



# Impact of fiber types on gut microbiota, gut environment and gut function in fattening pigs



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## ABSTRACT

This study was designed to evaluate the impact of different fibrous diets on intestinal bacteria, fermentation metabolites and mucosal digestive physiology in fattening pigs. A total of 125 weaned piglets were allocated to five treatments, and each treatment was replicated in five pens of five pigs each. Pigs were fed *ad libitum* for 160 d. The experimental diets consisted of three-phase feeding program and four sources of fiber (maize fiber, soybean fiber, wheat bran fiber and pea fiber) were evaluated in each phase, including 10%, 20% or 30% of fiber source in the different phase feeding diets, respectively. Cereal fiber (maize fiber and wheat bran fiber) predominantly consisted of xylose and arabinose. Soybean fiber was characterized by high contents of galactose, and pea fiber was rich in glucose. Average daily feed intake (ADFI) was reduced ( $P < 0.05$ ) in pigs fed SF, but supplemental pea fiber had a higher feed conversion ratio ( $P < 0.05$ ) compared to control diet (CON). In ileum, increased villus height ( $P < 0.05$ ) was found in pea fiber diet (PF) and wheat bran fiber diet (WB) compared to soybean fiber diet (SF). Higher ileal sucrase ( $P < 0.05$ ) and maltase activities ( $P < 0.05$ ) occurred in pigs fed PF compared to CON and SF. In cecum, acetate concentrations in SF ( $P < 0.05$ ) and butyrate concentration in WB ( $P < 0.05$ ) were higher than those in CON. Lower ileal *Lactobacillus* populations ( $P < 0.05$ ) and higher cecal *Escherichia coli* populations in SF ( $P < 0.05$ ) were found compared to CON. Meanwhile, cecal *Lactobacillus* populations in PF ( $P < 0.05$ ) and *Bifidobacterium* populations in WB ( $P < 0.05$ ) were higher than CON. The glucose transporters gene expression was up-regulated ( $P < 0.05$ ) in WB and/or PF compared to CON. To be concluded, influences of dietary sources on intestinal microflora and volatile fatty acids seemed to be related to fiber components, which possibly led to the changes in intestinal mucosal digestive physiology and thus affect production parameters of fattening pigs.

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**Abbreviations:** ADF, acid detergent fiber; ADFI, average daily feed intake; ADG, average daily gain; ADL, acid detergent lignin; AX, arabinoxylan; CON, control diet; CP, crude protein; DM, dry matter; FCR, feed conversion ratio; GLUT2, facilitated glucose transporter 2; MF, maize fiber diet; NDF, neutral detergent fiber; PF, pea fiber diet; SF, soybean fiber diet; SGLT1, Na<sup>+</sup>-glucose co-transporter 1; VFA, volatile fatty acid; WB, wheat bran fiber diet.

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## 1. Introduction

Dietary fiber is usually an important ingredient in diet for pigs, since it promotes the intestinal development and intestinal health of pigs (Wenk, 2001; Montagne et al., 2003). The impact of dietary fiber on intestinal function is accepted to predominantly depend on the interaction with intestinal bacteria in the hindgut, including the changes in the intestinal microflora composition (Castillo et al., 2007) and production of fermentation end-products (i.e. volatile fatty acids, VFA) (Henningsson et al., 2001), because of the resistance to digestion and absorption in the foregut.

Further studies showed that supplemental fiber sources with different fiber components resulted in inconsistent microflora composition and VFA production in intestinal tract of pigs (Van Nevel et al., 2006; Jonathan et al., 2012). Wheat arabinoxylan (AX) was reported to increase *Bifidobacterium* and *Lactobacillus* populations and *Escherichia coli* was stimulated by degrading arabinogalactan from soy fiber *in vitro* (Van Laere et al., 2000; Crittenden et al., 2002; Neyrinck et al., 2011). Mortensen et al. (1988) and Salvador et al. (1993) proposed that the production and proportion of acetate, propionate and butyrate were relevant to monosaccharide composition of fiber source during fermentation by human intestinal bacteria. The type of polysaccharides was also believed to be involved in the profiles of fermentation end-products in human and pigs (Titgemeyer et al., 1991; Jonathan et al., 2012).

Meanwhile, modulation of intestinal mucosal digestive physiology by intestinal bacteria and VFA has been investigated. Shirkey et al. (2006) and Yang et al. (2009) reported that intestinal morphology was improved when gnotobiotic animals were administered *Lactobacillus* species or *Bifidobacterium* species. Beneficial bacteria were also shown to affect Na<sup>+</sup>-coupled glucose absorption by up-regulating glucose transporters in intestinal mucosa (Buts, 2009; Rooj et al., 2010). Volatile fatty acids, especially butyric acid, were demonstrated to promote the secretion of the digestive enzymes and gene expression of nutrient transporters in brush-border membrane (Fernandezmeja and Davidson, 1993; Mangian and Tappenden, 2009). Therefore, we considered that fiber source could change intestinal mucosal digestive physiology by modulating intestinal bacteria and fermentation metabolites (VFA).

In the present study, we assayed monosaccharide composition of dietary fibers, i.e. cereal fibers (wheat bran fiber and maize fiber) and legume fibers (soybean fiber and pea fiber) chosen in our short-term study (Chen et al., 2013). Our objective was to study whether the long-term fiber source intake with different fiber components could affect intestinal mucosal digestive physiology through regulating intestinal bacteria and fermentation end-products in fattening pigs.

## 2. Materials and methods

### 2.1. Dietary fiber sources

Wheat bran (Shangyidao Science and Technology Co., Jiangsu, PR China), maize fiber (Ci Yuan Biotech. Co., Shanxi, PR China), soybean fiber (Winway Biotech. Co., Shanghai, PR China) and pea fiber (Jianyuan Food Co., Shandong, PR China) were purchased from Chinese food companies, which were purified from wheat, maize, soybean and pea respectively by extracting starch and protein following common industrial processing.

### 2.2. Experimental design and diets

A total of 125 weaned pigs (Duroc × Landrace × Yorkshire, weaned at  $28 \pm 2$  d) were allocated to one of five treatments depending on body weight, gender and litter. Each treatment was replicated in five pens of five pigs each, and pigs were fed *ad libitum* for 160 d. Experimental pigs were fed in slatted floor pens. Ambient temperature was maintained at 26 °C for the first 3 d after weaning and then reduced by 2 °C per week in the nursery stage. The experimental protocol was in accordance with the Guide for the Care and Use of Laboratory Animals prepared by the institutional animal care and use committee, Sichuan Agricultural University, China.

A maize–soybean meal basal diet (Table 1) was formulated, corresponding to the nutrient requirements of swine (NRC, 1998). The experimental diets included control diet without fiber source (CON) and four fibrous diets, i.e. maize fiber diet (MF), soybean fiber diet (SF), wheat bran fiber diet (WB) and pea fiber diet (PF). Experimental diets were given as phase feeding program according to the physiological stage, i.e. weaning period (weaning to 30 d post-weaning), growing period (30–90 d post-weaning) and finishing period (90–160 d post-weaning), including 10%, 20% or 30% of fiber sources in three-phase diets, respectively. Expanded maize was replaced by fiber source and fat powder was added to maintain similar energy levels between control and fibrous diets at each phase feeding.

### 2.3. Growth performance measurement

The pigs were weighed at 0 d, and at the end of the experiment, i.e. 160 d. Voluntary feed intake was recorded weekly. Daily weight gain and feed conversion ratio were calculated.

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