

**Minnesota Pork Board Final Report
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I. Project Title:

Dietary Evaluation of Dried Distillers Grains with Solubles (DDGS) in Lactating Sows.

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II. Abstract:

A study was conducted to evaluate the dietary effect of increasing levels of dried distiller's grains with solubles (DDGS) to corn-soybean meal based sow lactation diets on sow and litter performance, energy and nitrogen digestibility, plasma urea nitrogen, milk fat and protein levels, and the economic implication of DDGS in sow lactation diets. Three hundred and seven mixed parity sows were randomly assigned to one of five dietary treatments; control diet (corn-soybean meal), 10% DDGS, 20% DDGS, 30% DDGS, 30% DDGS High Protein (HP). Thirty randomly selected sows (6 sows per dietary treatment) in parities 3 to 5 were selected for energy and nitrogen digestibility study, blood for plasma urea nitrogen analysis, and milk for fat and protein levels. Inclusion of DDGS in sow lactation diets did not influence ($P > 0.05$) sow average daily feed intake, backfat change, and wean to estrus interval. However, sows fed 30% DDGS HP lost body weight ($P < 0.05$) compared to sows fed the control diet. DDGS in sow diets did not affect ($P > 0.05$) piglet pre-weaning mortality, litter weight gain, average daily piglet gain, and coefficient of variation of individual piglet's body weight within a litter. DDGS not affect ($P > 0.05$) digestible and metabolizable energy and nitrogen digestibility and retention. There were no differences ($P > 0.05$) in nitrogen and fat in milk at weaning (d 19) among dietary treatments. Sows fed 20% DDGS and 30% DDGS had lower ($P < 0.05$) plasma urea nitrogen at weaning (d 19) than sows fed the control and 30% DDGS HP diets. However, sows fed diet containing 10 to 30% DDGS had lower ($P < 0.05$) plasma urea nitrogen at weaning (d 19) compared to sows fed the control diet. Sows fed 30% DDGS and 30% DDGS HP diets had lower ($P < 0.01$) total feed cost than sows fed the control, 10%, and 20% DDGS diets. However, sows fed 10% DDGS and 30% DDGS had lower ($P < 0.05$) revenue than sows fed 20%. In addition, sows fed 10% DDGS had a lower ($P < 0.05$) Margin Over Feed Cost than sows fed 20% DDGS. Based on these results, inclusion of up to 30% DDGS in lactation diet did not affect sow and litter performance, DE and ME, nitrogen retention and digestibility, and economic benefit compared to corn-soybean control diet. These results indicate that addition of up to 30% DDGS in lactation diet will support sow and litter performance.

III. Introduction:

The maximal inclusion rate for DDGS in sow diets as recommended in the Feed Co-Products Handbook (1997) is 50% in gestation and 20% in lactation. The Pork Industry Handbook (1998) recommends that DDGS be included at slightly lower levels (up to 40% in gestation diets and 10% in lactation diets). However, it should be noted that these recommendations are based on a limited number of studies and the DDGS used in the studies was produced by old ethanol manufacturing plants.

Changes have occurred within both the swine and ethanol industries that have resulted in increased nutrient requirements for sows and a higher quality, more digestible DDGS product compared to older plants (Shurson et al., 2003). Dried distiller's grains with solubles produced in "new generation", modern ethanol plants is higher in digestible and metabolizable energy, higher in digestible amino acids, and higher in available phosphorus than DDGS produced in older, more traditional ethanol plants (Shurson et al., 2003).

Recent research by Wilson et al. (2003) evaluated effects of adding DDGS to gestation and lactation diets on reproductive performance and nutrient balance in sows. These research results suggested that 50% DDGS in gestation diets supported satisfactory reproductive performance, but 20% DDGS in lactation diets was not recommended unless sows had previously been offered DDGS in gestation diets. Hill et al. (2005) evaluated the utilization of 5% beet pulp and 15% DDGS by lactating sows and concluded that 15% DDGS in lactating sow diets linearly reduced excretion of total P during lactation and maintained sow performance. Most of the studies (Wilson et al., 2003; Hill et al., 2005) evaluating DDGS for lactating sows have been inconclusive in determining the optimal inclusion level for lactating sows.

IV. Objectives:

The overall objective of the study is to determine the optimum level of inclusion of DDGS in lactating sow diets on sow and litter performance. The specific objectives are to determine the effects of different levels of DDGS in lactating sow diets on:

- a) Sow body weight and back fat changes (determine utilization of nutrients from experimental diets)
- b) Milk composition (nitrogen and fat)
- c) Blood urea nitrogen changes (evaluation of protein quality of the lactation diet)
- d) Litter performance (weaning weights and variation within litter)
- e) Economic benefits

V. Procedures:

Animal Management and Production Data Collection

The experimental protocols used in this study were approved by the University of Minnesota Institutional Animal Care and Use Committee. The experiment was conducted at the University of Minnesota, Southern Research and Outreach Center, Swine Research Center, Waseca, MN. Multi-parity lactating sows ($n = 307$; English Belle, GAP genetics, Winnipeg, MB, Canada) were used in the study. Sows had an initial body weight of 222 ± 15 kg and were housed in two housing systems during gestation. One hundred and forty seven sows housed in large group pens equipped with electronic sow feeders and 160 sows housed in individual stalls were used in the study. Sows were assigned randomly to one of five dietary treatments: Control, 10% DDGS, 20% DDGS, 30% DDGS, and 30% DDGS High Protein.

Sows were moved to farrowing rooms on d 109 of gestation and housed individually in fully slatted farrowing crates (2.13 m long \times 0.97 m high \times 0.66 m wide) after sows were washed, weighed, and backfat measurements recorded. Each crate had a single feeder and water was always available by a nipple drinker. The farrowing room temperature was maintained at about 18 to 20 °C. Rooms were mechanically ventilated. A heat mat and a heat lamp (for 48 hrs after parturition) in each crate were provided for newborn piglets.

