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Towards integrated biorefinery from dried distillers grains: Evaluation of feed application for Co-products

Robert Lupitskyy [a], *Charles Staff* [b], *Jagannadh Satyavolu* [a,*]

[a] *Conn Center for Renewable Energy Research, University of Louisville, Louisville, KY, USA*
[b] *Distillers Grain Technology Council, University of Louisville, Louisville, KY, USA*

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ABSTRACT

In this paper, we presented an integrated C5-based biorefinery concept to produce C5-platform of biofuels and biochemicals using corn fiber from Dried Distillers Grains (DDG). The process utilizes a selective hydrolysis process to generate a xylose-rich hydrolyzate stream and two co-product streams: fine fraction generated during mechanical pretreatment of DDG using Mesh 20 sieve and residual fiber after hydrolysis. Utilization of these two co-product streams is critical to the success of the biorefinery. This paper discusses how the two streams are generated, their composition, and their potential value in animal feed applications. Composition analysis of the first co-product stream showed that it is enriched in proteins compared to original DDG (11% higher crude protein content; 36% higher lysine content). The second co-product stream has 113% higher fat content compared to original DDG, as well as 15% higher total digestible nutrients, and 15% higher digestible energy. The results of this study suggest that these co-product side streams can be potentially applied as additives in animal feed, allowing for cost-effective utilization of DDG for bio-products without negatively impacting feed markets associated with DDG.

1. Introduction

Several economic models have been developed to guide the cost effective production of biofuels, chemicals and materials from ligno-cellulosic biomass [1–5]. One common conclusion from these models is the high cost attributed to both the starting biomass material and its handling which results in significant impact on the overall cost of biofuels, chemicals, and materials. The share of feedstock was estimated to be up to 70% of the overall production cost. In order to reduce the impact of the cost of feedstock on the overall production cost, Zhang [6] suggested some of the top priorities of biofuels (biomaterials) R&D to be: 1) cost-effective release of sugars from lignocellulose and 2) co-utilization of lignocellulose components for the production of value-added compounds that subsidize whole biorefineries.

The integrated C5-based biorefinery shown in Fig. 1 is based on the findings from the economic models and is developed with an aim to make biomass-derived chemicals cost competitive in the market place.

* *Corresponding author*. Conn Center for Renewable Energy Research, University of Louisville, 216 Eastern Parkway, Ernst Hall, Louisville, KY 40292, USA. Tel.: +1 502 852 3923.
E-mail address: Jagannadh.Satyavolu@louisville.edu (J. Satyavolu).
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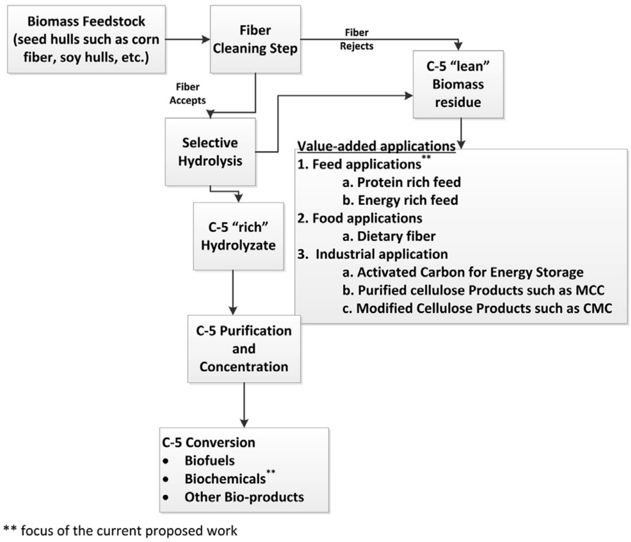

Fig. 1 – Our approach to reduce costs in the production of biofuels, biochemicals, and other bioproducts.

