Minnesota Pork Board
INTERIM RESEARCH REPORT

I. Title: Impact of reduced-oil DDGS, dietary energy system, and wheat midds in growing-finishing pig diets on growth performance and pork fat quality.

Identification Number:
Principal Investigator: Gerald C. Shurson
Institution: University of Minnesota
Date Report Submitted: December 9, 2014

II. Stated Objectives from original proposal

The primary objective of this project was to validate equations for prediction of metabolizable energy (ME), net energy (NE), and digestible amino acids that were developed for distillers dried grains with solubles (DDGS). Sources of DDGS vary in crude fat content, and it is necessary to determine effects of reduced-oil DDGS (RO-DDGS) on growth performance of growing-finishing pigs. A secondary objective was to evaluate the impact of feeding diets containing RO-DDGS, and the combination of RO-DDGS and wheat-midds, on pork fat quality. Specific objectives include:

- Determine if feeding diets containing RO-DDGS formulated on a predicted ME and digestible lysine content basis affects pig growth performance.
- Determine the magnitude of change in backfat and belly fat iodine value (IV) from feeding RO-DDGS diets.
- Determine if formulating RO-DDGS diets on a NE basis vs. an ME basis affects growth performance and pork fat quality.
- Determine the impact of wheat midds and RO-DDGS on growth performance and carcass characteristics when diets are formulated on a NE basis.

III. Progress toward meeting objectives

This project involved 3 experiments designed to meet the objectives described previously. Activities for each experiments were divided into preparation, feeding, carcass data collection, sample chemical analysis, data analysis, and report writing.
Experiment 1. Validation of ME prediction equations and the impact of feeding diets containing corn DDGS with variable oil content on growth performance, carcass composition, and pork fat quality of growing-finishing pigs. We completed the animal feeding, carcass sample collection, and data analyses. Currently, we are writing a manuscript for publication. Results from Exp.1 were reported in Interim Research Report submitted on November 27, 2013.
Experiment 2. Impact of feeding DDGS with variable NE content on growth performance and carcass quality of growing-finishing pigs, and evaluation and development of NE prediction equations. We have completed animal feeding, carcass sample collection, and data analysis. Currently, we are writing a manuscript for publication. In addition to the original objectives, we conducted additional evaluations to: 1) Determine the NE content of DDGS sources and evaluate

published NE prediction equations, and 2) Determine the back iodine value (IV) of pigs fed 8 different diets and evaluate published backfat IV prediction equations.

Experiment 3. Impact of feeding DDGS and wheat middlings on growth performance and carcass composition of growing-finishing pigs. The animal feeding trial was completed on November 19th, 2014, and ultrasound data for carcass composition are currently being summarized and statistically analyzed.

IV. Status of project in regards to stated timeline

This project is currently following the planned schedule.

V. Modifications of project from original proposal

When we wrote and submitted the original proposal, we anticipated that we would be able to use NE prediction equations for reduced-oil DDGS developed from a previously funded National Pork Board funded project. Unfortunately, due to the limited number of DDGS samples (n = 6) evaluated in this project, and the less than expected variability in NE content among these samples, we were unable to use multiple linear regression analysis to generate any NE prediction equations. Therefore, we modified the approach in our original proposal to evaluate NE estimates of DDGS sources provided by Illuminate® (NutriQuest, Mason City, IA), which are widely used by nutritionists and pork producers in MN and throughout the US. As a result, we used NE values from Illuminate® to formulate diets in Experiment 2. We also added 2 other objectives for to this project to obtain more information using the growth performance and carcass composition data collected from Experiment 2. We wanted to determine the NE content of the DDGS sources using NRC (2012) growth model calculations, which included actual body weight and gain:feed of pigs fed these DDGS diets as the main model input factors. We also used the NRC (2012) model to calculate NE estimates and compare precision and accuracy of 5 published NE prediction equations as well as NE estimates from Illuminate®. In addition, we used pork fat samples that were collected and analyzed for fatty acid composition in Experiment 1 and 2 to determine the iodine value of pork fat from pigs fed 8 different diets containing DDGS with variable oil content. These data allowed us to evaluate the precision and accuracy of 6 equations used to predict pork fat IV of carcasses from pigs fed DDGS sources with varying in oil content.

