Increasing ethanol yield from a bushel of corn; fermentation of distillers grains. Results from the Midwest Consortium for Sustainable Biobased Products and Energy

INTRODUCTION

The expansion of the dry grind ethanol industry provides a unique opportunity to introduce cellulose conversion technology to existing grain to ethanol plants, while enhancing ethanol yields by up to 14%, and decreasing the volume while increasing protein content of distiller's grains. The technologies required are cellulose pretreatment, enzyme hydrolysis, fermentation, and drying. Laboratory data combined with compositional analysis and process simulations are used to present a comparative analysis of a dry grind process to a process with pretreatment and hydrolysis of cellulose in distiller's grains. The additional processing steps are projected to give a 32% increase in net present value if process modifications are made to a 100 million gallon/year plant.

Who are we?

The Midwest Consortium for Biobased Products and Bioenergy (est 1999) is a group of academic and Federal laboratories all doing leading-edge research related to developing advance biofuels and biorefinaires for production of chemicals, power, and other value-added products. Our members have a cumulative research experience in biomass research of over 100 years and member institutions have made fundamental contributions in the areas of pretreatment, strain development, fermentation, and ethanol recovery. Our members include: Purdue University (Michael Ladisch, Randy Woodson, Nathan Mosier, Wally Tyner); University of Illinois: Hans Blaschek, Thaddeus Ezeji; Michigan State University: Bruce Dale, Balan Venkatesh; USDA NCAUR: Mike Cotta, Bruce Dien; Iowa State University: Brent Shanks; Ames Laboratory: John Verkade; Argonne: Seth Synder

A comprehensive approach to process development

The research includes extensive laboratory work on composition, pretreatment, enzymes, and fermentation, techno-economic modeling, cost analysis, and life-cycle analysis.

- **Advanced pretreatments** to enhance the digestibility/reactivity of the fiber component (cellulose and hemicellulose) of DG,

2. **Enzymatic hydrolysis of pretreated DG** to extract fermentable sugars and remove fiber from the DG, thereby, increasing its feed value (see references)

3. **Ethanol and butanol fermentation:** of hexose and pentose sugars to further increase yield from a bu of corn; for butanol see references.

4. **Analysis of composition** and advanced separation methods for ethanol and other products,

5. **Life cycle analysis** to quantify key environmental features of corn based biorefineries and the crop production systems that support them (see references)

6. **Economic analysis** of the processes, technologies, and markets, incorporating uncertainty in key technological and market parameters.

What is in DDGS?

Our study has included perhaps the most complete analysis for base samples of DDGS, wet distillers grains, and thin stillage; see reference list for complete compositional results.

Component (g/kg, db)	DDGS	WDG	Component (g/l)	Thin Stillage
Dry Matter	88.8	35.3	Dry Matter	7.7
Water Extractives	24.7	8.8	Crude protein, fat, & ash	1.3, 1.3, & 0.8
Ether Extractives	11.6	9.6	Glucose & Glucans	13.3
Crude Protein	24.9	36.6	Xylose & Xylans	4.4
Carbohydrates	21.2		Arbinose & Arabinans	0.9
Cellulose	16	12.6	Lactic acid	16.8
Starch	5.2	5.9	Glycerol	14.4
Xylan	8.2	14.9	Acetic acid	0.3
Arabinan	5.3	5.5	Butanediol	1.9
Ash	4.5	2.0	Ethanol	0.6
Total Closure	100.4	96.4	Total Closure	100

AFEX and LHW Processes

Process is only modified on backend to facilitate adding to current ethanol production facilities. DG needs to be pretreated to open up structure prior to extraction of sugars, which was done with either Ammonia Fiber Expansion or Liquid Hot-Water.

DDGS or WDG
+ thin stillage

Pretreatment
(AFEX or LHW)

Enzymatic extraction
of sugars

Fermentation to
Ethanol or Butanol

Butanol or Ethanol
& Enhanced DDGS

Producing Ethanol from DG

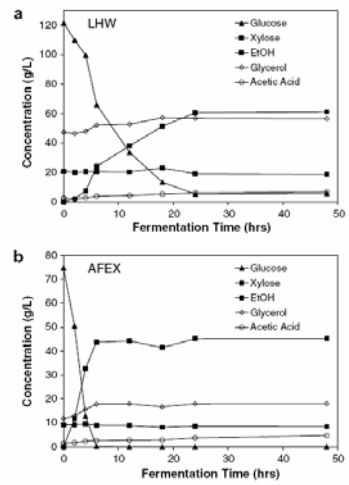

Fig. 3. Fermentation of (a) hydrolyzate of LHW treated WDG at 13% solids (w/w), and (b) hydrolyzate of AFEX treated WDG at 15% solids (w/w). Enzyme loading: 15 FPU/g glucan cellulase (Spezyme CP) and 40 IU/g glucan β-glucosidase (Novozyme 188). Hydrolysis at 50 °C, 200 rpm for 72 h. Final hydrolyzates were concentrated by 5 times for LHW treated WDG and 3.4 times for AFEX treated WDG via lyophilization, prior to the fermentation.

Changes in DDGS

Feed analysis results of DDGS and enhanced DDGS

% Compositions	DDGS Average value[d]	DDGS, (this work)	Enhanced DDGS (from LHW WDG)	Enhanced DDGS (from AFEX WDG)
Moisture	11.1	10.4	6.6	11.5
Crude protein[a]	30.2	28.3	41.2	50.8
Crude fat	10.9	14.5	14.7	7.2
Crude fiber	8.8	6.5	2.9	0.5
Ash	5.8	4.8	5.3	6.0
Pepsin digestibility[b]	–	86.7	86.7	92.2
Carbohydrates[c]	–	52.5	38.8	36.0

Results are expressed on a dry matter basis (wt/wt%).
[a] Crude protein by Kjeldahl.
[b] Percentage of crude protein digested by pepsin.
[c] Carbohydrates calculated by difference from proximate data.
[d] Spichs et al., 2002.

Current vs. LHW Processes for DG

Input and output rate changes of major ingredients

	Base Process	Adv. Process
Yellow dent corn (tons)	998,143	998,143
Ethanol (gallons)	100,000,000	112,670,293
DDGS (tons)	358,997	277,951
Change in outputs from modifying process from base		
DDGS		-22.6%
Ethanol		+12.7%

Capital and financial analysis

	Base Process	Adv. Process
Total capital investment	$148,260,425	$158,454,889
40% equity paid	$59,304,170	$63,381,955
Initial loan payment	$10,901,732	$11,651,340
IRR (real)	33.1%	38.5%
NPV	$161,957,921	$214,581,147
Change in NPV		$52,623,226
% diff from base		32%

Priced when corn was $3.82 /bu and ethanol $2.23/gal.

Where to learn more

A complete summary of the results can be found in the special issue of Bioresource Technology, volume 99, Issue 12, Pages 5155-5260 (August 2008). Cellulose Conversion in Dry Grind Plants, Edited by M. Ladisch and B. Dale.

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