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SHORT COMMUNICATION

Comparative digestibility of energy, dry matter, and nutrients by gestating and lactating sows fed corn–soybean meal diets without or with full-fat or defatted rice bran

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Abstract: Twenty-four gestating sows and 24 lactating sows were randomly allotted to three diets with eight replicate sows per treatment in a 3 × 2 factorial arrangement. Different sows were used in gestation and lactation periods. The hypothesis was that digestibility of gross energy (GE), dry matter (DM), and nutrients in lactating sows is not different from that in gestating sows. A corn–soybean-meal diet and two full-fat-rice-bran or defatted rice bran diets were used. Results indicated that regardless of diet, lactating sows had greater ($P < 0.01$) apparent total tract digestibility of GE, DM, neutral detergent fiber, organic matter, and phosphorus than gestating sows.

Key words: digestibility, energy, rice bran, lactating sows.

Résumé : Vingt-quatre truies en gestation et 24 truies en lactation ont été assignées de façon aléatoire à 3 diètes avec 8 truies réplicats par traitement selon un arrangement factoriel 3 × 2. Différentes truies ont été utilisées pour les périodes de gestation et de lactation. L'hypothèse était que la digestibilité de l'énergie brute (GE — « gross energy »), des matières sèches (DM — « dry matter »), et des éléments nutritifs chez les truies en lactation ne différaient pas des digestibilités chez les truies en gestation. Une diète à base de tourteau de maïs-soja et 2 diètes son de riz gras ou son de riz dégraissé ont été utilisées. Les résultats indiquent que, peu importe la diète, les truies en lactation montraient de plus grandes ($P < 0,01$) digestibilités apparentes du tractus total de GE, DM, fibres au détergent neutre, matières organiques, et phosphore que les truies en gestation. [Traduit par la Rédaction]

Mots-clés : digestibilité, énergie, son de riz, truies en lactation.

Introduction

Use of cereal coproducts to formulate diets for pigs has increased. Full-fat rice bran (FFRB) and defatted rice bran (DFRB) are produced in the rice milling process and are available for animal feeding (Casas and Stein 2016, 2017). However, because of the high concentration of dietary fiber, FFRB and DFRB may be better suited for diets fed to sows than for diets for weanling or growing pigs, but there is a lack of data on the digestibility of energy and nutrients in FFRB and DFRB fed to sows.

The physiological stage of pigs may influence total tract digestibility of nutrients because the digestibility of energy and some nutrients increases as body weight increases, but the impact of physiological stage may be greater for high-fiber diets than for diets with less concentration of fiber (Le Goff and Noblet 2001). Thus, differences between gestating sows and growing pigs in apparent total tract digestibility (ATTD) of dry matter (DM) and gross energy (GE) of feed ingredients have been reported (Le Goff and Noblet 2001; Casas and Stein 2017). Gestating sows fed 2 kg of feed per day also have greater standardized ileal digestibility of protein and amino acids than growing pigs or lactating sows that are allowed ad libitum intake of feed (Stein et al. 2001). However, recent data demonstrated that the ATTD of DM and GE in gestating sows offered ad libitum access to feed is not different from the ATTD obtained in sows fed 1.5 times the maintenance requirement for metabolizable energy, but ATTD values by sows are greater than by growing gilts (Casas and Stein 2017). Thus, it appears

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that the level of feed intake is not the major contributor to the observed differences between growing pigs and gestating sows that values for the ATTD of GE have been reported. As a consequence, it is likely that the ATTD of GE and DM obtained in gestating sows are more applicable to lactating sows than values obtained in growing pigs, but this hypothesis has not been experimentally verified. Therefore, the objective of this experiment was to test the null hypothesis that the ATTD of GE, DM, organic matter (OM), neutral detergent fiber (NDF), and phosphorus (P) in a corn–soybean meal diet and in diets containing FFRB or DFRB is not different between lactating sows and gestating sows if both groups are allowed to consume their diet on an ad libitum basis.

Materials and Methods

The protocol for the experiment was reviewed and approved by the Institutional Animal Care and Use Committee at the University of Illinois before the experiment was initiated (protocol #13355). Animal procedures followed the Canadian Council on Animal Care Guidelines on the care and use of farm animals in research, teaching, and testing.

Experimental design

Twenty-four crossbred Landrace–Yorkshire gestating sows (Fertilis 25; Genetiporc, Alexandria, MN) that were 35 ± 0.8 days into gestation (parity 2 to 6) and 24 lactating sows (parity 2 to 6) were randomly allotted to two blocks of 12 sows, three diets, and four sows per treatment in each block for a total of eight replicate sows per treatment. Different sows were used in gestation and lactation periods to avoid possible impact of gestation treatment on lactation performance. Gestating sows were housed for 12 d in individual stalls, but on day 13, sows were moved to metabolism crates where they stayed for 12 d. Lactating sows were moved to farrowing crates 4 d before farrowing and remained there until weaning on day 20 post-farrowing.