VI. Preliminary results

Experiment 1

Data collection and analyses have been completed, and preliminary results have been presented at the 2014 Midwest Section ASAS/ADSA meeting in Des Moines, IA. The experimental protocol was approved by the University of Minnesota Institutional Animal Care and Use Committee (1305-30619A). Growing-finishing mixed sex pigs (n = 432; initial BW = 25.9 kg) were housed in 48 pens, blocked by initial BW, and blocks were randomly allotted to 1 of 4 dietary treatments (9 pigs/pen, 12 pens/treatment). Pigs were fed 4 experimental diets using a 4-phase feeding program (Table 1). Dietary treatments consisted of a corn-soybean meal diet (CON) and 3 corn-soybean meal diets containing

40% RO-DDGS with variable concentrations of ether extract (EE). Diet 2 contained a low oil DDGS (5.9% EE; LOW) source, diet 3 contained a medium oil DDGS (9.9% EE; MED) source, and diet 4 contained a high oil DDGS (14.2% EE; HIGH) source. During the 90-day trial, BW and feed disappearance were measured bi-weekly and phases were change based on average pen BW. The ADFI, ADG, and G:F data were analyzed as repeated measures using the MIXED procedure of SAS, with pen and block as random effects and diet as a fixed effect. Preliminary data suggest that pigs fed CON had greater ADFI than pigs fed MED and HIGH, but similar to pigs fed LOW (Table 2). However, there were no differences in ADFI and ADG among pigs fed diets containing the 3 sources of DDGS (Table 2). However, gain:feed was slightly reduced in pigs fed LOW compared with other dietary treatments (Table 2). Pigs fed CON had greater HCW, dressing percentage, and loin muscle area than those fed the DDGS diets, but there were no differences among DDGS dietary treatments (Table 3). No treatment differences were observed for backfat depth and percentage carcass fat-free lean (FFL; Table 3). Belly fat iodine value (IV) of pigs fed LOW and MED was decreased compared with pigs fed HIGH, but IV from pigs fed LOW and MED was greater than pigs fed CON (Table 4). These preliminary results suggest that despite variable oil concentration among 3 sources of DDGS, growth performance and carcass composition of pigs was generally not affected. Furthermore, the reduced oil content of DDGS improved pork fat quality by decreasing IV of carcass fat. However, the ME prediction equation from Anderson et al. (2013) slightly overestimated ME content of low-oil DDGS based on reduced G:F, compared with the medium and high-oil DDGS sources.

Table 1. Description of dietary treatments used in Experiment 1.

Treatment	**% DDGS and source**	**Ingredient source**
CON	0%, Corn-soybean meal - Control	Corn and soybean meal Morris, MN
LOW	40%, Low oil POET (~5.9%)	POET Dakota Gold Groton, SD
MED	40%, Medium oil ADM (~8.7%)	ADM, Cedar Rapids, IA
HIGH	40%, High oil Abengoa (~10.6%)	Abengoa BioEnergy, Mt. Vernon, IN

Table2. Least square means for BW, ADFI, ADG, and G:F of pigs fed diets with reduced oil dried distillers grains with solubles (RO-DDGS) in Experiment 1.

		40% DDGS		
Item	Control	LOW	MED	HIGH
No. Pens	12	12	12	12
BW, kg				
Initial BW[2]	39.24	39.52	38.95	39.58
Phase 1	55.91	54.72	54.15	55.03
Phase 2	81.11	78.93	79.01	79.02
Phase 3	104.04	103.04	105.14	102.89
Final BW	122.66^{x}	118.65^{y}	118.59^{y}	119.44^{y}
SEM	0.91	0.91	0.88	0.91
P-value				
Diet		0.41		
Phase		<0.01		