In our approach, we selected pentoses (C-5 sugars) as a primary biomass-derived product. Pentoses can be a precursor for synthesis of a variety of commodity chemicals (C-5 platform), which are currently derived from oil [7]. For this reason, we choose a biomass feedstock with the most appropriate composition, such as seed hulls from grain processing (e.g., corn pericarp fiber from wet milling or dry milling), which will allow us to reduce the number of process steps, capital cost, and downstream processing costs. Seed hulls and grain fiber have a unique composition – higher hemicellulose content compared to cellulose and lower lignin content, compared to other common biomass sources [8,9]. Seed hulls from grain processing are available in large volumes at a consistent quality. For example, corn seed hulls are commercially available at corn processing plants as a component of dried distiller's grains (DDG). The amount of corn seed hulls available in the US is estimated to be about 20 Tg. Their shipping, storage, and other logistics costs are more effectively manageable compared to other traditional biomass feedstocks, such as corn stover.

Currently, DDG are used as a protein-rich animal feed supplement [10]. However, such utilization of a valuable biomass resource is not efficient and there is a strong interest to produce higher value products from DDG with increased income potential. Here we describe an integrated approach to produce higher value product from DDG without jeopardizing the animal feed market. The more efficient utilization of biomass using an integrated approach will not only make the existing processing facilities more cost efficient, but will also create new business and employment opportunities. This will also promote new opportunities for local agriculture and agricultural products.

In our integrated C5-based biorefinery approach, we developed a process for selective extraction of pentoses from DDG using a dilute acid hydrolysis. The process generates two co-product streams: a protein-rich stream and a cellulose-rich stream. This paper discusses the generation of the two co-product streams from our selective hydrolysis process, their resulting composition, nutrition analysis, and their potential applications in animal feed markets. The described approach can co-exist with present grain processing operations with a minimal economic impact on food and feed markets.

2. Materials and methods

2.1. Materials

The dried distiller's grains without solubles (DDG) used for this work were obtained from Brown-Forman distillery (Louisville, KY, 38°12′32″N/85°47′54″W). The grains used in the distillation process were predominantly corn (Zea mays L.). Composition of the DDG used in this study is presented in Table 1. Concentrated sulfuric acid (Sigma–Aldrich) was used for fiber hydrolysis. Sodium hydroxide (Sigma–Aldrich) was used for hydrolyzate neutralization.

2.2. Methods

2.2.1. DDG pretreatment

About 54% by weight of DDG is corn fiber. Mechanical screening of DDG was performed using U.S. standard sieve N 20 (0.85 mm opening). The objective of the screening was to produce a coarse DDG fraction with increased fiber content. During our lab procedure, 0.2 kg of DDG was screened at a time until visually no material was passing through the sieve. On an average, 38% weight fraction of the DDG passed though the sieve. This coarse fraction on the sieve was used in the hydrolysis process. The fines fraction through the sieve was evaluated for feed applications.

2.2.2. Dilute acid hydrolysis

The coarse fraction from physical screening of DDG as obtained above was used in dilute acid hydrolysis. The hydrolysis was performed using a 6 L Mini-mill Laboratory Digester (M/K Systems Inc., Peabody, MA, USA). A schematic of the digester is shown in Fig. 2. As shown in the Figure, acid solution is percolated through a bed of the coarse fiber placed in the basket of the digester. The basket has a perforated bottom; the percolated liquid drains through the bottom and recirculated to the top of the basket through a pump and a heater. The hydrolysis conditions were as follows: 0.4% weight fraction of H_2SO_4; 140 °C; 1 h. Material load was 300 g of the coarse fiber fraction of DDG. The mass ratio of DDG to liquid was 1:10. After the hydrolysis, the hydrolyzate was collected and the residual or post-hydrolysis fiber was washed 2 times with 3 L

Table 1 – The composition: mass fraction of the dry mass of DDG (%).

Protein (crude)	32.7
Fat (crude)	12
Fiber (neutral detergent)	51.7
Fiber (acid detergent)	27.7
ADF indigestible protein	10.7
Ash	2.01

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