A basal diet based on corn and soybean meal and two diets based on corn, soybean meal, and 40% FFRB or DFRB were used (Table 1). All diets contained 500 units per kg of microbial phytase (Quantum Blue, AB Vista, Marlborough, UK), 0.50% titanium dioxide as an indigestible marker, and vitamins and minerals in concentrations that met or exceeded the requirement for gestating and lactating sows [National Research Council (NRC) 2012]. Gestating sows were fed at 3.5 times the maintenance metabolizable energy requirement (i.e., 100 kcal·kg^{-1} body weight$^{0.75}$; NRC 2012), which was considered close to voluntary feed intake. Gestating sows were fed equal amounts of feed twice daily at 0700 and 1600 h. Lactating sows were fed 2 kg of experimental diet from day 110 of gestation until farrowing, but on the day of parturition, sows were offered only 1 kg of feed. However, from day 2 after farrowing, sows were allowed free access to feed. Both groups of sows had free access to water at all times throughout the experiment.

Gestating and lactating sows were fed experimental diets for 24 d. The initial 17 d were considered an adaptation period to the diet. Fecal samples were collected via rectal palpation on day 18 to 23 after initiation of feeding experimental diets. In gestating sows, that period corresponded to day 6 to 11 after sows were moved to metabolism crates, and in lactating sows, the collection period was from day 13 to 18 of lactation. Feces were collected twice daily and stored at –20 °C as soon as collected.

Chemical analyses

Fecal samples were dried at 65 °C in a forced air oven and ground through a 1 mm screen before chemical analysis. Diet and fecal samples were analyzed for GE using an isoperibol bomb calorimeter (Model 6300, Parr Instruments, Moline, IL), and samples were also analyzed for DM [Method 930.15; Association of Official Analytical Collaboration (AOAC) International 2007] and ash (Method 942.05; AOAC Int. 2007). Concentrations of NDF in diet and fecal samples were analyzed using Ankom Technology method 13 (Ankom^{2000} Fiber Analyzer, Ankom Technology, Macedon, NY). Diets were analyzed for nitrogen by combustion (Method 990.03; AOAC Int. 2007) using an Elementar Rapid N-cube Protein/Nitrogen Apparatus (Elementar Americas Inc., Mt Laurel, NJ), and crude protein was calculated as nitrogen × 6.25. Acid-hydrolyzed ether extract was analyzed by acid hydrolysis using 3 *N* HCl (Sanderson, 1986) followed by crude fat extraction with petroleum ether (Method 2003.6; AOAC Int. 2007) on an automated analyzer (Soxtec 2050; FOSS North America, Eden Prairie, MN). Diets were also analyzed for acid detergent fiber using Ankom Technology method 12 (Ankom^{2000} Fiber Analyzer, Ankom Technology, Macedon, NY), and lignin was analyzed using the Daisy^{II} Incubator (Ankon Technology, Macedon, NY). Calcium and P were analyzed in diets by inductively coupled plasma optical emissions spectrometry using an internally validated method (Method 985.01 A, B, and C; AOAC Int. 2007), and the same method was used to analyze P in fecal samples. Diets were also analyzed for phytase activity (Phytex Method, Version 1; Eurofins, Des Moines, IA), and diets and fecal samples were analyzed for titanium (Method 917.01; AOAC Int. 2007).

Calculations and statistical analysis

Organic matter was calculated as the difference between DM and ash. The digestible energy (DE) and ATTD of GE, DM, OM, NDF, and P in all diets were calculated according to Kong and Adeola (2014). The contribution of the basal diet to the output of energy and nutrients in diets containing FFRB or DFRB was then calculated, and the ATTD of GE, DM, and NDF in FFRB and DFRB was calculated by difference (Widmer et al. 2007).

Outliers and homogeneity of the variances among treatments were tested using the UNIVARITE procedure

Table 1. Composition of the corn–soybean meal diet and diets containing full-fat rice bran (FFRB) or defatted rice bran (DFRB), as-fed basis.