Diet x Phase			<0.01	
ADFI, kg/d				
Phase 1	2.062	2.008	1.949	1.982
Phase 2	2.547^{x}	2.477^{xy}	2.404^{y}	2.426^{y}
Phase 3	3.049^{x}	2.927^{y}	2.881^{y}	2.862^{y}
Phase 4	3.228	3.196	3.212	3.121
Overall	2.721^{x}	2.652^{xy}	2.612^{y}	2.598^{y}
SEM	0.029	0.029	0.029	0.029
P-value				
Diet			0.02	
Phase			< 0.01	
Diet × Phase			0.62	
ADG, kg/d				
Phase 1	0.967^{x,}	0.872^{y}	0.872^{y}	0.892^{y}
Phase 2	0.980^{x}	0.943^{xy}	0.927^{y}	0.933^{y}
Phase 3	0.994^{x}	0.948^{y}	0.952^{xy}	0.934^{y}
Phase 4	0.934	0.909	0.946	0.946
Overall	0.969^{x}	0.918^{y}	0.924^{y}	0.926^{y}
SEM	0.009	0.009	0.009	0.009
P-value				
Diet			< 0.01	
Phase			< 0.01	
Diet × Phase			0.06	
G:F				
Phase 1	0.471^{x}	0.436^{y}	0.449^{y}	0.451^{y}
Phase 2	0.386	0.382	0.386	0.386
Phase 3	0.326	0.324	0.331	0.326
Phase 4	0.289^{xy}	0.284^{x}	0.295^{xy}	0.303^{y}
Overall	0.368^{x}	0.356^{y}	0.365^{x}	0.367^{x}
SEM	0.003	0.003	0.003	0.003
P-value				
Diet			0.02	
Phase			< 0.01	
Diet × Phase			0.06	

[1]Concentration of ether extract in each source of RO-DDGS, % as is basis.

[2]Body weight of pig when feeding experimental diets started.

[xyz]Superscripts with different letters within a row diets differ ($P < 0.05$).

Table 3. Effects of feeding diets containing distillers dried grains with solubles (DDGS) with variable oil content on carcass characteristics in Experiment 1.

		40% DDGS				
Item	Control	LOW	MED	HIGH	SEM	*P*-value
HCW, kg	90.97^{x}	86.69^{y}	86.80^{y}	87.24^{y}	0.88	<0.01
Carcass yield, %	74.22^{x}	73.03^{y}	72.85^{y}	73.00^{y}	0.17	<0.01
Backfat depth[1], mm	20.56	19.86	19.21	19.77	0.48	0.29
LMA[1], cm^2	42.06^{x}	39.38^{y}	39.09^{y}	39.37^{y}	0.53	<0.01
Fat-free lean[1], %	51.87	51.62	51.88	51.68	0.26	0.86

[1]Final BW was used as covariance in the statistical analysis.

[xy]Superscripts with different letters within a row diets differ ($P < 0.05$).

Table 4. Fatty acid composition of pigs fed diets containing DDGS with variable oil concentration in Experiment 1.