Sow weights and backfat depth were measured and recorded within 24 h after farrowing. Litter weights were also measured and recorded, but individual weights of piglets from 65 sows (14 sows for control, 9 sows for 10% DDGS, 15 sows for 20% DDGS, 12 sows for 30% DDGS, and 15 sows for 30% DDGS HP) were measured and recorded to evaluate coefficient of variation of individual piglet weight within a litter.

Cross-fostering was performed within the same dietary treatment group within 48 h after farrowing to adjust litter size to about 10 piglets per sow.

Each lactation dietary treatment was fed twice daily at 0700 h and 1430 h. Sows were given 2.5 kg of their respective dietary treatments from d 109 of gestation until parturition. After parturition, sows were allowed ad-libitum access to feed and water. Sows were introduced to their lactation diets beginning on d 109 of gestation. At farrowing feed was gradually increased through d 5 then sows were allowed ad libitum intake until weaning on d 19. Feed offered was recorded daily. Feed refusals were weighed and recorded at weaning.

At weaning, sow weights and backfat depth were measured and recorded to assess body condition and sows were returned to their respective gestation housing systems at weaning. Sows were monitored for estrus for a 10-day period after weaning. Litter weight or individual piglet weight at weaning was measured and recorded. Piglets were weaned at approximately 19 ± 3 day of age.

Parity, lactation days, and interval from wean to estrus were recorded. Litter size (total number of born alive, mummies, stillborn, dead, weaned piglets and litter size after cross-fostering) were also recorded.

Dietary Treatments

The DDGS used in this study was from Heartland Corn Products, Winthrop, MN. The composition of the DDGS is presented in Table 1. The diet composition and analyses are presented in Table 2 and 3. All dietary treatments were formulated on true ileal digestible lysine and iso-nitrogenous basis and formulated to meet or exceed NRC (1998) nutrient requirement recommendations for lactating sows with average pre-farrowing weight of 200 kg, expected average loss weight of 10 kg, and expected average piglet daily gain of 200 g. The 30% DDGS HP was formulated on non-iso-nitrogenous basis to compare nitrogen utilization to 30% DDGS formulated on iso-nitrogenous basis. Same sources of corn, soybean meal, and DDGS were used during the duration of the study.

Table 1. Analyzed nutrient composition of DDGS.

	As fed basis	As dry matter basis
Moisture, (%)	14.78	0.00
Dry matter, (%)	85.22	100.00
Nitrogen, (%)	4.30	5.05
Crude protein, (%)	26.90	31.57
Acid detergent fiber, (%)	12.55	14.73
Calcium, (%)	0.07	0.08
Phosphorus, (%)	0.72	0.84
Potassium, (%)	0.72	0.84
Magnesium, (%)	0.29	0.34
Sulfur, (%)	0.29	0.34
Sodium, (%)	0.25	0.29
Zinc (mg/kg)	53.00	62.00
Manganese (mg/kg)	15.00	18.00
Copper (mg/kg)	4.00	5.00
Iron (mg/kg)	84.00	99.00
Cobalt (mg/kg)	1.00	1.00
Aluminum (mg/kg)	10.00	12.00

Table 2. Composition and analyzed nutrient levels of experimental diets.

Ingredient (%)	Control	10% DDGS	20% DDGS	30% DDGS	30% DDGS HP
Corn	66.20	62.34	58.81	54.92	47.70
SBM, 47.5%	27.40	21.75	15.87	10.33	18.14
DDGS	0.00	10.00	20.00	30.00	30.00
Choice white grease	2.50	1.92	1.25	0.62	0.41
Dicalcium phosphate	2.38	2.14	1.87	1.59	1.52
Limestone	0.47	0.65	0.83	1.01	1.00
Salt	0.35	0.35	0.35	0.35	0.35
Sow Vitamin-Mineral premix ^a	0.50	0.50	0.50	0.50	0.50
Biotin premix ^b	0.20	0.20	0.20	0.20	0.20
Lysine –HCl	0.00	0.15	0.32	0.48	0.18
TOTAL	100.00	100.00	100.00	100.00	100.00

Analyzed Composition (as fed basis)

Dry matter, %	88.09	88.12	88.23	88.18	89.14
Crude protein, %	17.81	18.00	17.33	16.99	20.27
ADF, %	8.94	4.37	5.29	6.98	8.48
Calcium,%	0.88	0.88	0.84	0.82	0.76
Phosphorus,%	0.81	0.78	0.75	0.74	0.73
GE, Mcal/kg	3.95	4.03	4.10	4.18	4.02

^a Premix supplied the following per kg of diet: Zn, 90.31 mg; Mn, 18.01 mg; Fe, 53.96 mg; Cu, 5.40 mg; Se, 0.30 mg; I, 2.20 mg; niacin, 55.07 mg; pantothenic acid, 33.04 mg; vitamin A, 11013 IU; vitamin D, 2753 IU; vitamin E, 55 IU; riboflavin, 9.9 mg; vitamin K, 4.41 mg; vitamin B₁₂, 0.06 mg; choline, 495 mg; pyridoxine, 1.65 mg; folic acid, 1.65 mg; thiamine, 1.01 mg

^b The premix supplied 0.51 mg of biotin per kg of diet

Table 3. Calculated nutrient levels of experimental diets.

	NRC 1998	Control	10% DDGS	20% DDGS	30% DDGS	30% DDGS HP
ME, Mcal/kg	3.26	3.40	3.41	3.41	3.41	3.41
Crude protein, %	18.50	18.80	18.80	18.80	18.80	22.00
Crude fiber, %	-----	2.61	2.95	3.29	3.64	3.78
Crude fat, %	-----	5.36	5.68	5.93	6.20	5.79
Total calcium, %	0.75	0.80	0.80	0.80	0.80	0.80
Total P, %	0.60	0.80	0.79	0.77	0.74	0.76
Available P, %	0.35	0.51	0.51	0.51	0.51	0.51
Total lysine, %	0.97	1.04	1.06	1.07	1.09	1.12
TID lysine, %	0.85	0.98	0.98	0.98	0.98	0.98
TID met + cys, %	0.42	0.59	0.60	0.62	0.63	0.71
TID threonine, %	0.53	0.68	0.65	0.61	0.58	0.72
TID tryptophan, %	0.16	0.22	0.20	0.17	0.16	0.20

Backfat Depth Measurement:

Sow backfat depth was measured at the P2 position (65 mm down both sides from the midline at the level of the last rib) by using an ultrasound Lean-Meater (Renco Corp., Minneapolis, MN) after farrowing (d 0) and at weaning (d 19).