Item	Corn–soybean meal diet	FFRB	DFRB
Ingredient, %			
Corn	63.60	37.11	37.11
Soybean meal	32.27	19.05	19.05
Rice coproduct	–	40.00	40.00
Limestone	0.78	1.64	1.64
Dicalcium phosphate	1.15	–	–
Sodium chloride	0.40	0.40	0.40
Vitamin mineral premix[a]	0.30	0.30	0.30
Phytase premix[b]	1.00	1.00	1.00
Titanium dioxide	0.50	0.50	0.50
Total	100.00	100.00	100.00
Analyzed composition			
Gross energy, kcal·kg^{-1}	3,819	4,260	3,809
Dry matter, %	88.03	92.63	88.95
Crude protein, %	20.26	17.58	18.96
Acid-hydrolyzed ether extract, %	2.15	8.32	3.50
Ash, %	5.3	6.9	8.8
Acid detergent fiber,%	4.78	5.74	6.75
Neutral detergent fiber,%	9.07	11.48	12.17
Lignin,%	0.73	1.42	2.63
Calcium, %	0.65	0.66	1.16
Phosphorus, %	0.60	0.98	1.09
Phytase, phytase units·kg^{-1}	690	690	430

[a]The vitamin–micromineral premix provided the following quantities of vitamins and micro minerals per kilogram of complete diet: vitamin A as retinyl acetate, 11 136 IU; vitamin D_3 as cholecalciferol, 2208 IU; vitamin E as DL-alpha tocopheryl acetate, 66 IU; vitamin K as menadione dimethylprimidinol bisulfite, 1.42 mg; thiamin as thiamine mononitrate, 0.24 mg; riboflavin, 6.59 mg; pyridoxine as pyridoxine hydrochloride, 0.24 mg; vitamin B_{12}, 0.03 mg; D-pantothenic acid as D-calcium pantothenate, 23.5 mg; niacin, 44.1 mg; folic acid, 1.59 mg; biotin, 0.44 mg; Cu as copper sulfate and copper chloride, 20 mg; Fe as ferrous sulfate, 126 mg; I as ethylenediamine dihydriodide, 1.26 mg; Mn as manganese sulfate, 60.2 mg; Se as sodium selenite and selenium yeast, 0.3 mg; and Zn as zinc sulfate, 125.1 mg.

[b]The phytase premix was formulated to provide 500 units of phytase per kilogram of complete feed in all diets. The premix was prepared by mixing 10 g of phytase concentrate [Quantum Blue (5000 units per gram) AB Vista, Marlborough, UK] with 990 g of ground corn. The premix thus contained 50 000 units of phytase per kilogram, and at 1% inclusion provided 500 units of phytase per kilogram of complete diet.

of SAS. Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC; SAS software, version 9.4) as a randomized complete block design with a 2 × 3 factorial arrangement for diets and a 2 × 2 factorial arrangement for ingredients. The fixed effects were the physiological stage of sows, the diet or ingredient, and the interaction between physiological stage and diet or ingredient. The LSMeans statement was used to calculate treatment means, and the PDIFF option was used to separate means if differences were detected. The sow was the experimental unit for all analyses. Statistical significance was considered at $P < 0.05$.

Results and Discussion

All sows remained healthy during the experimental period, and feed refusals were not observed. On average, sows fed experimental diets farrowed 11.54 pigs and weaned 10.54 pigs. The daily feed intake of sows was not affected by dietary treatment, but lactating sows had greater ($P < 0.05$) daily feed intake than gestating sows (Table 2). The ATTD of DM, OM, GE, and NDF was greater ($P < 0.01$) by lactating sows than by gestating sows. However, the ATTD of DM, OM, GE, and NDF was greater ($P < 0.01$) for the basal diet than for diets containing FFRB or DFRB regardless of physiological stage of

Table 2. Effects of reproductive stage of sows on apparent total tract digestibility (ATTD) of gross energy (GE), dry matter (DM), organic matter (OM), neutral detergent fiber (NDF), and phosphorus (P), and concentration of digestible energy (DE) in a corn–soybean meal basal diet and in diets containing full-fat rice bran (FFRB) and defatted rice bran (DFRB).[a]

	Gestating sows			Lactating sows				*P* value		
Item	Basal	FFRB	DFRB	Basal	FFRB	DFRB	SEM	Diet	Stage	Diet × stage
Diets										
Feed intake, $kg \cdot d^{-1}$	6.12	6.29	6.83	7.01	6.98	7.17	0.36	0.471	0.035	0.748
ATTD of DM, %	87.0	80.3	76.5	88.5	83.0	79.9	0.41	<0.001	<0.001	0.078
ATTD of OM, %	90.1	85.0	82.3	90.8	86.3	84.8	0.40	<0.001	<0.001	0.099
ATTD of NDF, %	66.2	42.3	38.0	67.3	48.2	45.7	2.11	<0.001	0.007	0.276
ATTD of GE, %	87.1	82.9	79.6	88.0	84.9	82.8	0.53	<0.001	<0.001	0.126
DE, $kcal \cdot kg^{-1}$ DM	3,325	3,531	3,033	3,361	3,617	3,153	20.76	<0.001	<0.001	0.139
ATTD of P, %	18.4b	5.5c	5.8c	43.9a	19.7b	16.8b	2.70	<0.001	<0.001	0.026
Ingredients										
ATTD of DM, %	–	78.4	69.1	–	81.6	75.4	1.36	<0.001	<0.001	0.275
ATTD of NDF, %	–	71.7	62.0	–	76.0	68.0	1.06	<0.001	<0.001	0.433
ATTD of GE, %	–	78.1	70.6	–	80.2	75.7	1.08	<0.001	0.002	0.178
DE, $kcal \cdot kg^{-1}$ DM	–	4,012	2,678	–	4,176	2,921	57.55	<0.001	0.001	0.503