	CON			LOW			MED			HIGH				*P* Values		
Item	Back	Belly	Jowl	Back	Belly	Jowl	Back	Belly	Jowl	Back	Belly	Jowl	Pooled SEM	Diet	Depot	Diet × Depot
C14:0	1.41^{de}	1.57^{f}	1.39^{de}	1.19^{b}	1.42^{e}	1.27^{bc}	1.19^{b}	1.42^{de}	1.27^{bc}	1.11^{a}	1.33^{cd}	1.18^{b}	0.034	<0.001	<0.001	0.29
C16:0	25.66^{h}	24.99^{g}	23.51^{f}	21.84^{cd}	22.65^{e}	21.67^{cd}	21.64^{cd}	22.16^{de}	21.40^{bc}	20.67^{ab}	21.18^{bc}	20.46^{a}	0.281	<0.001	<0.001	<0.001
C18:0	13.57^{f}	10.60^{e}	10.12^{de}	10.31^{de}	9.15^{bc}	8.91^{abc}	10.30^{de}	8.80^{ab}	8.84^{ab}	9.72^{cd}	8.26^{a}	8.75^{ab}	0.297	<0.001	<0.001	<0.001
C20:0	0.28^{e}	0.23^{ab}	0.22^{ab}	0.26^{de}	0.23^{bc}	0.22^{ab}	0.25^{d}	0.23^{b}	0.22^{a}	0.25^{cd}	0.23^{ab}	0.23^{ab}	0.007	0.86	<0.001	0.06
SFA[2]	41.69^{h}	38.17^{g}	36.02^{f}	34.43^{e}	34.23^{e}	32.82^{bcd}	34.20^{de}	33.42^{cde}	32.49^{abc}	32.52^{abc}	31.75^{ab}	31.33^{a}	0.524	<0.001	<0.001	<0.001
C16:1	2.32^{cd}	3.35^{f}	2.97^{e}	1.66^{ab}	2.61^{cd}	2.50^{cd}	1.70^{ab}	2.61^{d}	2.37^{cd}	1.43^{a}	2.30^{c}	1.95^{b}	0.112	<0.001	<0.001	0.50
Oleic18:1	39.05^{ef}	41.26^{g}	42.14^{g}	35.35^{b}	38.09^{de}	39.17^{f}	35.78^{b}	38.19^{def}	38.72^{ef}	34.08^{a}	37.00^{cd}	36.82^{bc}	0.427	<0.001	<0.001	0.53
C20:1	0.79^{c}	0.74^{bc}	0.48^{a}	0.66^{b}	0.70^{bc}	0.70^{bc}	0.69^{bc}	0.71^{bc}	0.66^{b}	0.66^{b}	0.69^{bc}	0.74^{bc}	0.044	0.94	0.04	<0.001
MUFA[3]	45.33^{e}	49.59^{f}	49.75^{f}	40.12^{bc}	44.77^{e}	45.87^{e}	40.66^{c}	44.86^{e}	45.12^{e}	38.30^{a}	43.03^{d}	42.43^{d}	0.575	<0.001	<0.001	0.58
Linoleic18:2	10.28^{ab}	9.50^{a}	10.97^{b}	22.02^{d}	17.86^{c}	17.72^{c}	21.76^{d}	18.50^{c}	18.70^{c}	25.62^{e}	21.87^{d}	22.48^{d}	0.563	<0.001	<0.001	<0.001
Linolenic18:3	0.42^{a}	0.46^{ab}	0.40^{a}	0.63^{cd}	0.56^{bc}	0.48^{ab}	0.62^{cd}	0.57^{bcd}	0.47^{ab}	0.68^{d}	0.64^{cd}	0.64^{cd}	0.041	<0.001	0.006	0.45
C20:2	0.50^{a}	0.50^{a}	0.47^{a}	0.94^{cd}	0.83^{b}	0.95^{cd}	0.96^{d}	0.87^{bc}	0.98^{d}	1.07^{e}	0.97^{d}	1.14^{f}	0.029	<0.001	<0.001	0.002
C20:3	0.07^{cde}	0.06^{abc}	0.04^{a}	0.08^{de}	0.07^{cde}	0.05^{ab}	0.08^{de}	0.06^{bcd}	0.06^{abc}	0.08^{e}	0.07^{cde}	0.06^{bcde}	0.006	0.05	<0.001	0.84
PUFA[4]	11.51^{ab}	10.79^{a}	12.23^{b}	24.05^{d}	19.68^{c}	19.63^{c}	23.78^{d}	20.38^{c}	20.58^{c}	27.81^{e}	23.92^{d}	24.75^{d}	0.604	<0.001	<0.001	<0.001
IV[5]	57.72^{a}	60.17^{b}	62.53^{c}	74.11^{ef}	70.74^{d}	71.22^{d}	74.34^{fg}	72.03^{de}	72.25^{de}	78.96^{i}	76.41^{gh}	76.89^{h}	0.789	<0.001	0.004	<0.001

[1] Concentration of fatty acids are expressed as grams of fatty acid/100 g fat.

[2] Total saturated fatty acids=([C8:0]+[C10:0]+[C12:0]+[C14:0]+[C16:0]+ [C17:0] + [C18:0] +[C20:0] + [C22:0] + [C24:0]); brackets indicate concentration.

