Original Articles

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Productive performance of sows fed increasing levels of distillers dried grains with solubles (DDGS) across parities¤

Comportamiento productivo de cerdas alimentadas con niveles crecientes de granos secos de destilería con solubles (DDGS) durante varios partos

Desempenho produtivo de porcas alimentadas com níveis crescentes de grãos secos de destilaria com solúveis (DDGS) durante vários partos

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Summary

Background: addition of distillers dried grains with solubles (DDGS) in lactation diets may contribute to productive performance of lactating sows of different parities. **Objective:** the objective of this study was to determine the effects of feeding diets containing different levels of DDGS on productive performance of lactating sows of different parities. **Methods:** a total of 245 sows were divided into 3 parity groups of 1 to 2, 3 to 5, and over 5 parities. Within each parity group, sows were allotted to 1 of 4 dietary treatments that were prepared by inclusion of 0, 10, 20, and 30% DDGS in lactation diets. Diets were fed to sows during the whole lactation period. **Results:** average piglet weaning weight tended (quadratic, $p<0.10$) to increase by feeding diets containing increasing levels of DDGS to lactating sows of 3 to 5 and over 5 parities. Likewise, increasing levels of DDGS in diets tended (quadratic, $p<0.10$) to increase average piglet weight gain in all sow parity groups. The improvement of average piglet weaning weight and average piglet weight gain was the greatest when sows of 3 to 5 parities were fed diets containing 20% DDGS or when sows of over 5 parities were fed diets containing 10% DDGS compared with other dietary treatments. Feeding diets containing different levels

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of DDGS had no negative effects on other productive performance of lactating sows, regardless of parity. **Conclusions:** DDGS can be included up to 30% in diets fed to lactating sows of different parities.

Key words: *corn byproducts, ethanol byproducts, multiparity, pigs, reproductive traits, swine nutrition.*

Resumen

Antecedentes: la inclusión de granos secos de destilería con solubles (DDGS) en las dietas de lactancia puede contribuir al desempeño productivo entre cerdas lactantes de diferentes partos. **Objetivo:** determinar los efectos de varios niveles dietarios de DDGS en el comportamiento productivo de cerdas lactantes de diferentes partos. **Métodos:** un total de 245 cerdas fueron divididas en 3 grupos según el número de partos: de 1 a 2, 3 a 5, y más de 5 partos. Dentro de cada grupo de partos, las cerdas se asignaron a 1 de 4 tratamientos dietarios que incluían 0, 10, 20, o 30 % de DDGS en la dieta de lactancia. Las dietas fueron administradas a las cerdas durante todo el período de lactancia. **Resultados:** el peso al destete de los lechones tendió (cuadrática, $p<0,10$) a aumentar con el consumo creciente de DDGS por cerdas lactantes de 3 a 5 o de más de 5 partos. Del mismo modo, los niveles crecientes de DDGS tendieron (cuadrática, $p<0,10$) a aumentar la ganancia media de peso de los lechones en todos los partos. La mejora del peso promedio al destete y ganancia de peso de los lechones fue mayor para las cerdas de 3 a 5 partos que consumieron 20 % de DDGS, o para cerdas de más de 5 partos consumiendo 10 % de DDGS. Las dietas con diferentes niveles de DDGS no tuvieron efectos negativos sobre otros parámetros productivos de las cerdas lactantes, independientemente de la paridad. **Conclusiones:** los DDGS se pueden incluir hasta un 30% en las dietas de cerdas lactantes de diferente orden de parto.

Palabras clave: *características reproductivas, cerdos, multíparas, nutrición porcina, subproductos de etanol, subproductos de maíz.*

Resumo:

