiency of the biomass materials highly depended on biomass types. The cellulose, hemicellulose, and lignin contents of biomass materials and accessibility of these fractions in the biomass structures (hemicellulose fraction is more accessible versus cellulose fraction embedded in the lignin matrix) play significant roles in solubilization. Based on the experimental results, it is evident that none of the biomass materials studied can compete with field corn kernel, which was vulnerable to hydrolysis and resulted in high organic carbon concentrated hydrolysate. However, availability, abundance, and requirements for growth, growth rate, etc., parameters considerably affect the feedstock selection for value-added products. In this matter, eastern red cedar and corn stover can be good alternatives for production of value-added products.

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