[3] Total monounsaturated fatty acids = ([C14:1] + [C16:1] + [C18:1 – 9c] + [C18:1 – 11c] + [C20:1] + [C24:1]); brackets indicate concentration.

[4] Total polyunsaturated fatty acids = ([C18:2*n*-6] + [C18:3*n*-3] + [C18:3*n*-6] + [C20:2] + [C20:4*n*-6]); brackets indicate concentration.

[5] IV = Iodine value.

[abcdefg] Superscripts with different letters within a row diets differ ($P < 0.05$).

Experiment 2

Data collection and analyses have been completed, and preliminary results will be presented in three abstracts at the 2015 Midwest Section ASAS/ADSA meeting in Des Moines, IA. The experimental protocol was approved by the University of Minnesota Institutional Animal Care and Use Committee (1311-31086A). Pigs (n = 432) were blocked by initial BW (22.0 ± 4.3 kg) and pens were allotted randomly to 1 of 4 dietary treatments (9 pigs/pen, 12 replicates/treatment). Dietary treatments consisted of corn-soybean meal diets containing 40% DDGS with increasing NE (as-fed basis) content (Table 5) predicted from Illuminate®: 1) low NE (2,083 kcal/kg; LOW), 2) medium-low NE (2,255 kcal/kg; ML), 3) medium-high NE (2,469 kcal/kg; MH), and 4) high NE (2,743 kcal/kg; HIGH). Diets met or exceeded NRC (2012) nutrient requirements and were calculated to contain the same standardized ileal digestible Lys:NE within phases. Growth performance and carcass data were analyzed using the Proc MIXED of SAS. As shown in Table 6, overall ADFI (kg) of pigs fed ML (2.63) was greater ($P < 0.05$) than MH (2.45) and HIGH (2.41), but not different from LOW (2.53), and ADFI differed among LOW, MH, and HIGH treatments. The overall ADG (Table 6) of pigs fed ML (0.90 kg/d) was less ($P < 0.05$) than MH (0.94 kg/d). However, ADG of pigs fed LOW (0.93 kg/d) and HIGH (0.91 kg/d) was similar and was not different from pigs fed ML or MH. Gain:feed was reduced ($P < 0.05$) in pigs fed ML (0.361) compared with LOW (3.84), MH (0.398), and HIGH (0.394). No treatment differences ($P > 0.40$) were observed in HCW, dressing percentage, backfat depth, LM area, and carcass percent fat-free lean among dietary treatments (Table 7). Assuming NE content of corn and soybean meal based using values published in NRC (2012), calculations were made using the NRC (2012) model to match the model-predicted G:F with the observed G:F. These calculations resulted in NE estimates of 2,532, 2,068, 2,773, and 2,672 kcal/kg as-fed for LOW, ML, MH, and HIGH DDGS sources, respectively (Table 8). Error and bias of predicting NE using the NRC (2012) model estimates for the 4 DDGS sources were calculated for each equation and Illuminate® estimates (Table 8). Illuminate® estimates provided the lowest error and bias (289.1 and -123.8 kcal/kg, respectively). These preliminary results suggest that G:F responses of pigs did not correspond to the increasing NE estimates of the 4 DDGS sources provided by Illuminate®. However, Illuminate® provided the best estimates compared with other NE equations evaluated, but appeared to have overestimated NE content for ML and HIGH DDGS sources, and underestimated NE content for the LOW and MH DDGS sources. The variable NE content of the DDGS sources evaluated had no impact on carcass composition of growing-finishing pigs.

Backfat samples were collected from 2 pigs (n = 96/experiment, 24 pigs/treatment) with BW closest to the pen mean BW. Backfat samples were analyzed for fatty acid composition, and IV was calculated using: IV = [C16:1] × 0.95 + [C18:1] × 0.86 + [C18:2] × 1.732 + [C18:3] × 2.616 + [C20:1] × 0.785 + [C22:1] × 0.723. Iodine value data of backfat samples collected from Experiment 1 were combined with the data collected in Experiment 2 to evaluate the prediction precision and accuracy of published backfat IV equations. Calculated backfat IV of the 8 diets ranged from 57.7 to 82.3 g/100g (Table 9). Error and bias of equations used to predict backfat IV of pigs fed the 8 diets were calculated and results indicated that backfat IV was predicted poorly using equations based on percentage of DDGS in diet. However, using equation: 52.4 + (0.315 × diet IVP) resulted in the best estimates for backfat IV due to the lowest prediction error and low bias.