Sows for Energy and Nitrogen Digestibility, Milk Fat and Protein Concentration, and Plasma Urea Nitrogen Determinations:

Thirty randomly selected sows (6 sows per dietary treatment) in parity 3 to 5 were used for collection of blood, milk, feces, and urine samples. Sows had an initial body weight of 215 ± 15 kg. These 30 sows included 15 sows from group housing and 15 sows from individual housing during the gestation period.

Blood Collection and Plasma Urea Nitrogen Analysis:

Blood samples were collected via venipuncture of the jugular vein with a 21-gauge needle into vacutainer tubes containing the anticoagulant lithium heparin (Becton, Dickinson, Rutherford, NJ) 2 hrs after morning feeding on d 0 and d 19 of lactation. Plasma

was harvested from the blood by centrifugation (3000 rpm for 10 min), after which time plasma was pipetted into vials and frozen at -20°C until analyzed for plasma urea nitrogen (PUN) concentration. Plasma urea nitrogen was analyzed by the Stanbio urea nitrogen kit (Stanbio laboratory, Boeme, TX)

Milk Collection and Analysis:

Milk samples were collected on d 0 and d 19 of lactation. Sows were given an intravenous injection of 1 ml oxytocin to stimulate milk release before collection. Milk samples were collected manually from all teats and frozen at -20°C, for fat and nitrogen analyses.

Feed Sample Collection:

Feed samples were collected from each batch of manufactured feed and stored at -20°C until analysis. To reduce the number of samples to be analyzed, feed samples were pooled within treatments before proximate analysis could be conducted.

Feces Collection:

Sows were fed their respective dietary treatment containing 0.3% chromic oxide as an indigestible marker from d 3 after farrowing for 10 days. Fecal samples were collected twice daily for 3 days by rectal palpation after a 7-day adjustment period. Grab samples were pooled and placed in labeled plastic bags and frozen at -20°C. At the end of collection period, fecal samples were dried in a forced-air oven (60°C) for 48 h.

Urine Collection:

Urine samples were collected on the same days as fecal samples. Urine samples were collected using Foley catheters. Foley catheters (Allegiance Healthcare Co., McGaw Park, IL) were placed into the urethra of sows for 48 h. A 25 ml hydrochloric acid (4N) was added to each collection bucket to prevent microbial growth and ammonia volatilization. At 0800 h and 1500 h of each day of the

collection period, urine volume was measured and a sub-sample was collected, mixed and pooled per sow, and frozen at -20°C until freeze dried and analyzed for energy and nitrogen.

Feed, Feces, Urine, and Milk Sample Analyses:

Gross energy in ground feeds and feces and freeze-dried urine samples were analyzed by bomb calorimetry with a Parr 1281 bomb calorimeter (Parr instrument Co., Moline, IL).

Total tract dry matter digestibility was measured by chromic oxide analysis using the procedure of Fenton and Fenton (1979).. The following equation was used to determine digestibility:

$$\% \text{ Digestibility of nutrient} = 100 - 100 \times \frac{\% \text{ indicator in feed} \times \% \text{ nutrient in feces}}{\% \text{ indicator in feces} \times \% \text{ nutrient in feed}}$$

Economic Analysis:

Margin over feed cost (MOFC) was calculated as follows:

$$\text{MOFC} = \text{Revenue} - \text{Total feed cost}$$

Revenue per litter was calculated from total number of piglet weaned multiplied by \$35 plus a sliding scale (Table 2.4) for weaning weight.

Table 4. The sliding scale for weaning weight.

Piglets weaning weight	Content
Under 4.5 kg	- \$1.10 / kg

4.5 – 5.5 kg	0
Over 5.5 kg	+ \$1.10 / kg

No addition was given if pigs weighed between 4.5 and 5.5 kg, a bonus of \$ 1.10 was given per kg above 5.5 kg, and \$ 1.10 was deducted per kg under 4.5 kg of body weight. Sow total feed cost was calculated from total feed intake during the lactation period multiplied by the price of the lactation feed.

Statistical Analysis:

Data were analyzed in completely randomized design by using the GLM procedures of SAS (SAS Inst. Inc, Cary, NC). The statistical model for sow and litter performance included the effects of dietary lactation treatments, gestation housing type and parity as covariates. The statistical model used for the analyses such as energy and nitrogen digestibility, plasma urea nitrogen, sow’s milk fat and nitrogen content, margin over feed cost, and coefficient of variation of individual piglet’s weight within a litter included the effects of dietary lactation treatments. Repeated measures in time were used to analyze plasma urea nitrogen, sow’s milk fat and nitrogen contents, and coefficient of variation of individual piglet’s weight within a litter. The multiple comparisons were used for the effects of dietary lactation treatments by Tukey-Kramer adjustment when there was a significant difference ($P < 0.05$) in the model.

VI. Results and Discussion:

Sow and Litter Performance:

The results of the effect of DDGS level in lactation diets on sow performance are presented in Table 5. There were no differences ($P > 0.05$) on parity, lactation length, sow weight at d 0 and d 19, sow backfat at d 0 and d 19, sow backfat change during the lactation period, and wean to estrus interval between sows fed the control diet based on corn-soybean meal and sows fed DDGS dietary treatments. Sows fed the 10%, 20%, and 30% DDGS diets had a tendency ($P < 0.10$) of higher average daily feed intake compared to sows fed the control diet and 30% DDGS HP. In addition, sows fed 30% DDGS HP lost more body weight during the lactation period compared to sows fed the control diet ($P < 0.05$). Sows fed DDGS diets containing 10%, 20%, and 30% had similar body weight changes and backfat changes during the lactation period compared to sows fed the control and the 30% DDGS HP diets ($P > 0.05$).