Note: Values within a row lacking a common lowercase letter are different ($P < 0.05$).
[a]Data are means of eight observations per treatment.

sows. Likewise, the concentration of DE was greater ($P < 0.01$) if diets were fed to lactating sows than to gestating sows, but diets containing FFRB had a greater ($P < 0.01$) concentration of DE than the basal diet and the diet containing DFRB. The greater ATTD of GE in the corn–soybean meal diet compared with diets containing FFRB or DFRB concurs with data obtained in gestating sows and growing pigs (Casas and Stein 2017).

The ATTD of GE, DM, and NDF, and the concentration of DE in FFRB and DFRB were greater ($P < 0.01$) for lactating sows than for gestating sows. Sows fed FFRB had greater ($P < 0.01$) ATTD of GE, DM, and NDF and DE than sows fed DFRB. The greater ATTD of GE in FFRB and DFRB by lactating sows than gestating sows is partly due to the greater ATTD of NDF in lactating sows compared with gestating sows. It is, however, possible that lactating sows also had greater ATTD of other energy containing nutrients in the FFRB and DFRB diets compared with gestating sows (Stein et al. 1999).

Greater energy values and digestibility of DM and GE in gestating sows than in growing pigs have been reported, but level of feed intake does not affect digestibility of energy and DM in gestating sows (Noblet and van Milgen 2004; Casas and Stein 2017). Therefore, it is assumed that digestibility values obtained in gestating sows fed at maintenance levels may be extrapolated to lactating sows that are allowed ad libitum intake of diets (Noblet and van Milgen 2004), but data from the current experiment do not support this hypothesis. It is possible that the greater demand for energy in lactating sows, due to the demand for milk, results in upregulation of digestive enzymes or transporters in the small intestine, which may increase energy absorption. The length and weight of the small intestine in lactating rats increased during lactation, and the height of the villi and absorption of leucine and glucose increased on day 10 of lactation compared with gestation or post-weaning periods (Cripps and Williams 2008). If similar adaptations take place in lactating sows, this may explain the increased ATTD of GE observed in the present experiment. However, to the best of our knowledge, no data comparing ATTD of GE, DM, and nutrients in lactating and gestating sows have been published. Therefore, more research is needed to elucidate the mechanism that is responsible for the increased ATTD of GE in lactating sows. It is also possible that the ATTD of GE may increase during gestation and be greater in the last trimester of gestation than in the first or second trimester as has been demonstrated for the digestibility of P (Lee et al. 2019). It is, therefore, possible that results would have been different if we had used gestating sows in late gestation rather than sows in mid-gestation, but we are not aware of data comparing energy digestibility of sows in the different trimesters of gestation.

The ATTD of P increased more in the basal diet than in the other diets when fed to lactating sows instead of gestating sows (interaction, $P < 0.05$), but no difference in ATTD of P between diets containing FFRB or DFRB was observed. In this experiment, phytase was included in diets to meet digestible P requirement in gestating and lactating sows. However, the observed unexpected low digestibility of P in diets containing rice bran indicates that dietary inclusion of 500 units of phytase is not enough to meet P requirement of sows fed diets containing rice bran and no feed phosphates. Nevertheless, the level of dietary P in experimental diets does not influence ATTD of P in experimental diets (Stein et al. 2008). The ATTD of P in gestating sows obtained in this experiment was slightly lower than published data (Jongbloed et al. 2004). The observation that lactating sows have greater digestibility of P than gestating sows concurs with previous data (Jongbloed et al. 2004). Thus, it appears that lactating sows upregulate the digestibility of P, which might be due to an increase in demand for P during lactation. The ATTD of P increases from early and mid-gestation to late gestation, which coincides with increased fetal demand for P (Lee et al. 2019), and it is, therefore, possible that lactating sows have a similar ability to respond to increased demand for P by increasing digestibility.

In conclusion, lactating sows have greater digestibility of GE, DM, NDF, and P than gestating sows, and the hypothesis that ATTD of GE and nutrients is not different between gestating and lactating sows was rejected. It is possible that lactation is associated with increased efficiency of energy and nutrient digestion and (or) absorption, but further research is needed to address this hypothesis.

Conflict of Interest

The authors have no conflicts of interest.

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