

(21) Utilizing the National Corn-to-Ethanol Pilot Plant to Develop a Predictive Model for Distillers Dried Grain for the Fuel Ethanol and Animal Feed Industries

The objective of this two-year effort is to develop and validate a neural network predictive plant model for the composition of Distillers Dried Grain with Solubles (DDGS), a coproduct resulting from the dry grind fuel ethanol process.

Total project cost: \$807,221

Funding request: \$633,149

Project Lead: Southern Illinois University Edwardsville: National Corn-to Ethanol Research Center

Project Participants: Washington University, St. Louis, Missouri-Department of Chemical Engineering; Emerson Process Management; Illinois Department of Commerce and Economic Opportunity.

Start Date: May 23, 2005

End Date: May 23, 2007

Presentations/Publications

No specific publications or presentations, outside of frequent tours and education at the Center, were provided this quarter.

Patents

No patents have been applied for or are anticipated in the course of this work. The results of this publicly funded work will be readily communicated to the industry.

Progress in Past Quarter and Current Status

Pilot plant trials test for phosphorous conversion in fermentation.

In October, 2005 a plant trial was run to test the change in phytate levels during cooking and fermentation of corn slurry. Samples were taken during the run and analyzed for free phosphorous composition using the experimental method attached (see Appendix A). Although phytate levels on a lab scale showed a significant change with time, similar results were not found in the pilot plant. Figure 1 shows a ratio of phytate to the total phosphorous amounts in several plant fermentations with time. The results do not show a significant change in the nutritionally available phosphorous over the fermentation period. Possible reasons for not observing a change in the phosphorous content could be due to the addition of yeast during the filling of the tank with corn slurry. The yeast could convert free phosphorous while the tank is filling making accurate determination of the change in phosphorous concentration difficult. Further experiments are planned for future baselines to determine if a statistically significant change in free phosphorous occurs as a result of fermentation.