The results of the effect of DDGS level in lactation diets on litter performance are presented in Table 6. There were no differences ($P > 0.05$) on litter size at birth (alive) and weaning, pre-weaning mortality of piglets, weight of litter at birth and weaning, and litter

weight gain among dietary treatments. However, sows fed 10% and 20% DDGS had a tendency ($P < 0.10$) of higher average daily piglet gain compared to sows fed the control and the 30% DDGS HP diets.

The results of the effect of DDGS level in lactation diets on body weight variability within a litter are presented in Table 2.7. Sows fed DDGS had no effect ($P > 0.05$) on coefficient of variation of individual piglet's body weight within a litter after farrowing (d 0) and weaning (d 19) compared to sows fed the control diet. No time effect ($P > 0.05$) was observed for coefficient of variation of individual piglet's body weight between farrowing (d 0) and weaning (d 19).

Wilson et al. (2003) reported that sows fed a 20% DDGS diets during the lactation period had a tendency of lower ($P < 0.10$) average daily feed intake during the first reproductive cycle compared to sows fed the corn-soybean control diet and had no difference in average daily feed intake during the second reproductive cycle. The feed intake pattern in the present study is similar to the result of second reproductive cycle as reported by Wilson et al. (2003).

Yang et al. (2000) reported dietary total lysine concentration (0.60, 0.85, 1.10, 1.35, and 1.60%) had no effect on sow weight change in any of the three parities during the lactation period. Johnston et al. (1993) reported sow weight loss was reduced in mixed-parity sows when dietary lysine intake (0.62, 0.76, 0.90, and 1.05%) increased during the lactation period. However, the present study with DDGS shows that sow's weight change between 30% DDGS HP and control diet had a different result compared to result by Yang et al. (2000) and Johnston et al. (1993). The present study shows crude protein and total lysine of 30% DDGS HP (20.27% and 1.12%) was higher than those of the control diet (17.81% and 1.04%). The 30% DDGS HP had 3 percentage units higher protein level than the control and the other DDGS diets, such as 10%, 20%, and 30% DDGS, formulated on iso-nitrogenous basis. The excess protein had to be deaminated and excreted as urine. Deamination requires energy (Le Bellego et al., 2001) and that energy in sows fed 30% DDGS HP may have originated from the fatty tissue. Wilson et al. (2003) reported that there was no significant difference in sow weight change between sows fed the 20% DDGS diet and sows fed the control diet. The control (crude protein, 13.42%) and the 20% DDGS diet (crude protein, 21.20%) in Wilson et al. (2003) were formulated on non-iso-nitrogenous basis and sows fed both diets lost weight during the lactation period. However, the present research shows the different result in weight change compared to the result reported by Wilson et al. (2003). In the present study, sows fed the control and the other DDGS diets (crude protein, about 18%), such as 10%, 20%, and 30% DDGS, formulated on iso-nitrogenous basis gained similar weight during the lactation period, but sows fed the 30% DDGS HP diet (crude protein, about 21%) lost weight and had a difference in weight change compared to sows fed the control diet. Therefore, these results suggest that DDGS could be included in lactation sow diets at a level of up to 30% with no negative effect on sow and litter performance.

Table 5. Effect of DDGS level in lactation diets on sow performance.

Criteria	Treatments					PSE	P-value
	Control	10% DDGS	20% DDGS	30% DDGS	30% DDGS HP		
No. of sows	60	61	63	61	62		
Parity	4.57	4.60	4.58	4.46	4.51	0.15	0.97
Lactation length, day	18.3	18.4	18.1	18.1	18.4	0.14	0.48
Average daily feed intake, kg ^a	6.48	6.57	6.98	6.65	6.47	0.16	0.10
Sow weight at d 0, kg	217.7	220.1	225.1	219.9	220.0	2.90	0.46
Sow weight at d 19, kg	223.2	224.3	225.7	222.3	219.4	2.87	0.59
Sow weight change, kg/lactation	5.43 ^b	4.17 _{bc}	0.66 ^{bc}	2.40 ^{bc}	-0.63 ^c	1.42	0.02
Sow backfat at d 0, mm	16.4	16.6	17.1	16.4	17.6	0.54	0.42
Sow backfat at d 19, mm	15.8		16.17	15.77	16.53	0.50	0.35
Sow backfat change, mm/lactation	-0.6	15.99 -0.6	-1.0	-0.6	-1.1	0.19	0.21
Wean to estrus interval, day	4.9	5.0	5.1	5.0	5.3	0.12	0.35
Sows rebred within 7 days, %	91.0	98.0	95.0	97.0	100.0		

^{b,c} Means are different within main effect ($P < 0.05$)

^a 10%, 20%, and 30% DDGS vs. Control or 30% DDGS HP ($P < 0.1$)

Table 6. Effect of DDGS level in lactation diets on litter performance.

Criteria	Treatments					PSE	P-value
	Control	10% DDGS	20% DDGS	30% DDGS	30% DDGS HP		
No. of sows	60	61	63	61	62		
Litter size at birth (alive)	10.74	10.46	10.72	10.60	10.61	0.15	0.81
Litter size at weaning	9.74	9.65	9.88	9.77	9.83	0.08	0.31
Piglet pre-weaning mortality, %	10.26	8.37	8.48	8.48	7.97	1.22	0.71
Litter weight at birth (alive), kg/litter	14.93	15.41	15.38	15.01	14.97	0.34	0.74
Litter weight at weaning, kg/litter	60.45	62.26	62.14	60.53	61.05	1.06	0.60
Litter weight gain, kg/litter/lactation	45.51	46.84	46.75	45.52	46.08	0.86	0.67
Average daily piglet gain, g ^a	256	265	262	257	255	4.00	0.08

^a 10%, 20%, and 30% DDGS vs. Control or 30% DDGS HP (P < 0.1)

Table 7. Effect of DDGS level in lactation diets on variability of piglet weight within a litter at birth and weaning.

