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Effect of dietary fiber type on intestinal nutrient digestibility and hindgut fermentation of diets fed to finishing pigs

Lixiang Gao [a,1], Liang Chen [a,b,1], Qinghua Huang [a], Lihui Meng [a], Ruqing Zhong [a], Chenglin Liu [a], Xiangfang Tang [a], Hongfu Zhang [a,*]

[a] State Key Laboratory of Animal Nutrition, Institute of Animal Sciences, Chinese Academy of Agricultural Sciences, Beijing 100193, China
[b] Key Laboratory for Feed Biotechnology of the Ministry of Agriculture, Feed Research Institute, Chinese Academy of Agricultural Sciences, Beijing 100081, China

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ABSTRACT

The objective of this experiment was to determine the effects of dietary fiber type on intestinal nutrient and energy digestibility and hindgut fermentation in finishing pigs. Six ileal-cannulated pigs (initial BW = 21.4 ± 1.5 kg) were allotted to 3 treatments in a replicated 3 × 3 Latin square. The pigs were provided a corn-soybean meal control diet or a diet in which corn and soybean meal was partly replaced by 5% inulin (INU) or carboxymethylcellulose sodium (CMC). The apparent ileal digestibility (AID) and apparent total tract digestibility (ATTD) of nutrients and energy were measured. The VFA concentration was also determined in the ileal and fecal samples. The AID of DM, carbohydrates (CHO), NDF and GE were less ($P < 0.01$) for pigs fed the INU diet than those fed the control and CMC diets. The ATTD and hindgut fermentation of DM, CHO, ADF, NDF, and GE were less ($P < 0.01$) in the CMC diet than in the control diet or the INU diet, whereas, the AID of CP was greater ($P < 0.05$) in the CMC diet than in the other diets. The ATTD of NDF and hindgut fermentation of EE were greater ($P < 0.01$) in the control diet than in the INU diet or the CMC diet. The hindgut fermentation of CHO and GE were greater ($P < 0.01$) in the INU diet than in the control diet or the CMC diet. The total tract flow of nutrients and energy increased ($P < 0.01$) by inclusion of 5% CMC in the diet. There were no differences in ileal VFA concentrations between the diets. The fecal acetate and total VFA concentrations were greater ($P < 0.01$) in pigs fed the INU diet than fed the control diet or the CMC diet. The fecal pH and concentration of acetate, propionate, isobutyrate, butyrate, isovalerate, and total VFA were less ($P < 0.01$) in pigs fed the CMC diet than those fed the control diet or the INU diet. In conclusion, addition of 5% inulin into a diet had a low digestibility of nutrients and energy in upper gut and high hindgut fermentation. In contract, the CMC increased the AID of CP and reduced other nutrient and energy digestibility and fermentation.

1. Introduction

Dietary fiber is made of non-starch polysaccharides and lignin. It is resistant to degradation by endogenic digestive enzymes in the stomach and small intestine of pigs, but it may be mostly fermented by hindgut microbial (Topping and Clifton, 2001). The functional properties of dietary

* Correspondence to: Institute of Animal Sciences, Chinese Academy of Agricultural Sciences, No. 2 Yuan Ming Yuan West Road, Haidian District, Beijing 100193, China. Tel./fax: +86 10 62818910.
E-mail address: zhanghfcaas@gmail.com (H. Zhang).
[1] These authors contributed equally to this work.

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fiber mainly include solubility, viscosity, fermentability, and water holding capacity (Bach Knudsen et al., 1993; Guillon et al., 2007; Johansen et al., 1996). The effect of dietary fiber on nutrient digestion and absorption largely reflects the structural and functional characteristics of dietary fiber (Chen et al., 2013, 2014; Renteria-Flores et al., 2008).

Viscous dietary fiber has a high water holding capacity, increases digesta viscosity, reduced digesta passage rate and thereby reduces apparent ileal digestibility (AID) of macronutrients (Dikeman and Fahey, 2006). Fermentable fiber can pass into the large intestine and is fermented by microbial populations, thereby producing VFA (Bach Knudsen and Hansen, 1991).

Most studies reporting the role of dietary fiber are based on a diet with high-fiber ingredients fed to growing pigs. Specific effects of functional or structural properties can be differentiated by using of feeding purified fiber fractions, such as low viscous, high fermentable inulin or high viscous, low fermentable sodium carboxymethylcellulose (Hooda et al., 2011; Yan et al., 2013). Moreover, viscosity and fermentability of dietary fiber interact to affect the digestibility and fermentation of nutrients and energy in pigs (Hooda et al., 2011). However, there is a little information about the nutrient functional roles of dietary fiber type from purified fiber fractions compared to the control diet fed to finishing pigs.