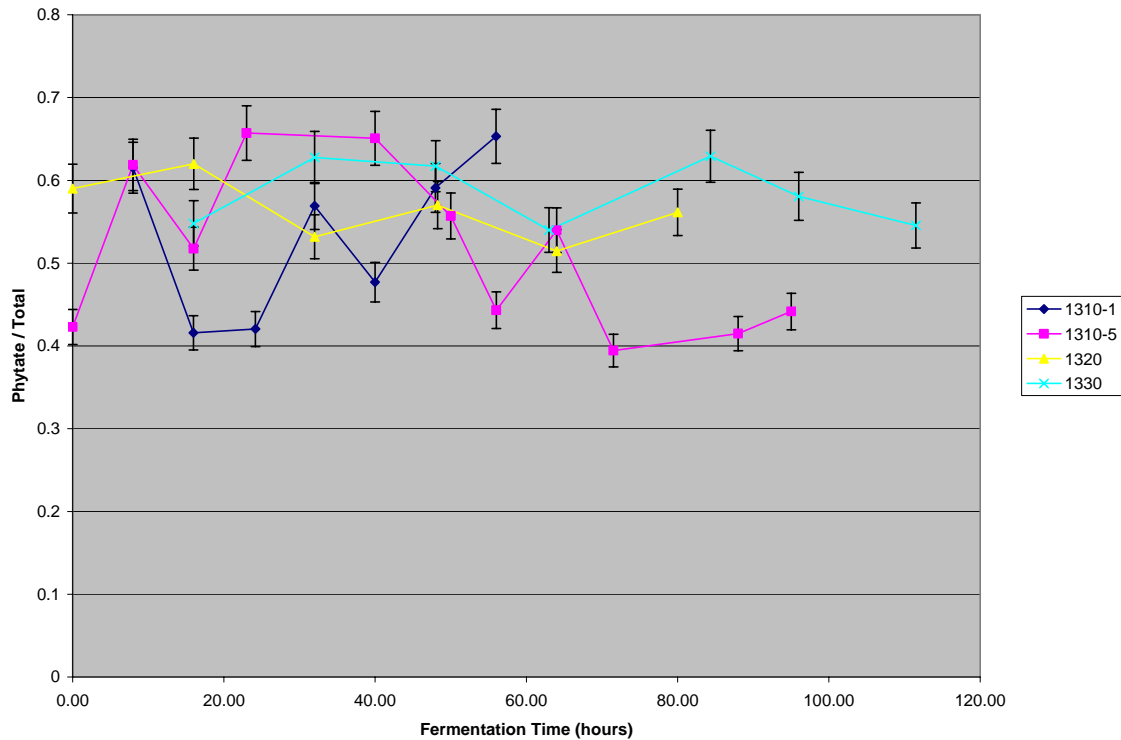


Figure 3: Time-varying plant phosphorous ratios

New pilot-scale dryer will be used to test protein digestibility

In this first stage of DDGS experiments, we will focus on drying DDGS using a Dupps Company pilot-scale dryer. The Dupps pilot dryer has unique capabilities for creating DDGS from wet distiller’s grains. With a residence time of approximately one hour, compared to eight hours or longer for commercial drying systems, the Dupps dryer can generate larger sets of data from a smaller amount of feed than conventional systems. However, compared with laboratory methods for making DDGS, the Dupps pilot dryer is much more representative of a conventional drum dryer, due to it being an exact scale-model of a commercial drum dryer. In addition, the Dupps dryer has the ability to run in two modes: a normal mode which dries with heated air and an air-less mode which dries with steam. This provides a unique ability to control the amount of oxygen and moisture that DDGS comes in contact with during the drying process.

Experimental Plan

The Dupps pilot dryer has several controllable conditions that can be changed, as listed in Table 1.

Table 1: Factors in the experimental trial of the Dupps dryer.

<i>Operating Variable</i>	<i>Significance</i>
Air / Steam Inlet Temperature	Control variable of dryer. Important for rate of drying and product quality.
Drum Rotation Speed	Determines rate of mixing in the dryer

Blower Fan Speed	Rate of air / steam flow. Determines the temperature gradient across the dryer.
Feed Auger Speed	Determines the rate of wet DDGS that can be fed to the dryer.
Oxygen Percentage in Dryer	Determines the amount of moisture in the inlet gas to the dryer. Possible predictor for protein quality.

Other variables will be recorded, such as dryer pressure and outlet temperature, but these are not control variables and are determined by the other factors.

In order to minimize the variability of the trial, a set industry standard composition of DDGS will be used. Wet distillers grains will be mixed with condensed stillage and dried DDGS such that the feed to the dryer will be 30-35% moisture. The corn feed-stock will be used from the same supplier and, preferably, the same bin.

Although the Dupps dryer can separate dried DDGS by particle size, this practice does not occur in industry. In order to be industry representative, samples of the different DDGS particle sizes will be mixed at each sampling period to create a uniform particle size before analysis.

Design of the Experiment

The experimental design will be full-factorial with two blocks representing the two different baseline runs. Full factorial provides the most complete screen for significant variables. Enough of each sample will be collected to allow for replicates if necessary.

A pseudo-randomized table of the different experimental conditions is shown in Table 2. Due to the necessity to un-bolt a flange to change the oxygen content in the dryer, a randomized oxygen percentage is not feasible. At least an hour must be allotted to allow the flange to cool before it can be removed and to seal it takes overnight.

Table 2: Pseudo-randomized conditions for testing dryer operating parameters on DDGS quality.

<i>Condition #</i>	<i>Baseline Run</i>	<i>Inlet Temperature (°F)</i>	<i>Drum Rotation Speed (Amps)</i>	<i>Blower Speed (Hz)</i>	<i>Feed Auger Speed (Hz)</i>	<i>Oxygen (%)</i>
1	1	575	0.25	45	10	0
2	1	575	0.45	45	20	0
3	1	575	0.45	15	10	0
4	1	575	0.25	15	20	0
5	1	525	0.45	45	10	0
6	1	525	0.25	15	10	0
7	1	525	0.45	15	20	0
8	1	525	0.25	45	20	0
9	1	550	0.35	30	15	10
10	1	550	0.35	30	15	10
11	1	525	0.45	15	10	20
12	1	575	0.25	15	10	20