Criteria	Treatments					PSE	P-value	
	Control	10% DDGS	20% DDGS	30% DDGS	30% DDGS HP			
No. of sows	14	9	15	12	15			
Coefficient of variation of individual piglet's weight within a litter	d 0, %	15.90	16.70	17.28	14.29	16.20	1.61	0.85
	d 19, %	16.90	15.28	16.62	14.91	17.45	1.85	0.53

The results of the effect of sow housing type during the gestation period on sow performance during the lactation period are presented in Table 8. Housing type during the gestation period had no effect ($P > 0.05$) on parity, lactation length, average daily feed intake, sow weight at d 0 and d 19, sow weight change during lactation period, sow backfat at d 0 and d 19, sow weight change during lactation period, and wean to estrus interval between dietary treatments.

The results of the effect of sow housing type during the gestation period on litter performance during the lactation period are presented in Table 9. Housing type during the gestation period had no effect ($P > 0.05$) on litter size at birth (alive) and weaning, piglet pre-weaning mortality, litter weight at birth and weaning, litter weight gain, and average daily piglet gain between dietary treatments. There was no effect between dietary treatments and housing type during the gestation period as a covariate.

Hulbert and McGlone (2006) reported comparison of sow performance between pen and crated housing systems during the gestation period. At weaning, sows housed in pens had greater ($P < 0.05$) backfat thickness than sows housed in crates. However, there was no housing effect for the other sow and litter performance during the lactation period. Den Hartog et al. (1993) reported comparisons between stall housing and group housing for pregnant sows. The number of live-born pigs per sow per year and average birth weight was higher ($P < 0.05$) for the sows housed in stalls than for the group-housed sows, but there were no differences on mortality, the number of litters per sow per year, and weaned pigs per sow per year. They concluded that productivity of stalled sows was equal to that of sows housed in groups during pregnancy. The present study shows similar result reported by Hulbert and McGlone (2006) and Den Hartog et al. (1993).

Cronin et al. (1991) suggested that housing treatment near the time of parturition and during lactation may have only limited effects on the welfare of sows provided that the lactation period is not longer than 28 d. In the present study, sows were moved to farrowing rooms on d 109 of gestation and housed individually in fully slatted farrowing crates whether sows were from group or individual housing during gestation. Sows had enough time to adapt to individual crate environment before farrowing. Housing type during gestation did not affect sow performance in the present study. Therefore, the present study supports the conclusion that gestation housing type (individual vs. group) had no effect on sow and litter performance during lactation.

Table 8. Effect of sow housing type during the gestation period on sow performance during the lactation period.

Criteria	Housing type during the gestation period		PSE	P-value
	Group housing	Individual housing		
No. of sows	147	160		
Parity	4.52	4.57	0.10	0.72
Lactation length, day	18.30	18.22	0.85	0.53
Average daily feed intake, kg	6.67	6.59	0.10	0.58
Sow weight at d 0, kg	220.96	220.18	1.83	0.76
Sow weight at d 19, kg	223.81	222.15	1.81	0.51
Sow weight change, kg	2.85	1.96	0.90	0.48
Sow backfat at d 0, mm	16.94	16.71	0.34	0.64
Sow backfat at d 19, mm	16.14	15.97	0.32	0.70
Sow's backfat change, mm	-0.80	-0.73	0.12	0.69
Wean to estrus interval, day	5.14	4.99	0.07	0.12

Table 9. Effect of sow housing type during the gestation period on litter performance during the lactation period.

Criteria	Housing type during the gestation period		PSE	P-value
	Group housing	Individual housing		
No. of sows	147	160		
Litter size at birth (alive)	10.61	10.66	0.10	0.45
Litter size at weaning	9.81	9.74	0.05	0.29
Piglet pre-weaning mortality, %	8.12	9.46	0.77	0.21
Litter weight at birth (alive), kg	15.31	14.98	0.15	0.27
Litter weight at weaning, kg	61.20	61.37	0.67	0.86
Litter weight gain, kg/sow	45.89	46.39	0.54	0.50
Average daily piglet gain, g	256	261	2.00	0.18

The results of the effect of sow parity on sow performance during the lactation period are presented in Table 10. There were no differences ($P > 0.05$) in lactation length and wean to estrus interval among parities. However, parities 1-2 sows had lower ($P < 0.01$) average daily feed intake, sow weight at d 0 and 19, and sow weight change during the lactation period than sows of parity 3 or greater. Furthermore, parities 1-2 sows had higher ($P < 0.01$) backfat loss during the lactation period than parities 3-5 sows, although parities 1-2 sows had higher ($P < 0.01$) sow backfat at d 0 and 19 than parities 3-5 sows.

The results of the effect of sow parity on litter performance during the lactation period are presented in Table 11. There were no differences ($P > 0.05$) in litter size at weaning and piglet pre-weaning mortality among parities. However, parity 6+ sows had lower ($P < 0.05$) litter size at birth (alive) than parities 3-5 sows which had higher ($P < 0.05$) litter weight at birth than parities 1-2 sows. Furthermore, parity 6+ sows had lower ($P < 0.01$) litter weight at weaning than parities 3-5 sows and had lower ($P < 0.01$) litter weight gain and average daily piglet gain than parities 1-2 and 3-5 sows. There was no effect between dietary treatments and parities as a covariate.

Mahan (1998) reported that parity 1 sows had lower average daily feed intake and sow weight change during lactation period than parities 2-5 sows. There were no differences in sow backfat loss between parity 1 sows and parities 2-5 sows. Furthermore, parity 1 sows had lower average daily litter gain than parities 2-5 sows. The present study supports results on average daily feed intake, sow weight change during lactation period, and average daily litter gain for the parities 1-5 sows reported by Mahan (1998). However, the present study shows that parity 1-2 sows had higher sow backfat loss than parities 3-5 sows.