Table 5. Description of DDGS sources used in Experiment 2.

Treatment	**DDGS source**	**Manufacturer**
LOW	Low NE DDGS (2,083 kcal NE/kg; 10.7% EE)	CornPlus, LLC, MN
ML	Medium-low NE DDGS (2,255 kcal NE/kg; 5.6% EE)	Poet Biorefining, Mitchell, SD
MH	Medium-high NE DDGS (2,469 kcal NE/kg; 14.2% EE)	Highwater Ethanol, LLC, Lamberton, MN
HIGH	High NE DDGS (2,743 kcal NE/kg; 16.0% EE)	Pine Lake Corn Processors, LLC, Steamboat, IA

Table 6. Least square means for BW, ADFI, ADG, and G:F of pigs fed diets containing 40% of 1 of 4 sources of dried distillers grains with solubles (RO-DDGS) with variable predicted NE content in Experiment 2.

	40% DDGS			
	LOW	ML	MH	HIGH
No. Pens	12	12	12	12
BW, kg				
Initial BW	22.0	22.0	21.9	21.9
Period 1	44.5	43.3	44.8	44.5
Period 2	58.5	56.4	58.7	57.6
Period 3	72.8	70.0	72.9	71.5
Period 4	87.2	83.5	86.7	85.2
Period 5	99.0	95.3	98.8	97.2
Period 6	112.2	109.6	112.7	110.8
SEM	2.2	2.2	2.2	2.2
P-value				
Diet			0.85	
Phase			<0.01	
Diet × Period			<0.01	
ADFI, kg/d				
Period 1	1.54	1.54	1.49	1.49
Period 2	2.27	2.31	2.23	2.17
Period 3	2.69	2.70	2.56	2.52
Period 4	2.82^{xy}	2.87^{y}	2.68^{xz}	2.63^{z}
Period 5	2.78^{x}	2.97^{y}	2.71^{x}	2.67^{x}
Period 6	3.06^{x}	3.38^{y}	3.03^{x}	2.98^{x}
Overall	2.53^{xy}	2.63^{y}	2.45^{x}	2.41^{x}
SEM	0.058	0.058	0.058	0.058
P-value				
Diet			0.053	
Phase			< 0.01	
Diet × Period			< 0.01	
ADG, kg/d				
Period 1	0.81^{xy}	0.76^{x}	0.82^{y}	0.81^{xy}
Period 2	0.99^{x}	0.94^{y}	0.99^{xy}	0.94^{y}
Period 3	1.04^{x}	0.97^{y}	1.01^{xy}	0.99^{xy}
Period 4	1.03^{x}	0.97^{y}	0.99^{xy}	0.97^{y}
Period 5	0.87	0.84	0.86	0.86
Period 6	0.88^{x}	0.95^{yz}	0.97^{z}	0.89^{xy}

Overall	0.93^{xy}	0.90^{x}	0.94^{y}	0.91^{xy}
SEM	0.012	0.012	0.012	0.012
P-value				
Diet			0.12	
Phase			< 0.01	
Diet × Period			0.075	
G:F				
Period 1	0.524^{x}	0.498^{z}	0.552^{y}	0.545^{xy}
Period 2	0.440^{x}	0.410^{y}	0.448^{x}	0.437^{x}
Period 3	0.388^{x}	0.362^{y}	0.401^{x}	0.397^{x}
Period 4	0.365^{x}	0.337^{y}	0.368^{x}	0.370^{x}
Period 5	0.305^{x}	0.282^{y}	0.319^{x}	0.323^{x}
Period 6	0.280	0.277	0.303	0.294
Overall	0.384^{x}	0.361^{y}	0.398^{x}	0.394^{x}
SEM	0.006	0.006	0.006	0.006
P-value				
Diet	< 0.01			
Phase	< 0.01			
Diet × Period	0.48			

^{xyz}Superscripts with different letters within a row diets differ $P < 0.05$.
^{abcd}Superscripts with different letters within a column phases differ $P < 0.05$.

