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Effects of liquid and fermented liquid feeding on energy, dry matter, protein and phosphorus digestibility by growing pigs ☆

C. Pedersen *, H.H. Stein [1]

South Dakota State University, Department of Animal and Range Sciences, Brookings, SD, 57007, USA

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ABSTRACT

Two experiments were conducted to compare the apparent ileal digestibility (AID) of dry matter (DM), gross energy (GE) and crude protein (CP) and the apparent total tract digestibility (ATTD) of DM, GE, and P by growing pigs fed a diet in dry form to values obtained with pigs fed the same diet in a liquid form or in a fermented liquid form. A diet consisting of maize (728 g/kg), soybean meal (240 g/kg), soybean oil (10 g/kg) and vitamins and minerals was formulated and used in both experiments. In Exp. 1, the diet was fed to pigs as a dry diet or as liquid diets that were produced immediately before feeding by mixing the dry diet and water in a 1:1 ratio or in a 1:3 ratio. In Exp. 2, the diet was fed to pigs as a dry diet or as one of two fermented liquid diets. The fermented liquid diets were produced by mixing the dry diet with water (1:3 ratio) 24 h before feeding. Either 10 (F10) or 50% (F50) of the fermented feed was left in the fermentation tanks when new feed and water were added. Results of Exp. 1 showed that there was a tendency ($P<0.10$) for a reduction in the AID of DM, GE and CP when dry feed and water were mixed in a 1:3 ratio, but this was not the case when dry feed and water were mixed in a 1:1 ratio. The ATTD of DM, GE, and P was, however, not affected by the addition of water to the dry feed regardless of the dry feed to water ratio. In Exp. 2, pigs fed both fermented diets had lower ($P<0.05$) AID of CP than pigs fed the dry diet, but the AID of DM and GE were not affected by fermentation. The ATTD of DM in pigs fed the F50 diet tended ($P=0.06$) to be greater than in pigs fed the dry diet or the F10 diet, but the ATTD of GE and P were not affected by fermentation.

1. Introduction

Liquid feeding is often used in swine production because liquid feeding systems allow for the inclusion of a variety of alternative feed ingredients and by-products in the diets (Scholten et al., 1999). Liquid feeding may also improve the intestinal health of pigs (Deprez et al., 1987) and performance of pigs fed diets in a liquid form is often improved compared with pigs fed dry diets (Hurst et al., 2008). An improvement in nutrient digestibility has also been demonstrated in diets based on barley and wheat (Pedersen and Lindberg, 2003; Lyberg et al., 2006), and performance and apparent total tract digestibility (ATTD) of P in a maize–soybean meal diet was improved if feed was soaked prior to feeding (Liu et al., 1997). To our knowledge, there are, however, no data on the effect of soaking or fermentation on the ileal digestibility of energy and nutrients in pigs fed a maize–soybean meal diet. It was, therefore, the objective of this experiment to test the hypothesis that the apparent ileal digestibility (AID) of gross energy (GE), dry matter (DM), and crude protein (CP) and the ATTD of GE, DM and P is improved if a diet based on maize and soybean meal is fed as a liquid diet or as a fermented liquid diet.

2. Materials and methods

2.1. Animals and housing

Six finishing barrows (initial BW: 77.2 ± 5.9 kg) that were equipped with a T-cannula in the distal ileum were used in

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* Corresponding author. Schothorst Feed Research, Lelystad, The Netherlands. Tel.: +31 320 292 190; fax: + 31 320 255 030.
E-mail address: cpedersen@schothorst.nl (C. Pedersen).
[1] Current address: Univ. of Illinois, Urbana-Champaign, IL, 61801, USA.

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two digestibility experiments. Pigs were housed individually in 1.2 × 1.6 m pens in an environmentally controlled building. The same pigs were used in both experiments and the weight at the beginning and at the end of Exp. 2 was 91.9 ± 5.7 kg and 107.1 ± 5.1 kg, respectively. Room temperature was maintained at 22 °C throughout the experiments. A feeder and a nipple drinker were installed in each pen. In both experiments, pigs were allotted to a replicated 3 × 3 Latin square design with three periods and three dietary treatments per square. Each period lasted 7 days. The protocols for both experiments were reviewed and approved by the Animal Care and Use Committee at South Dakota State University.