In the present study, parities 6+ sows had lower average daily piglet gain than parities 1-2 sows although parities 6+ sows had high average daily feed intake and sow weight change than parities 1-2 sows. This could be affected by milk fat concentration. Mahan (1998) reported that parities 1-2 sows had higher milk fat at weaning than parities 3-5 sows and found linear decrease in milk fat between parities 1-5. Therefore, the present study indicates that parities 3-5 sows had better performance than the other parity sows.

Table 10. Effect of sow parity on sow performance during the lactation period.

Criteria	Parity			PSE	P-value
	1-2	3-5	6+		
No. of sows	75	123	109		
Lactation length, day	18.20	18.40	18.18	0.11	0.25
Average daily feed intake, kg	5.99 ^a	7.08 ^b	6.82 ^b	0.12	< 0.01
Sow weight at d 0, kg	203.90 ^a	222.71 ^b	235.10 ^c	2.28	< 0.01
Sow weight at d 19, kg	202.18 ^a	226.88 ^b	239.86 ^c	2.25	< 0.01
Sow weight change, kg	-1.72 ^a	4.18 ^b	4.76 ^b	1.12	< 0.01
Sow backfat at d 0, mm	18.17 ^a	15.53 ^b	16.79 ^{ab}	0.42	< 0.01
Sow backfat at d 19, mm	16.97 ^a	15.06 ^b	16.13 ^{ab}	0.39	< 0.01
Sow's backfat change, mm	-1.19 ^a	- 0.48 ^b	-0.68 ^{ab}	0.15	< 0.01
Wean to estrus interval, day	5.03	5.07	5.08	0.09	0.91

^{a,b,c} Means are different within main effect (P < 0.05)

Table 11. Effect of sow parity on litter performance during the lactation period.

Criteria	Parity			PSE	P-value
	1-2	3-5	6+		
No. of sows	75	123	109		
Litter size at birth (alive)	10.55 ^{ab}	10.83 ^a	10.51 ^b	0.12	< 0.05
Litter size at weaning	9.77	9.85	9.69	0.07	0.15
Piglet pre-weaning mortality, %	7.94	9.97	8.44	0.95	0.33
Litter weight at birth, kg	14.54 ^a	15.67 ^b	15.21 ^{ab}	0.27	< 0.05
Litter weight at weaning, kg	61.40 ^{ab}	63.65 ^a	58.81 ^b	0.83	< 0.01
Litter weight gain, kg/sow	46.86 ^a	47.98 ^a	43.59 ^b	0.68	< 0.01
Average daily piglet gain, g	264 ^a	266 ^a	248 ^b	3.33	<0.01

^{a,b,c} Means are different within main effect (P < 0.05)

Energy and Nitrogen Digestibility

The results of the effect of DDGS level in lactation on energy digestibility are presented in Table 12. Average daily feed intake was not different ($P > 0.05$) among sows fed DDGS dietary treatments and sows fed the control diet. There were no significant differences ($P > 0.05$) in gross energy intake, energy excreted in feces, gross energy in urine, energy excreted in urine, digestible energy, and metabolizable energy among dietary treatments. However, sows fed 30% DDGS had higher ($P < 0.05$) gross energy in feces than sows fed the control diet.

Table 12. Effect of DDGS level in lactation diets on energy digestibility.

Criteria	Treatments					PSE	P-value
	Control	10% DDGS	20% DDGS	30% DDGS	30% DDGS HP		
No. of sows	6	6	6	6	6		
Average daily feed intake, kg/d	6.57	6.79	7.47	7.37	6.25	0.47	0.24
Gross energy in feed, kcal/g	3.95	4.03	4.10	4.18	4.02		
Gross energy intake, kcal/d	25,952	27,365	30,627	30,807	25,125	1,943	0.23
Gross energy in feces, kcal/g	4.57 ^a	4.62 ^{ab}	4.68 ^{ab}	4.79 ^b	4.58 ^{ab}	0.05	0.04
Energy excreted in feces, kcal/d	3,825	4,337	4,218	4,182	3,479	419	0.56
Gross energy in urine, kcal/g	2.38	2.54	2.62	2.53	2.57	0.08	0.29
Energy excreted in urine, kcal/d	258.01	322.44	213.24	289.56	258.23	80.45	0.92
Digestible energy, % of GE	85.26	84.15	86.23	86.42	86.15	0.67	0.66
Metabolizable energy, % of GE	84.27	82.97	85.53	85.48	85.12	0.65	0.37

^{a,b} Means are different within main effect ($P < 0.05$)

The results of the effect of DDGS level in lactation on nitrogen digestibility are presented in Table 13. Average daily feed intake, nitrogen intake, nitrogen in feces, nitrogen excreted in feces, nitrogen digestibility, nitrogen in urine, nitrogen excreted in urine, nitrogen retention (g/d), and nitrogen retention (%) did not differ ($P > 0.05$) among dietary treatments.

Thong et al. (1964) reported that nitrogen retention decreased as the level of DDGS in the diet was increased from 0 to 17.7 and 44.2%. Stanogias et al. (1985) found a tendency for increased nitrogen retention when high fiber diets containing soybean hulls and wheat bran were fed to growing pigs, but Holt et al. (2006) showed that nitrogen retention for sows fed the corn-soybean meal control diet and the soybean hull diet were similar. Wilson et al. (2003) reported that sows fed the 50% DDGS diet during the gestation period had higher nitrogen intake, fecal nitrogen excreted, and urinary nitrogen excreted than sows fed the control diet, had a tendency for higher total nitrogen retention (g/d), but had no difference in nitrogen retention (%) compared to sows fed the control diet. However, the present study shows no differences in nitrogen digestibility and retention (%) among dietary treatments. This indicates that the inclusion of DDGS in lactation diets did not affect nitrogen retention in lactating sows.

Table 13. Effect of DDGS level in lactation diets on nitrogen digestibility.

