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SHORT COMMUNICATION

Metabolizable energy in corn is greater than in hybrid rye when fed to gestating sows, but exogenous enzymes did not increase energy digestibility

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Abstract: The metabolizable energy (ME) in corn was greater ($P < 0.05$) than in hybrid rye when fed to sows in mid-gestation, although the difference between the two grains was less than the difference previously observed in growing pigs. An exogenous enzyme mixture did not increase apparent total tract digestibility of dry matter or gross energy in corn or hybrid rye fed to gestating sows. Likewise, digestible energy and ME in corn and hybrid rye were not increased by the enzymes.

Key words: corn, energy, enzymes, hybrid rye, sow.

Résumé : L'énergie métabolisable dans le maïs était plus élevée ($P < 0,05$) que celle dans le seigle hybride lorsque donnée aux truies en milieu de gestation, même si les différences entre les deux grains étaient moindres que les différences observées au préalable chez les porcs en croissance. Un mélange exogène d'enzymes n'a pas augmenté la digestibilité apparente du tractus total des matières sèches ou de l'énergie brute dans le maïs ou le seigle hybride donné aux truies en gestation. De même, l'énergie digestible et l'énergie métabolisable dans le maïs et le seigle hybride n'ont pas été augmentées par les enzymes. [Traduit par la Rédaction]

Mots-clés : maïs, énergie, enzymes, seigle hybride, truie.

Introduction

The metabolizable energy (ME) in hybrid rye is less than in corn if fed to growing pigs, which is likely a result of the greater concentration of dietary fiber and the reduced digestibility of starch in hybrid rye compared with corn (McGhee and Stein 2020). However, the ME of feed ingredients is influenced by the physiological stage of the pig because mature pigs have greater capacity for fermenting fiber than younger pigs (Jørgensen et al. 2007). Therefore, the digestible energy (DE) in feed ingredients is greater if measured in sows or finishing pigs than in growing pigs, which is likely due to increased digestibility of fiber and longer intestinal retention time (Goff et al. 2002; Lowell et al. 2015; Casas and Stein 2017). However, no differences were observed for average daily feed intake or average daily gain of gestating sows fed diets based on corn and soybean meal or diets based on corn, soybean meal, and hybrid rye (McGhee and Stein 2021), which indicates that DE and ME in corn and hybrid rye may not be different when fed to sows.

Exogenous carbohydrate digesting enzymes may increase the digestibility of energy in wheat, but it is unclear if blends of exogenous carbohydrases also increase the digestibility of energy in hybrid rye. Therefore, the objective of this experiment was to determine apparent total tract digestibility (ATTD) of dry matter (DM) and gross energy (GE) and concentrations of DE and ME in corn and hybrid rye when fed to gestating sows without or with an exogenous microbial enzyme blend. It was hypothesized that the exogenous enzyme blend increases ATTD of DM and GE in hybrid rye and corn and that the DE and ME in hybrid rye are not different from DE and ME in corn.

Materials and Methods

Before the experiment was initiated, the protocol was reviewed and approved by the Institutional Animal Care and Use Committee at the University of Illinois. All animal procedures followed the Canadian Council on Animal Care Guidelines on the care and use of farm

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animals in research, teaching, and testing. A total of 36 gestating Camborough sows (Pig Improvement Company, Henderson, TN, USA) were randomly allotted to four dietary treatments on day 50 of pregnancy. There were three blocks of 12 sows with three sows per diet in each block for a total of nine observations per treatment. The average parity was 2.1 ± 0.3, and the initial body weight (BW) was 211.5 ± 21.4 kg. Sows were housed individually in metabolism crates equipped with a self-feeder, a nipple waterer, and slatted floors to allow for the total, but separate, collection of urine and fecal materials. A screen floor was installed under the slatted floor, and feces were quantitatively collected from the screen floor. A urine pan was installed under the screen floor, and urine was captured in this pan and drained into a urine bucket that was placed under the pan, which allowed for quantitative collection of urine. Sows were limit fed at 1.5 times the estimated ME requirement for maintenance [i.e., 100 kcal ME·kg^{-1} $BW^{0.75}$; National Research Council (NRC) 2012], which is close to the quantity of feed provided to commercially fed gestating sows. Feed was provided each day in two equal meals at 0800 and 1700, and orts were collected daily. Diets were fed for 11 d, where the initial 5 d were considered the adaptation period to the diet, and urine and fecal materials were collected for 4 d according to standard procedures using the marker-to-marker approach (Adeola 2001). The start marker was fed in the morning meal on day 6, and the stop marker was fed in the morning meal on day 10. Urine was collected in buckets over a preservative of 50 mL of hydrochloric acid to minimize N evaporation. Fecal samples and 20% of the collected urine were stored at −20 °C immediately after collection.