2.2. Diet and feeding

A diet based on maize (728 g/kg) and soybean meal (240 g/kg) was formulated and used in both experiments. Ground limestone (8.5 g/kg), dicalcium phosphate (3.5 g/kg), soybean oil (10 g/kg) and chromic oxide (4 g/kg) were also included in the diet. Vitamins and micro minerals were included at levels that met or exceeded the estimated requirements for growing pigs (NRC, 1998). This diet analyzed 190 g/kg of CP and 4.2 g/kg of total P. In both experiments, feed was provided to the pigs in a daily amount of three times the calculated requirement for maintenance energy (i.e., 1.06 kcal ME × BW $kg^{0.75}$; NRC, 1998). Water was available at all times.

In Exp. 1, the diet was fed as a dry diet, as a liquid diet that was produced by mixing feed and water in a 1:1 ratio, or as a liquid diet that was produced by mixing feed and water in a 1:3 ratio. The two liquid diets were produced by mixing water (~10 °C) and dry feed immediately before feeding to avoid fermentation of the diets. In Exp. 2, the diet was fed to pigs as a dry diet or as one of two fermented liquid diets that were produced by mixing the dry diet with water (1:3 ratio; water ~10 °C) 24 h before feeding and allowing this mixture to ferment at 20 °C in plastic containers. Two containers were used for each diet, one for the morning feeding and one for the afternoon feeding. Either 10 (F10) or 50% (F50) of the fermented feed was left in the fermentation tanks when new feed and water were added. Fermentation started 5 days before feeding of the fermented feed.

2.3. Sample collections and analyses

The initial 4 days of each experimental period were considered an adaptation period to the diet. Faecal samples were collected on day-5 of each period and stored at −20 °C. Ileal samples were collected on days 6 and 7 by attaching a 250-ml plastic bag to the opened cannula and digesta flowing into the bag were collected for nine hours per collection day. Collected digesta were stored at −20 °C. Digesta were mixed within the pig and the period at the conclusion of the experiment and a sub-sample was collected and lyophilized. Faecal samples were dried in a forced air oven. Diets and ileal digesta were analyzed for DM and CP (AOAC, 2000) and faecal samples were analyzed for DM and P (AOAC, 2000). All samples were also analyzed for GE using bomb calorimetry (Parr Instruments, Moline, IL).

2.4. Calculations and statistical analyses

The AID of GE, DM, and CP and the ATTD of GE, DM, and P were calculated. Data from each experiment were analyzed using the MIXED procedure of SAS (SAS Stat. Inc., Cary, NC). Diet was the main effect and period and pigs were random variables. Least square means were calculated and separated using the PDIFF option of SAS. An alpha level of 0.05 was used to assess significance among treatments.

3. Results

In Exp. 1, a tendency ($P<0.10$) for a reduction in the AID of DM, GE and CP was observed when dry feed and water were mixed in a 1:3 ratio, but this was not the case when dry feed and water were mixed in a 1:1 ratio (Table 1). The ATTD of DM, GE, and P was, however, not affected by the addition of water to the dry feed regardless of the dry feed to water ratio.

In Exp. 2, pigs fed both fermented diets had lower ($P<0.05$) AID of CP than pigs fed the dry diet, but the AID of DM and GE were not affected by fermentation (Table 2). The ATTD of DM in pigs fed the F50 diet tended ($P=0.06$) to be greater than in pigs fed the dry diet or the F10 diet, but the ATTD of GE and P were not affected by fermentation.