Criteria	Treatments					PSE	P-value
	Control	10% DDGS	20% DDGS	30% DDGS	30% DDGS HP		
No. of sows	6	6	6	6	6		
Average daily feed intake, kg/d	6.57	6.79	7.47	7.37	6.25	0.47	0.24
Nitrogen in feed, %	2.73	2.88	2.69	2.64	3.23		
Nitrogen intake, g/d	179.36	195.55	200.94	194.57	201.88	13.58	0.52
Nitrogen in feces, %	2.88	2.76	2.74	2.74	2.93	0.07	0.20
Nitrogen excreted in feces, g/d	23.76	25.34	24.12	23.85	21.99	2.24	0.42
Nitrogen Digestibility, %	86.75	87.04	87.98	87.74	89.10	0.69	0.29
Nitrogen in urine, %	0.79	0.94	1.14	0.80	0.97	0.12	0.28
Nitrogen excreted in urine, g/d	33.51	40.98	40.77	39.48	40.88	10.09	0.91
Nitrogen retention, g/d	122.09	129.23	136.05	131.24	139.26	13.00	0.67
Nitrogen retention, %	68.06	66.08	67.71	67.45	68.86	5.39	0.91

The results of the effect of DDGS level in lactation on nitrogen and fat concentrations in milk are presented in Table 14. Lactation dietary treatments had no influence ($P > 0.05$) on milk nitrogen and fat concentrations after farrowing (d 0) and at weaning (d 19).

Darragh and Morghan (1998) indicated that the nitrogen content of colostrum and milk were 2.5% and 0.88%, respectively. The fat content of colostrum and milk were reported to be 5.9% and 7.6%, respectively. The present study indicates that DDGS treatments do not affect nitrogen and fat level in milk at weaning.

The result of the effect of DDGS level in lactation on plasma urea nitrogen is presented in Table 15. There was no significant difference ($P > 0.05$) in plasma urea nitrogen after farrowing (d 0) among dietary treatments. However, sows fed the 20% and 30% DDGS diets had lower ($P < 0.05$) plasma urea nitrogen at weaning (d 19) than sows fed the control and 30% DDGS HP diets. In addition, sows fed 10%, 20%, and 30% DDGS diets had lower ($P < 0.05$) plasma urea nitrogen at weaning (d 19) compared to sows fed the control diet and had a tendency ($P < 0.10$) of lower plasma urea nitrogen at weaning (d 19) compared to sows fed the DDGS 30% HP diet.

Plasma urea nitrogen is used to indicate nitrogen metabolism within the sow when urea is the end product of protein utilization. Wilson et al. (2003) reported that a high dietary crude protein content in a DDGS diet resulted in the increased blood urea nitrogen concentration in sows because of the excess protein in a DDGS diet. Frank et al. (1983) found that blood urea nitrogen increased as the level of fiber in the diet increased because of the increased ammonia production in the gastro-intestinal tract. In the present study, the control and 30% DDGS HP diets contained higher ADF than the other DDGS diets and the 30% DDGS HP diet also contained higher crude protein than the control and the other DDGS diets. Plasma urea nitrogen of sows fed the control and 30% DDGS HP diets was higher than sows fed the 20% and 30% DDGS diets. In addition, the present study indicates that DDGS dietary treatments can be used for lactating sows without affecting plasma urea nitrogen, but not 30% DDGS high protein because of excess protein and high fiber.

Table 14. Effect of DDGS level in lactation diets on nitrogen and fat concentrations in milk.

Criteria	Treatments					PSE	P-value
	Control	10% DDGS	20% DDGS	30% DDGS	30% DDGS HP		
No. of sows	6	6	6	6	6		
Nitrogen							
Farrowing (d 0), %	1.41	1.65	1.76	1.66	1.44	0.22	0.73
Weaning (d 19), %	0.73	0.77	0.77	0.74	0.82	0.03	0.41
Fat							
Farrowing (d 0), %	5.98	5.85	5.83	6.01	5.94	1.32	0.99
Weaning (d 19), %	7.41	7.55	7.79	7.89	7.97	0.29	0.59

Table 15. Effect of DDGS level in lactation diets on plasma urea nitrogen.

Criteria	Treatments					PSE	P-value
	Control	10% DDGS	20% DDGS	30% DDGS	30% DDGS HP		
No. of sows	6	6	6	6	6		
Plasma urea nitrogen after farrowing (d 0), mg/dL	15.58	14.60	13.78	13.23	14.93	1.13	0.60
Plasma urea nitrogen at weaning (d19), mg/dL ^a	22.84 ^b	21.85 ^{bc}	18.44 ^c	18.40 ^c	22.39 ^b	1.19	0.02

^{b,c} Means are different within main effect ($P < 0.05$)

^a 10%, 20%, and 30% DDGS vs. 30% DDGS HP ($P < 0.1$); 10%, 20%, and 30% DDGS vs. Control ($P < 0.05$)

Economic Analysis

The results of economic analysis of dietary DDGS level in lactation diets are presented in Table 16 and 17. Sows fed the 30% DDGS and 30% DDGS HP diets had lower ($P < 0.01$) feed cost during the lactation period than sows fed the control, 10% DDGS, and 20% DDGS diets. When the price of each ingredient is compared, the prices of choice white grease as fat source and di-calcium phosphate as phosphorus source are relatively more expensive than the prices of the other ingredients. Inclusion level of corn, soybean meal, choice white grease, and di-calcium phosphate are also decreased as the level of DDGS is increased. Therefore, the feed price of the 30% DDGS and 30% DDGS HP diets is lower than the other dietary treatments. Sows fed the 10% DDGS and 30% DDGS diets had lower revenue ($P < 0.05$) than sows fed the 20% DDGS diet. When the number of weaned pigs and average piglet weaning weights are compared between sows fed the 10% and 30% DDGS diets and the 20% DDGS diet, the number of weaned pigs of sows fed 20% DDGS tended to be higher than that of sows fed the 10% and 30% DDGS diets. However, average piglet weaning weight of sows fed 10% DDGS diet tended to be higher than that of sows fed the 20% and 30% DDGS diets. Therefore, sows fed the 20% DDGS diet could have higher revenue than sows fed the 10% and 30% DDGS diets. In addition, sows fed the 10% DDGS diet had a lower ($P < 0.05$) margin over feed cost (MOFC) than sows fed the 20% DDGS diet. Based on the results of feed cost and revenue, sows fed the 20% DDGS had higher MOFC than sows fed the 10% DDGS diet. Therefore, sows fed 20% DDGS had the highest margin over feed cost compared to sows fed the other DDGS and control diets.