Two diets were formulated to contain approximately 97% ground corn (IFN 4-02-935) or 97% ground hybrid rye (IFN 4-04-047), in addition to limestone (IFN 6-02-633), dicalcium phosphate (IFN 6-01-080), salt (6-04-152), and a vitamin–mineral premix. Two additional diets were formulated by adding 0.01% microbial enzyme cocktail (Superzyme, Canadian Bio-Systems Inc., Calgary, AB, Canada) to each diet at the expense of corn or hybrid rye. All diets were formulated to meet or exceed estimated requirements for vitamins and minerals for gestating sows (NRC 2012). According to the manufacturer, the enzyme product was formulated to contain the following minimum enzyme activities: xylanase, 8500 units·g^{-1}; glucanase, 3000 units·g^{-1}; invertase, 4000 units·g^{-1}; protease, 6500 units·g^{-1}; cellulase, 7000 units·g^{-1}; amylase, 80 000 units·g^{-1}; and mannanase, 750 units·g^{-1}. The enzyme cocktail contained fermentation extracts derived from *Trichoderma reesei*, *Saccharomyces cerevisiae*, *Aspergillus niger*, *Aspergillus oryzae*, *Bacillus subtilis*, *Bacillus licheniformis*, and *Rhizopus oryzae*.

At the conclusion of the animal part of the experiment, urine samples from each sow were thawed, mixed, sub-sampled, and filtered through a Whatman grade 4 filter paper. A sub-sample of the filtered urine was lyophilized. Fecal samples and orts were dried in a 50 °C forced air-drying oven, and fecal samples were ground using a 1 mm screen in a Wiley mill (model 4; Thomas Scientific, Swedesboro, NJ, USA). Diet samples were finely ground prior to analysis using a coffee grinder. The GE in diet, fecal, and urine samples were measured using an isoperibol bomb calorimeter (model 6400, Parr Instruments, Moline, IL, USA) with benzoic acid used as the standard for calibration.

The ATTD of DM and GE and values for DE and ME were calculated for each sow and treatment, and sow was considered the experimental unit. Normality of residuals was confirmed, and outliers were tested using the UNIVARIATE procedure (SAS Institute Inc., Cary, NC, USA). Outliers were defined as observations with internally studentized residuals less than −3 or greater than 3, but none were detected. Data were analyzed by the MIXED procedure as a 2 × 2 factorial with cereal grain, enzymes, and the interaction between cereal grain and enzymes being fixed effects. However, no interactions were observed, and the final model, therefore, included only the main effects of cereal grain and enzymes. Block and replicate within block were random effects. Least-square means were estimated for each treatment group using the LSMEANS statement in PROC MIXED. Results were considered significant at $P \leq 0.05$, and a tendency if $0.05 < P \leq 0.10$.

Results and Discussion

Daily DM intake was greater ($P < 0.05$) for sows fed hybrid rye than for sows fed corn, and the same was true for daily GE intake, daily DM fecal output, daily GE output in feces, and daily GE output in urine (Table 1). The ATTD of DM and GE tended ($P < 0.10$) to be reduced in hybrid rye compared with corn, and DE and ME in hybrid rye were less ($P < 0.05$) than in corn. Thus, the hypothesis that DE and ME in hybrid rye are not different from DE and ME in corn if fed to gestating sows was not supported. Although hybrid rye contains more fermentable dietary fiber than corn, it also contains less starch, which likely is the reason for the reduced DE and ME in hybrid rye.