Table 7. Effects of feeding diets containing 40% distillers dried grains with solubles (DDGS) with variable NE content on carcass characteristics in Experiment 2.

	40% DDGS					
Item	LOW	ML	MH	HIGH	SEM	*P*-value
HCW, kg	76.70	75.05	76.82	75.56	1.08	0.59
Carcass yield, %	69.57	69.51	69.77	69.43	0.19	0.63
Backfat depth (end of growing phase)[a], mm	14.99	14.64	14.92	15.44	0.79	0.91
Backfat depth (end of finishing phase)[a], mm	24.73	24.50	25.05	25.58	0.55	0.55
LMA (end of growing phase)[a], cm^2	38.01	38.51	38.58	39.10	3.13	0.996
LMA (end of finishing phase)[a], cm^2	65.02	66.46	66.42	66.71	0.78	0.42
Fat-free lean[a], %	59.43	60.10	59.72	59.75	0.46	0.79

[a] Final BW was used as covariance in the statistical analysis.

Table 8. Evaluation of published NE prediction equations and NE estimates from Illuminate® based on determined NE of DDGS fed to pigs in Experiment 2.

Item	Equation	LOW	ML	MH	HIGH	Error	Bias
GE[1], kcal/kg		4,578	4,406	4,814	4,809		
DE[2], kcal/kg	-2,161 + (1.39 × GE) – (20.7 × NDF) – (49.3 × EE)	3,408	3,466	3,473	3,498		
ME[2], kcal/kg	-261 + (1.05 × DE) – (7.89 × CP) + (2.47 × NDF) – (4.99 × EE)	3,157	3,215	3,200	3,204		
Predicted NE, kcal/kg							
ILLUMINATE®		2,083	2,255	2,469	2,743	259.2	31.2
EvaPig® (MJ/kg DM; composition as % DM)							
Eq. 1	(0.703 × DE) – (0.0404 × CP) + (0.0662 × EE) + (0.0197 × starch) – (0.0409 × crude fiber)	2,248	2,195	2,337	2,368	216.1	-69.3
Eq. 2	(0.703 × DE) + (0.041 × CP) + (0.0664 × EE) + (0.0197 × starch) – (0.0134 × NDF)	2,747	2,756	2,853	2,912	511.3	460.4
Eq. 3	(0.7 × DE) – (0.0382 × CP) + (0.0674 × EE) + (0.0202 × starch) – (0.0365 × ADF)	2,193	2,203	2,309	2,365	237.5	-88.9
NRC (2012; kcal/kg DM; composition as g/kg DM))							
Eq. 1-7	(0.726 × ME) + (1.33 × EE) + (0.39 × starch) – (0.62 × CP) – (0.83 × ADF)	2,149	2,177	2,242	2,281	276.7	-144.0
Eq. 1-8	(0.7 × DE) + (1.61 × EE) + (0.48 × starch) – (0.91 × CP) – (0.87 × ADF)	2,194	2,204	2,309	2,366	237.2	-88.1
Model NE[3], kcal/kg		2,377	1,924	2,612	2,513		

[1] Measured GE using bomb calorimetry.

[2] Anderson et al., 2012

[3] Back-calculated NE using NRC (2012) growth model based on observed growth performance data.

Table 9. Evaluation of backfat iodine value (IV) prediction equations based on calculated IV of pigs fed 8 diets in experiment 1 and 2.

