Pretreatment of Rice Straw to Intermediate Bio-Refinery Chemical, Hmf

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ABSTRACT

The conversion of biomass to chemicals on an industrial scale at a competitive cost requires the development of biorefineries analogous to petrochemical refineries. Hydroxymethylfurfural (HMF) is a promising platform chemical. Our objective of this experiment is the conversion of rice straw to HMF. There were three main stages of the process, pretreatment of rice straw, hydrolysis of cellulose to glucose, and dehydration of glucose to HMF. Optimum operating conditions for the process were calculated by conversion of raw material and yield of the products. The research aims to efficiently and effectively convert rice straw to HMF.

KEYWORDS: hydroxymethylfurfural (HMF), Pretreatment Hydrolysis, Dehydration

INTRODUCTION

Rice straw is termed as an agriculture waste which is usually burnt on site or used as a part of fodder. Although agricultural experts and soil scientists urge to boost reuse of Rice straw back in the field for the next season, the practicality of the method is questionable. Therefore, finding an alternative use for this massive quantity of waste is critically important. Hydroxymethylfurfural (HMF) is one of the most promising biomass derived platform chemicals. It can be synthesized from biomass carbohydrates mainly glucose and fructose via dehydration under acidic conditions. Cellulose is the main component of the biomass and there are many other constituents. Therefore, it is important to identify the type of biomass to be used for the experiment and its composition. Recently, lignocellulosic biomass such as rice straw has emerged as a feedstock to produce bioethanol. Even though bioethanol is a good way to reuse the biowaste, modern researches are moving toward the synthesis of HMF because it has a lot of advantages over bioethanol such as high energy density, water insolubility, and producing an important intermediate for many other chemicals like DMF.

METHODOLOGY

There were three major processes the in production of HMF.

Pretreatment of rice straw: The rice straw sample was dried and cut to a particle size < 1cm and stored at room temperature. Then the rice straw sample was treated with slightly acidic (H_2SO_4) hot water to remove hemicellulose. Then alkaline treatment was conducted with NaOH to remove lignin from the rice straw.

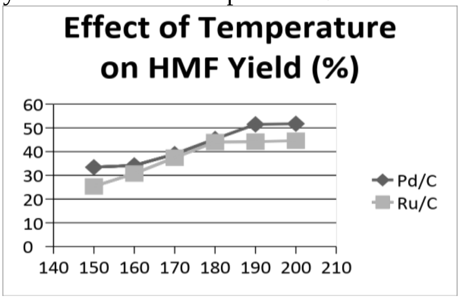
Hydrolysis of cellulose into Glucose: Then, 5g of cellulose sample was subjected to the hydrolysis reaction with H_2SO_4 acid. This autocatalytic reaction was conducted by varying the temperature from 180°C to 200°C and the reaction time from 1 hour to 5 hours. Glucose rich filtrate was collected by vacuum filtration.

Dehydration of glucose into HMF: Then 15 ml of glucose solution was mixed with 50 ml of DMSO solvent and heated in the autoclave reactor with Pd/C and Ru/C catalysts. The reaction was carried out by varying the temperature and reaction time. After that, the derived HMF was separated by conducting a liquid-liquid extraction with DCM.

RESULTS AND DISCUSSION

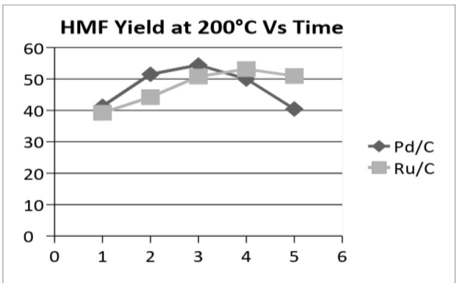
1. Effect of reaction temperature

Effect of the temperature for all the three processes is very critical and product yield increases with the temperature. When we consider the major reaction of conversion of glucose to HMF, 51.77% of HMF yield with Pd/C catalyst and 44.61% of HMF yield from Ru/C catalyst can be obtained. Figure 1 shows the HMF yield at different temperatures.



2. Effect of reaction time

Glucose yield is decreased with the reaction temperature. Maximum yield of 45% was obtained for 1 hour reaction time. When we consider the HMF yield, maximum yield was obtained for a 3 hour reaction time. The values are 54.46% for Pd/C catalyst and 50.79% for the Ru/C catalyst. HMF yields are shown in Figure 2.



CONCLUSIONS

From a series of experiments, we identified the most suitable conditions for hemicellulose removal to be 220°C and 2 pH acidic solutions. At 50°C and 12% (w/v) NaOH concentration, the efficiency of alkali treatment is very high. The most suitable temperature for the cellulose hydrolysis process is 200°C and 1-hour reaction time gives the highest glucose yield of 45%. For the dehydration reaction, Pd/C catalyst gives more conversion of glucose to HMF than Ru/C catalyst. The optimum temperature for the reaction is 200°C and the optimum reaction time is 1 hour.

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