Antecedentes: a inclusão de grãos secos de destilaria com solúveis (DDGS) em dietas de amamentação pode contribuir para o desempenho produtivo de porcas lactantes com diferentes partos. **Objetivo:** determinar os efeitos de diferentes níveis dietéticos de DDGS no desempenho produtivo de porcas em lactação com diferente número de partos. **Métodos:** um total de 245 fêmeas foram divididas em três grupos segundo seu número de partos: 1-2, 3-5, e mais de 5 partos. Dentro de cada grupo de parição, as porcas foram designadas para um de quatro tratamentos de diferentes dietas que forneciam 0, 10, 20, ou 30% de DDGS na dieta de amamentação. As dietas foram fornecidas às porcas durante o período de lactação. **Resultados:** o peso ao desmame dos leitões tendeu (quadrática, $p<0,10$) a incrementar com o aumento do consumo de DDGS das porcas lactantes dos grupos 3-5 e mais de 5 partos. Do mesmo jeito, os níveis crescentes de DDGS (quadrática, $p<0,10$) aumentaram o ganho de peso médio dos leitões das porcas dos três grupos avaliados. A melhora do peso médio a desmama e o ganho de peso médio dos leitões foi maior nas porcas de 3-5 partos que consumiram 20% de DDGS e nas porcas de mais de 5 partos que consumiram 10% de DDGS. As dietas com diferentes níveis de DDGS não tiveram efeitos negativos sobre os outros parâmetros produtivos das porcas em lactação, independentemente do número de partos. **Conclusões**: os DDGS se podem incluir nas dietas das porcas com diferentes números de partos até num 30%.

Palavras chave: *características reprodutivas, porcos, multíparas, nutrição suína, subprodutos do etanol, subprodutos do milho.*

Introduction

Recent increase in biofuel production has markedly increased the price of corn and production of distillers dried grains with solubles (DDGS). This change has resulted in the swine industry usage of increasing amounts of DDGS in swine diets as a partial replacement of traditional feed ingredients such as corn and soybean meal (Hoffman and Baker, 2011).

It has been suggested that addition of up to 50% DDGS to gestation diets and that of up to 30% DDGS to lactation diets has no negative effects on productive performance of sows (Stein and Shurson, 2009). However, it is not known if 30% DDGS can

be included in lactation diets for multiparous sows because feed intake, energy and nutrient utilization in diets, and productive performance differs among sows of different parity (Koketsu *et al.*, 1996; Etienne *et al.*, 1998; Noblet *et al.*, 1998; Eissen *et al.*, 2000). The objective of this experiment was to investigate the effect of increasing inclusion levels of DDGS in diets fed to sows of different parities on the productive performance during lactation.

Materials and methods

The experimental protocol was reviewed and approved by the Institutional Animal Care and Use Committee at the University of Minnesota (approval number: 0709A16002).

Animals and housing

A total of 245 lactating sows (English Belle, GAP genetics, Winnipeg, MB, Canada) of different parity (1 to 2 ($n = 62$), 3 to 5 ($n = 102$), and over 5 ($n = 81$)) were used in this experiment. There were 6 farrowing groups. On d 109 of gestation, sows were moved to farrowing stalls equipped with a feeder and waterer in farrowing rooms automatically ventilated and maintained at 20 °C. Feed and water were available at all times.

Diets and experimental design

Dietary treatments were based on corn and soybean meal and added with DDGS, as follows: 0% DDGS (CON), CON + 10% DDGS (DDGS10), CON + 20% DDGS (DDGS20), and CON + 30% DDGS (DDGS30). All diets were formulated to meet or exceed the National Research Council (1998) estimates of nutrient requirements. The concentrations of crude protein, metabolizable energy, and standardized ileal digestible lysine were similar across the four diets (Table 1). Sows were fed a common corn-soybean meal-based gestation diet until d 109 of gestation. When sows were moved to farrowing rooms, they were randomly assigned to dietary treatments and fed 2.5 kg of the dietary treatments from d 109 of gestation until farrowing. After farrowing, sows were provided the dietary treatments twice daily and close to *ad libitum* intake until weaning.

Data collection and chemical analysis

The amount of feed provided per sow was recorded daily and feed refusals were weighed and recorded at weaning. Piglets were weaned at 18.2 ± 1.2 d of age. Sow body weight and ultrasonic backfat depth at the P2 position as well as litter weight were measured within 24 h after farrowing and at weaning. Piglets were cross-fostered among sows within each dietary treatment group within 24 h after farrowing to adjust litter size to approximately 10 piglets per sow. Other productive performance traits were also measured: litter size, number of dead piglets, and weaning to estrus interval. Diet samples were collected from each batch of manufactured feed and analyzed for gross energy that was measured by bomb calorimetry (Parr 1281 bomb calorimeter, Parr instrument Co., Moline, IL), crude protein (method 934.13; AOAC 2006), acid detergent fiber (method 973.18; AOAC 2006), neutral detergent fiber (Holst, 1973), calcium and phosphorus (method 958.01; AOAC 2006), and total lysine (method 982.30 E; AOAC 2006).