		Exp.1				Exp.2					
Source	Eq.	CON	LOW	MED	HIGH	LOW	ML	MH	HIGH	Error	Bias
Backfat IV, g/100g		57.7	74.1	74.3	79.0	70.3	68.7	71.3	82.3		
Predicted backfat IV, g/100g											
Benz et al. (2011)											
Eq. 1	35.458 + 14.324 × Dietary 18:2n6, %	64.1	61.6	69.7	87.4	72.9	57.7	81.4	86.3	8.18	0.42
Eq. 2	51.946 + 0.2715 × Dietary IVP, g/100g	58.6	63.2	66.5	74.4	67.9	61.6	71.4	73.5	6.46	-5.07
Bergstrom et al. (2010)	57.89 + 0.18 × Dietary IVP, g/100g	62.3	65.3	67.6	72.8	68.5	64.3	70.8	72.2	6.18	-4.24
Boyd et al. (1997)	52.4 + 0.315 × Dietary IVP, g/100g	60.1	65.4	69.3	78.5	70.9	63.6	75.0	77.5	4.60	-2.18
Madsen et al. (1992)	47.1 + 0.14 × IVP/day, kg	56.4	62.5	66.8	77.2	68.3	60.5	71.9	74.4	6.44	-4.98
Cromwell et al. (2011)	64.5 + 0.432 × DDGS in diet, %	64.5	81.4	81.4	81.4	81.4	81.4	81.4	81.4	8.26	7.10
Restrepo et al. (2013)											
Eq. 1	70.06 + 0.29 × DDGS in diet, %	70.1	81.7	81.7	81.7	81.7	81.7	81.7	81.7	9.19	8.00
Eq. 2	60.13 + 0.27 × Dietary IVP, g/100g	66.7	71.3	74.6	82.5	76.0	69.7	79.5	81.6	5.03	3.03

Experiment 3

We have completed the animal feeding phase of Experiment 3 and are currently analyzing growth performance and carcass composition data. The experimental protocol was approved by the University of Minnesota Institutional Animal Care and Use Committee (1311-31086A). Pigs (n = 384) were blocked by initial BW and pens were randomly allotted to 1 of 4 dietary treatments (8 pigs/pen, 12 replicates/treatment). Treatments (Table 10) consisted of: 1) corn-soybean meal based control diets (CON); 2) Control + 30% DDGS (DDGS); 3) Control + 15% wheat midds (MIDDS); 4) Control + 30% DDGS + 15% wheat midds (BLEND). Diets were balanced to contain similar NE content and were calculated to contain the same standardized ileal digestible Lys:NE within phases. During the 90-day trial, BW and feed disappearance were measured bi-weekly, and dietary phase changes based on average pen BW. Ultrasound measurements of backfat thickness and loin muscle area were performed before marketing pigs on November 11 and 18, 2014. Growth performance and carcass data will be analyzed by end of December 2014.

Table 10. Description of dietary treatments used in Experiment 3.

Treatment	% DDGS and Wheat Midds	Ingredient source
CON	Corn-soybean meal - Control	Corn and soybean meal, Morris, MN
DDGS	Control + 30% Low oil DDGS (~ 6.2% EE)	Poet Biorefining, Mitchell, SD
MIDDS	Control + 15% wheat midds	Agri-Nutrition, MN
BLEND	Control + 30% DDGS and 15% wheat midds	-

Appendix 1. Schedule of experiments and description of project main tasks

Project Name	Start	End	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15
Experiment #1																						
Procurement of ingredients	6/1/2013	7/1/2013																				
Run Experiment Morris, MN	7/16/2013	10/29/2013																				
Marketing of pigs	10/29/2013	11/5/2013																				
Lab assay	11/5/2013	3/5/2014																				
Data summary	3/5/2014	4/4/2014																				
Experiment #2																						
Procurement of ingredients	11/20/2013	12/5/2013																				
Run Experiment Morris, MN	1/15/2014	4/30/2014																				
Marketing of pigs	4/30/2014	5/7/2014																				
Lab assay	5/7/2014	9/4/2014																				
Data summary	9/4/2014	10/4/2014																				
Experiment #3																						
Procurement of ingredients	6/6/2014	6/21/2014																				
Run Experiment Morris, MN	6/21/2014	10/4/2014																				
Marketing of pigs	10/4/2014	10/11/2014																				
Lab assay	10/11/2014	2/8/2015																				
Data summary	2/8/2015	3/10/2015																				
Final reports	3/10/2015	4/9/2015																				X