4. Discussion

In the present experiment, a liquid diet was produced by mixing feed and water in a 1:1 ratio to simulate the feed consumed by pigs using a wet–dry feeder, and the diet produced by mixing dry feed and water in a 1:3 ratio was used to simulate the feed fed to pigs via a liquid feeding system. We are not aware of other experiments in which energy or nutrient digestibility values have been measured in liquid diets under conditions similar to those used in this experiment. However, the observation that there was a tendency for a reduced AID of DM, GE and CP if dry feed and water was mixed in a 1:3 ratio indicates that energy and nutrient digestibility may be reduced if liquid feeding systems are used.

The reduced AID of CP for pigs fed the fermented diets was surprising and does not agree with observations showing that the AID of nitrogen is improved if a wheat–barley based diet is fermented for 24 h prior to feeding (Lyberg et al., 2006). We do

Table 1
Apparent ileal digestibility (AID) of DM, GE and CP and apparent total tract digestibility (ATTD) of DM, GE and P in pigs fed a diet in a dry form or in a liquid form with feed and water mixed in a 1:1 ratio or in a 1:3 ratio, Exp. 1.

Item	Dry feed	Liquid feed, dry feed:water		SEM	*P*-value
		1:1	1:3		
AID, %					
DM	74.5	75.4	73.0	0.96	0.06
GE	76.5	77.4	74.8	0.90	0.05
CP	78.6	80.2	76.2	1.28	0.09
ATTD, %					
DM	90.4	90.4	90.2	0.49	0.86
GE	89.7	90.0	89.5	0.54	0.72
P	39.0	40.1	38.9	2.18	0.81

Table 2
Apparent ileal digestibility (AID) of DM, GE and CP and apparent total tract digestibility (ATTD) of DM, GE and P in pigs fed a diet in a dry form or after fermentation with 10% (F10) or 50% (F50) residual feed in the fermentation tanks, Exp. 2.

Item	Dry feed	Fermented feed		SEM	*P*-value
		F10	F50		
AID, %					
DM	75.8	73.8	75.0	1.25	0.39
GE	77.2	74.8	73.9	1.35	0.14
CP	79.3	74.6	73.7	1.19	0.04
ATTD, %					
DM	90.9	90.9	91.6	0.45	0.06
GE	90.4	90.4	91.0	0.43	0.11
P	36.6	34.1	37.0	1.89	0.29

not have an explanation for this observation. The tendency for an improvement in the ATTD of DM in pigs fed the F50 diet agrees with observations showing that fermentation improves the ATTD of organic matter (Lyberg et al., 2006). The reason for this observation may be that fermentation increases the microbial activity, which may enhance fibre solubility and thereby fibre disappearance in the gastro-intestinal tract (Pedersen and Lindberg, 2003).

Fermentation of diets that contain barley increases the ATTD of P (Lyberg et al., 2006), but barley contains intrinsic phytase in relatively high concentrations, which initiates the release of P from the phytate molecule during fermentation (Carlson and Poulsen, 2003). Maize on the other hand does not contain intrinsic phytase, which may be the reason why no change in the ATTD of P was observed in the present experiment. It has been reported that a 2 h soaking of a maize–soybean meal diet prior to feeding may increase the ATTD of P (Liu et al., 1997). In Exp. 1 of the present work, feed and water were mixed immediately before feeding and in Exp. 2, feed was allowed to ferment for 24 h before feeding, which may be the reason why we did not observe an increase in the ATTD of P in these experiments. The concentration of P in the diets relative to the pigs' requirement of P is not believed to have influenced the results because diet P concentration does not affect the ATTD of P (Stein et al., 2008).

5. Conclusions

If dry feed and water is mixed in a 1:1 ratio, GE, DM, CP, or P digestibility is not affected, but mixing feed and water in a 1:3 ratio tended to reduce ileal digestibility of GE, DM, and CP compared with the digestibility in dry feed. Fermentation of a maize–soybean meal diet may reduce the ileal digestibility of CP, but the ATTD of DM may be increased if 50% fermented feed is left in the fermentation tanks when new feed is added. However, fermentation of a maize–soybean meal diet containing no exogenous phytase and 4.2 g/kg of total P does not affect the digestibility of energy or P in finishing pigs.

Conflict of interest

There are no conflicts of interest.

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