Statistical analysis

Data were analyzed using the Proc Mixed procedure (SAS Inst. Inc, Cary, NC) in a completely randomized design. The experimental unit was the sow or litter. The statistical model included effect of diet as a fixed effect and farrowing group as a random effect. The orthogonal polynomial contrast test was performed to determine linear and quadratic effect of increasing levels of DDGS in diets on productive performance of sows within each parity group. Pair-wise comparisons were also performed when the effect of diet showed significance or tendency. Statistical significance and tendency were considered at $p<0.05$ and $0.05\leq p< 0.10$, respectively.

Results

There were no effects of addition of up to 30% DDGS on sow feed intake, sow weight change, sow backfat change, weaning to estrus interval, litter size (nursing and weaning), and pre-weaning mortality within each parity group (Tables 2, 3, and 4). For sows of 1 to 2 parities, average piglet weight gain was increased (quadratic, $p<0.05$) by feeding increasing levels of DDGS to

Table 1. Ingredient and nutrient composition of dietary treatments (as-fed basis).

Item	Treatments[1]			
	CON	DDGS10	DDGS20	DDGS30
Ingredient (g/kg)				
Corn	662.0	622.9	587.8	549.5
Soybean meal, 47.5%	274.0	218.0	159.0	103.0
Distillers dried grains with solubles	0.0	100.0	200.0	300.0
Choice white grease	25.0	19.2	12.5	6.2
Dicalcium phosphate	23.8	21.4	18.7	15.9
Limestone	4.7	6.5	8.3	10.1
Salt	3.5	3.5	3.5	3.5
Sow Vit-Min premix[2]	5.0	5.0	5.0	5.0
Biotin premix[3]	2.0	2.0	2.0	2.0
L-Lysine HCl	0.0	1.5	3.2	4.8
Analyzed energy and nutrients				
Gross energy (MJ/kg)	16.5	16.8	17.1	17.5
Metabolizable energy (MJ/kg)[4]	14.2	14.2	14.2	14.2
Crude protein (g/kg)	180.4	182.6	177.0	175.7
Crude fat (g/kg)[4]	59.0	61.1	62.4	64.1
Acid detergent fiber (g/kg)	87.6	107.6	117.9	145.6
Neutral detergent fiber (g/kg)	50.2	62.2	70.2	81.7
Calcium (g/kg)	9.2	9.8	9.7	9.3
Phosphorus (g/kg)	8.0	8.1	7.7	7.2
Total lysine (g/kg)	10.4	10.6	10.7	10.9

[1]CON = control diet; DDGS10 = CON + 10% DDGS; DDGS20 = CON + 20% DDGS; DDGS30 = CON + 30% DDGS.

[2]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, 11,013 IU; vitamin D, 2,753 IU; vitamin E, 55 IU; riboflavin, 9.9 mg; vitamin K, 4.41 mg; vitamin B_{12}, 0.06 mg; choline, 495 mg; pyridoxine, 1.65 mg; folic acid, 1.65 mg; thiamine, 1.01 mg.

[3]The premix supplied 0.51 mg biotin per kg of diet.

[4]Calculated value.

lactating sows and was the greatest when sows were fed diets containing 10 or 20% DDGS (Table 2).

For sows of 3 to 5 parities, feeding diets containing increasing levels of DDGS to lactating sows increased (quadratic, $p<0.05$) average piglet weaning weight and tended (quadratic, $p<0.10$) to increase average piglet weight gain that were the greatest when sows were fed diets containing 20% DDGS (Table 3).

For sows of over 5 parities, average piglet weaning weight and average piglet weight gain tended (quadratic, $p<0.10$) to increase by feeding diets containing increasing levels of DDGS during lactation and were the greatest when sows were fed diets containing 10% DDGS (Table 4).