The hypothesis of the present study was that inclusion of purified fiber fractions in the diet affects intestinal nutrient digestibility and hindgut fermentation in finishing pigs. The objectives of this study were to determine the effects of the two functional properties of purified fiber in corn-soybean meal diets on nutrient and energy digestibility, digesta characteristics, and VFA concentration in ileal-cannulated finishing pigs.

2. Materials and methods

2.1. Animals, experimental design, and diets

The experimental protocol was reviewed and approved by the Institutional Animal Care and Use Committee of the State Key Laboratory of Animal Nutrition at the Chinese Academy of Agricultural Science.

Six crossbred barrows (Large White × Landrace; initial BW = 21.3 ± 1.0 kg) were surgically fitted with a T-cannula with an inner diameter of 1.5 cm in the distal ileum. All pigs were successfully cannulated at the distal ileum and recovered from surgery without complications. All pigs were housed in individual pens (1.2 × 1.5 m) and provided feed and water ad libitum. The room temperature was 20 ± 2 °C for the duration of the experiment.

The control diet based on corn and soybean meal fed to ileal-cannulated pigs for 56.0 kg of BW. The pigs were provided with a control diet (CON), or a diet in which corn and soybean meal partly were replaced by 5% inulin (INU) or carboxymethylcellulose sodium (CMC) in a double 3 × 3 Latin square design at 0800 and 1600 h (Table 1). Vitamins and minerals were included in the diets to meet or exceed nutritional requirements of growing pigs (NRC, 1998). Chromic oxide was included in all diets as an indigestible marker. The daily feed allowance was adjusted to 3 times the maintenance requirement for energy (i.e., 106 kcal of ME/kg of $BW^{0.75}$; NRC, 1998). The diets were offered to the pigs as pellets.

Table 1
Ingredient and nutrient composition of experimental diets (as-fed basis).

Items	Diet[a]		
	CON	INU	CMC
Ingredients (%)			
Corn	76.58	66.49	66.49
Soybean meal	19.29	21.04	21.04
CMC	0.00	0.00	5.00
Inulin	0.00	5.00	0.00
Soybean oil	1.10	4.39	4.39
Dicalcium phosphate	1.03	1.08	1.08
Limestone	0.40	0.40	0.40
Salt	0.30	0.30	0.30
Vitamin and mineral premix[b]	1.00	1.00	1.00
Chromic oxide	0.30	0.30	0.30
Nutrient composition			
GE (kcal/kg)	3995	4185	4097
DM (%)	89.3	90.1	89.3
CP (%)	15.3	15.2	15.1
Ether extract (%)	4.7	7.4	7.4
Ash (%)	3.9	3.9	4.5
Total carbohydrates (%)	65.5	63.7	62.3
NDF (%)	11.8	9.9	12.8
ADF (%)	2.4	2.2	2.5

[a] CON = control diet; INU = inulin diet; and CMC = carboxymethyl cellulose sodium diet.

[b] Provided per kilogram of diet: vitamin A, 8250 IU; vitamin D_3, 825 IU; vitamin E, 40 IU; menadione, 4 mg; biotin, 0.2 mg; choline chloride, 600 mg; folic acid, 2 mg; niacin, 35 mg; D-pantothenate, 15 mg; riboflavin, 5.0 mg; thiamin, 1.0 mg; pyridoxine, 2.0 mg; cobalamine, 25 μg; Cu, 50.0 mg as copper sulfate; I, 0.5 mg as potassium iodide; Fe, 53.3 mg as iron sulfate; Mn, 25.0 mg manganous oxide; Se, 0.15 mg as sodium selenite; and Zn, 65.0 mg as zinc sulfate.

2.2. Sample collection and processing

Pigs were fed the experimental diets during three 10-d periods, and pigs were weighed at the beginning and end of each period. Feces were collected via grab sampling from d 6 to 7 of each period. The pH of the fecal samples was measured immediately after collection, using a pH meter (PB-10; Sartorius AG, Göttingen, Germany). Ten grams of each fecal sample was stored at −20 °C until subsequent analysis for VFA concentration. The remaining feces were stored in plastic bags at −20 °C. One sample of ileal digesta was collected continuously from 0830 to 1630 h on d 8 and 10. The digesta collection method was similar to the excreta collection procedure described by Chen et al. (2013). From each bag of ileal digesta, 5 g of subsample was collected. These samples were combined by pig and collection period, and stored at −20 °C until subsequent VFA analysis. The pH of ileal samples collected from each pig was measured as described for the fecal samples. At the conclusion of each collection period, samples were thawed and mixed by individual animal, and a subsample was collected for chemical analysis. Ileal and fecal samples were lyophilized and ground before analysis.

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