The ATTD of GE in hybrid rye fed to gestating sows has not been previously reported, but the digestibility of GE in an older cultivar of rye was 87.0% in sows and 86.0% in growing pigs (Fernández et al. 1986), whereas the ATTD of GE in hybrid rye in this experiment was 89.6%. The ME in corn and hybrid rye determined in this experiment was 243 and 329 kcal·kg^{-1} DM greater than the ME in growing pigs that was previously reported (McGhee and Stein 2020). However, different hybrids of both rye and corn were used in the two experiments, and it is, therefore, possible that factors other than the physiological stage of the animals contributed to these differences. Nevertheless, the present data indicate that gestating sows obtained more energy from corn and hybrid rye than growing pigs as has also been

Table 1. Main effects of source of grain and enzyme inclusion in diets fed to gestating sows on apparent total tract digestibility of gross energy and concentration of digestible energy and metabolizable energy.[a,b]

	Source of grain		Enzyme inclusion			*P* value	
Item	Corn	Hybrid rye	No enzyme	Enzyme	SE	Grain	Enzyme
Feed intake (kg DM·d^{-1})	2.08	2.29	2.19	2.19	0.044	0.002	0.967
Fecal excretion (kg DM·d^{-1})	0.18	0.23	0.20	0.21	0.012	0.005	0.513
GE intake (kcal·d^{-1})	9086	9808	9470	9424	191.0	0.012	0.864
GE output from feces (kcal·d^{-1})	838	1028	921	946	48.8	0.010	0.722
GE output from urine (kcal·d^{-1})	212	263	252	223	15.9	0.024	0.180
ATTD of GE (%)	90.8	89.6	90.3	90.1	0.43	0.052	0.743
ATTD of DM (%)	91.2	90.0	90.8	90.5	0.45	0.062	0.611
DE (kcal·kg^{-1} DM)	4064	3926	4010	3980	18.9	<0.001	0.274
ME (kcal·kg^{-1} DM)	3959	3809	3892	3876	20.5	<0.001	0.595

Note: SE, standard error; DM, dry matter; GE, gross energy; ATTD, apparent total tract digestibility; DE, digestible energy; ME, metabolizable energy.

[a]Each least-squares mean for experimental diets represents nine observations.

[b]The initial model included grain, enzyme, and the interaction between grain and enzyme. However, none of the interactions were significant and the final model, therefore, only included the main effects of grain and enzyme.

demonstrated for other ingredients (Goff et al. 2002; Lowell et al. 2015; Casas and Stein 2017). In addition, the ME in hybrid rye and corn differed by only 150 kcal·kg^{-1} DM in the present experiment compared with a difference of 250 kcal·kg^{-1} DM in growing pigs (McGhee and Stein 2020). It is likely that the reason for the reduced difference between corn and hybrid rye in sows is that gestating sows obtain more energy from the fermentable fiber in hybrid rye than growing pigs due to the larger gastrointestinal tract and greater capacity for hindgut fermentation.

There were no effects of enzyme inclusion on any of the measured response parameters. Exogenous carbohydrate-digesting enzymes such as xylanase are frequently included in diets for pigs to increase the energy contribution from dietary fiber, but the mechanisms of action have not been completely elucidated, and the efficacy of xylanases differ among sources as well as among ingredient substrates (Adeola and Cowieson 2011). Microbial enzymes in diets containing rye and fed to growing pigs have resulted in inconsistent responses, but to our knowledge, effects of including carbohydrases in hybrid rye-based diets for sows have not been reported. However, the ATTD of GE in diets based primarily on barley and wheat and fed to lactating sows was increased by an exogenous xylanase (Zhou et al. 2018). It is possible that a longer adaptation period to exogenous enzymes than the 5 d used in this experiment is required to observe a response in sows (Petry and Patience 2020), which may be one of the reasons for the lack of effects of the enzyme mixture in this experiment. It is also possible that carbohydrases are more efficient if included in diets fed to younger pigs who have lower digestibility of DM and energy than gestating sows and, therefore, have more undigested or unfermented substrate for the enzymes in the hindgut. However, additional research is needed to test this hypothesis.

Conclusions

Results indicated that the ATTD of GE and the ME of corn fed to gestating sows is greater than in hybrid rye. It was hypothesized that exogenous carbohydrate-digesting enzymes would increase the digestibility of DM and energy and concentrations of DE and ME in corn and hybrid rye, but this hypothesis was not supported by results of the experiment. It is possible that other combinations of enzymes may positively impact digestibility of energy by sows.

Conflict of Interest

The authors have no conflict of interest.

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