Table 2. Effect of increasing levels of DDGS in the diet on the productive performance of lactating sows of parity 1 to 2.

	Treatments[1]					p-value[2]		
Item	**CON**	**DDGS10**	**DDGS20**	**DDGS30**	**SEM[3]**	**Diet**	**Linear**	**Quad**
Lactating sows (n)	18	12	17	15				
Initial sow body wt (kg)	203.16	203.36	208.38	208.24	4.22	0.739	0.328	0.969
Sow feed intake (kg/d)	5.76	6.41	6.11	6.10	0.27	0.518	0.569	0.273
Sow wt change (kg/d)	-0.140	0.115	-0.196	-0.002	0.123	0.298	0.844	0.799
Sow backfat change (mm/d)	-0.058	-0.051	-0.067	-0.053	0.019	0.950	0.997	0.867
Weaning to estrus (d)	4.80	4.83	5.36	4.80	0.24	0.333	0.664	0.269
Litter size, nursing	10.44	10.75	11.00	10.80	0.22	0.359	0.204	0.289
Litter size, weaning	9.83	9.58	9.88	9.80	0.16	0.668	0.789	0.625
Pre-weaning mortality (%)	5.29	7.55	6.94	6.46	1.93	0.903	0.760	0.548
Average piglet weaning wt (kg)	6.25	6.50	6.51	6.48	0.13	0.235	0.439	0.509
Average piglet wt gain (g/d)	260.26[a]	281.73[b]	279.54[b]	273.72[ab]	6.42	< 0.05	0.325	< 0.05

[1]CON = control diet; DDGS10 = CON + 10% DDGS; DDGS20 = CON + 20% DDGS; DDGS30 = CON + 30% DDGS.

[2]Diet = diet effect; Linear = linear effect; Quad = quadratic effect.

[3]Pooled SEM.

[a-b]Means within a row with different superscripts are different (p<0.05).

Table 3. Effect of increasing levels of DDGS in the diet on the productive performance of lactating sows of parity 3 to 5.

	Treatments[1]					P-value[2]		
Item	**CON**	**DDGS10**	**DDGS20**	**DDGS30**	**SEM[3]**	**Diet**	**Linear**	**Quad**
Lactating sows (n)	23	28	25	26				
Initial sow body wt (kg)	216.34	218.53	225.51	220.44	4.34	0.548	0.354	0.428
Sow feed intake (kg/d)	6.98	6.99	7.37	7.11	0.19	0.502	0.419	0.507
Sow wt change (kg/d)	0.374	0.366	0.204	0.299	0.111	0.719	0.471	0.657
Sow backfat change (mm/d)	-0.014	-0.006	-0.027	-0.013	0.013	0.761	0.771	0.841
Weaning to estrus (d)	5.00	5.12	5.04	5.13	0.15	0.935	0.678	0.923
Litter size, nursing	11.43	10.89	10.96	10.81	0.23	0.282	0.109	0.419
Litter size, weaning	9.83	9.75	9.84	9.81	0.12	0.961	0.953	0.866
Pre-weaning mortality (%)	12.40	9.76	9.47	8.54	1.78	0.534	0.166	0.648
Average piglet weaning wt (kg)	6.27[a]	6.46[ab]	6.75[b]	6.30[ab]	0.14	< 0.05	0.568	< 0.05
Average piglet wt gain (g/d)	267.33	274.41	286.67	273.12	5.18	0.082	0.321	0.097

[1]CON = control diet; DDGS10 = CON + 10% DDGS; DDGS20 = CON + 20% DDGS; DDGS30 = CON + 30% DDGS.

[2]Diet = diet effect; Linear = linear effect; Quad = quadratic effect.

[3]Pooled SEM.

[ab]Means with different superscripts within the same row indicate significant difference.

Table 4. Effect of increasing levels of DDGS in the diet on the productive performance of lactating sows over 5 parities.