13	1	525	0.25	45	10	20
14	1	575	0.45	15	20	20
15	1	575	0.45	45	10	20
16	1	575	0.25	45	20	20
17	1	525	0.25	15	20	20
18	1	525	0.45	45	20	20
19	2	525	0.25	15	20	0
20	2	575	0.45	45	10	0
21	2	575	0.25	15	10	0
22	2	575	0.25	45	20	0
23	2	525	0.45	15	10	0
24	2	525	0.45	45	20	0
25	2	575	0.45	15	20	0
26	2	525	0.25	45	10	0
27	2	550	0.35	30	15	10
28	2	525	0.25	45	20	10
29	2	550	0.35	30	15	10
30	2	575	0.25	15	20	20
31	2	525	0.45	45	10	20
32	2	525	0.25	15	10	20
33	2	575	0.25	45	10	20
34	2	575	0.45	45	20	20
35	2	575	0.45	15	10	20
36	2	525	0.45	15	20	20

Moisture measurements, dryer pressure, color, and notes will be logged. Samples will be checked into the lab and labeled. The samples will be stored in the cold room until analyzed. Swine protein digestibility of the samples will be estimated via Dr. Stein’s methodology.

Analyze Data

Data will be analyzed with Fusion Pro™ from S-Matrix Corporation. Fusion Pro is an integrated experimental design and statistics package. DeltaV Neural™ from Emerson Process Management will be used to create a neural-net model of the results. Other methods such as partial least-squares or step-wise regression may also be used to determine significant factors and model the results.

Document Results and Make Recommendations

A report will be produced summarizing the results and further experiments will be planned based on the relevant factors determined. A presentation will be presented at the Fuel Ethanol Workshop based on the results.

List of significant process variables that affect DDGS nutrient composition

Table 3 shows a listing of the significant input variables expected to affect DDGS composition. This list was compiled from communications with plant operations, the DDGS advisory group, from DDGS survey results, and from literature. In terms of developing a predictive model, these variables have been determined as most likely to impact DDGS composition.

Table 3: Variables in the plant which could significantly impact DDGS nutritional composition. The variables are ranked in order of importance. Entries with an asterisk are potential control variables for the process.

#	<i>Input Variables</i>
1	Dryer outlet temperature*
2	Dryer inlet temperature*
3	Dryer moisture content
4	Amount of backset in process
5	Product recycle ratio*
6	Solids percentage in wet cake
7	Moisture content in dryer feed
8	Solids content of syrup*
9	Moisture content of DDGS product*
10	Reboiler temperature*
11	Fermentation residual starch
12	Fermentation residual sugar
13	Fermentation time*
14	Yeast and yeast nutrient concentrations*
15	Jet cooker temperature*
16	Liquefaction hold time*
17	Liquefaction temperature
18	α-amylase, gluco-amylase, phytase enzyme concentrations*
19	Hammer mill particle size distribution*
20	Corn flour particle size distribution
21	Corn initial properties

These variables will be used as a guideline for planning future experiments.

Plans for Next Quarter

Phosphorous in DDGS is in two forms, an inorganic salt available to all animals and an organic bound molecule called phytate, which can only be processed by ruminants. Tailoring phosphorous concentration of DDGS to ruminants or non-ruminants could make it a more valuable co-product could possibly prevent environmental contamination by undigested phosphorous.

Some yeast strains contain an enzyme called phytase which can convert phytate into free phosphorous. Phytase can also be purchased commercially from several vendors. With the help of Joe Maurer, we are planning an experiment to test different strains of yeast and different phytase enzymes to determine their capability to convert phytate to phosphorous. Such a strategy if developed would allow a simple means to create a phosphorous composition tailored to a particular feed formulation.

Protein and Digestible Protein.

In an ethanol plant, the characteristics of these components are most likely changed in four unit processes, liquefaction, saccharification, fermentation and drying. In the liquefaction, saccharification and fermentation processes, protein and energy content vary due to the starting feedstock and the efficiency of conversion. In the dryer, protein and fat are likely degraded by excessive temperatures and conditions. The most likely contributor to protein degradation is the effect of the Maillard reaction, an example of which is shown in Figure 1. Initially, we will focus on drying as our first attempt to create a predictive model.