The present study indicates total feed cost could be decreased by inclusion of DDGS because levels of corn, soybean meal, animal fat, and di-calcium phosphate are decreased as DDGS inclusion level is increased. DDGS has lower price (\$ 0.083/kg, 2006) and contains higher fat content and available phosphorus than corn and soybean meal (\$0.099/kg and 0.182/kg, respectively, 2006). These indicate that costs of corn and soybean could be reduced and that costs of fat and phosphorus supplements could be saved as inclusion of DDGS.

Table 16. Cost of formulated diets and price list of feed ingredients (2006).

Ingredient, %	(\$/kg)	Level of DDGS				
		0	10	20	30	30 HP
Corn	0.099	66.20(6.55)	62.34(6.17)	58.81(5.82)	54.92(5.44)	47.70(4.72)
SBM, 47.5%	0.182	27.40(4.99)	21.75(3.96)	15.87(2.89)	10.33(1.88)	18.14(3.30)
DDGS	0.083	0(0)	10.00(0.83)	20.00(1.66)	30.00(2.49)	30.00(2.49)
Choice white grease	0.478	2.50(1.20)	1.92(0.92)	1.25(0.60)	0.62(0.30)	0.41(0.20)
Dicalcium phosphate	0.360	2.38(0.86)	2.14(0.77)	1.87(0.67)	1.59(0.57)	1.52(0.55)
Limestone	0.090	0.47(0.04)	0.65(0.06)	0.83(0.08)	1.01(0.09)	1.00(0.09)
Salt	0.170	0.35(0.06)	0.35(0.06)	0.35(0.06)	0.35(0.06)	0.35(0.06)
Sow Vit-Min premix	0.022	0.50(0.01)	0.50(0.01)	0.50(0.01)	0.50(0.01)	0.50(0.01)
Biotin premix	0.520	0.20(0.10)	0.20(0.10)	0.20(0.10)	0.20(0.10)	0.20(0.10)
Lysine -HCl	2.020	0(0)	0.15(0.30)	0.32(0.65)	0.48(0.97)	0.18(0.37)
Total		100(13.81)	100(13.18)	100(12.54)	100(11.91)	100(11.89)

Table 17. Economic analysis of dietary DDGS level in lactation diets.

Criteria	Treatments					PSE	P-value
	Control	10% DDGS	20% DDGS	30% DDGS	30% DDGS HP		
No. of sows	60	61	63	61	62		
Feed intake, kg/gestation period*	239.80	239.80	239.80	239.80	239.80	5.43	
Feed cost/sow/ gestation period, \$	32.00	32.00	32.00	32.00	32.00	0.73	
Feed intake, kg/lactation period	118.45	120.89	126.55	120.50	118.92	3.19	0.20
Feed cost, \$/kg	0.1381	0.1318	0.1254	0.1191	0.1189		
Feed cost/sow/ lactation period, \$	16.36 ^a	15.92 ^a	15.87 ^a	14.35 ^b	14.13 ^b	0.41	< 0.01
No. of weaned pigs / litter	9.74	9.65	9.88	9.77	9.83	0.10	0.82
Average piglet weaning weight, kg	6.21	6.45	6.29	6.20	6.21	0.10	0.08
Revenue/sow, \$	351.79 ^{ab}	349.92 ^a	363.42 ^b	350.35 ^a	352.74 ^{ab}	3.27	0.02
Total feed cost/sow/ gest-lact, \$	48.36 ^a	47.92 ^a	47.87 ^a	46.35 ^b	46.13 ^b	0.41	< 0.01
MOFC/sow, \$	303.43 ^{ab}	302.00 ^a	315.55 ^b	304.00 ^{ab}	306.61 ^{ab}	3.26	0.03

^{a,b} Means are different within main effect (P < 0.05)

*Assume average feed intake in gestation of 2.10 kg/day over 114 days

Objective Goals Achieved by the Study:

The following specific objectives were determined by including different levels of DDGS in lactating sow diets:

a) Sow body weight and back fat changes

Inclusion of up to 30% DDGS on iso-nitrogenous basis did not influence sow weight and back fat changes during lactation.

b) Milk composition (nitrogen and fat)

Sow milk composition was not influenced by the level of DDGS in sow lactation diets.

c) Plasma urea nitrogen (PUN) changes (evaluation of protein quality of the lactation diet)

DDGS diets formulated on iso-nitrogenous basis did not influence PUN levels in sows. The high protein DDGS diet (formulated to provide all required amino acids from corn, soy bean meal and DDGS) had a higher PUN levels. The excess nitrogen could be reduced with amino acid (lysine) supplementation.

d) Litter performance (weaning weights and variation within litter)

Inclusion of up to 30% DDGS in sow lactation diets did not affect litter performance.

e) Economic benefits

Margin over feed cost was higher for sows with 20% DDGS inclusion in their diets. Inclusion of 10% DDGS in sow diets had a lower margin over feed cost.

Implications

Inclusion of up to 30% DDGS in lactating sow diet has no negative effect on sow and litter performance, energy and nitrogen digestibility, milk composition, and plasma urea nitrogen. Further research to evaluate higher inclusion levels (40 – 50%) of DDGS is needed to determine the maximum inclusion rate of DDGS in lactation sow diets. Diets containing DDGS should preferably be formulated on iso-nitrogenous basis with amino acid supplementation.

Decimation of Project Results:

1. Presented at the January 2006 Minnesota Pork Congress
2. Two Abstracts presented at the 2006 American Society of Animal Science Mid-West Meetings in Des Moines, IA. March 2006.
3. Presented at the September 2006 Allen D. Leman Swine Conference KSU – U of M Nutrition Workshop: Impact of ethanol industry on swine farm nutrition economics.
4. Preparation of manuscript in progress for submission to American Journal of Animal Science.

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