	Treatments[1]					p-value[2]		
Item	CON	DDGS10	DDGS20	DDGS30	SEM[3]	Diet	Linear	Quad
Lactating sows (n)	19	21	21	20				
Initial sow body wt (kg)	235.46	240.62	240.71	237.36	4.96	0.857	0.801	0.403
Sow feed intake (kg/d)	6.60	6.56	7.40	6.81	0.30	0.191	0.300	0.375
Sow wt change (kg/d)	0.548	0.197	0.221	0.180	0.146	0.283	0.115	0.302
Sow backfat change (mm/d)	-0.015	-0.043	-0.036	-0.013	0.019	0.615	0.868	0.195
Weaning to estrus (d)	5.18	5.05	5.00	4.95	0.16	0.816	0.346	0.815
Litter size, nursing	10.79	10.38	10.57	10.70	0.25	0.696	0.947	0.296
Litter size, weaning	9.53	9.33	9.38	9.35	0.224	0.934	0.643	0.723
Pre-weaning mortality (%)	14.33	10.82	14.54	12.26	2.85	0.769	0.852	0.833
Average piglet weaning wt (kg)	5.76[a]	6.44[b]	5.95[ab]	6.08[ab]	0.16	< 0.05	0.516	0.096
Average piglet wt gain (g/d)	249.38	265.74	256.03	257.48	5.09	0.076	0.657	0.095

[1]CON = control diet; DDGS10 = CON + 10% DDGS; DDGS20 = CON + 20% DDGS; DDGS30 = CON + 30% DDGS.

[2]Diet = diet effect; Linear = linear effect; Quad = quadratic effect.

[3]Pooled SEM.

[ab]Means with different superscripts within the same row indicate significant difference.

Discussion

In the management of lactating sows, fast recovery of feed intake is very important due to the provision of adequate energy and nutrients for milk production and maintenance (Koketsu *et al.*, 1996; Eissen *et al.*, 2000). Stein and Shurson (2009) indicated that lactating sows may require some adaptation period to diets if diets contain high amounts of DDGS because of possible reduction of feed intake. However, the present study does not show a negative effect of DDGS on feed intake of lactating sows of any parity. This result agrees with Greiner *et al.* (2008), who suggested that adding up to 30% DDGS to lactation diets had no negative effects on feed intake of sows, regardless of parity.

Lactating sows fed DDGS may be expected to have poor performance within same parity group compared with lactating sows fed CON because DDGS contains higher fiber, especially insoluble fiber, than corn or soybean meal (Stein and Shurson, 2009). High fiber contents in DDGS may reduce energy and nutrient utilization in feeds, and this negative effect is likely greater for primiparous lactating sows than for multiparous lactating sows (Renteria-Flores *et al.*, 2008), because primiparous lactating sows have less capacity for microbial fermentation as compared to multiparous lactating sows (Noblet and Shi, 1993; Renteria-Flores *et al.*, 2008). Therefore, it was expected that different levels of DDGS in diets decrease productive performance in primiparous sows, but may have little impact in multiparous sows. However, the present experiment showed no adverse effects on productive performances of lactating sows of 1 to 2 parities as observed in lactating sows of other parities. The reason for this observation may be related to greater fat concentrations in DDGS than those in corn or soybean meal (Stein and Shurson, 2009). Fat in DDGS is able to provide highly-efficient energy (i.e., net energy) and may also contribute to increased digestibility of other dietary components through increased retention time in the intestine (Cervantes-Pahm and Stein, 2008; Kil and Stein, 2011). These potential effects of fat in DDGS may compensate the negative energy and nutrients utilization in lactating sows, regardless of parity. Accordingly, the results from the present experiment suggest that adding up

to 30% DDGS to lactation diets would not negatively affect reproductive performance of sows, regardless of parity. To our knowledge, the present experiment is the first to show the effects of DDGS on productive performance of lactating sows of different parity.

Another important concern in the management of lactating sows is milk production because it is directly related to litter performance. The present experiment shows that addition of 10 or 20% DDGS to lactating sow diets increased average piglet weight gain from sows of any parity. The reason for this observation may be greater fat concentrations in milk from lactating sows fed DDGS, although it was not determined in this experiment. It was reported that increasing levels of fat in diets increased milk fat content (Pettigrew, 1981; Lauridsen and Danielsen, 2004), which could improve piglet performance (Lauridsen and Danielsen, 2004).

In conclusion, addition of up to 30% DDGS to corn-soybean meal-based lactation diet has no negative effects on productive performance of lactating sows of different parities.

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