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Long-term intake of raw potato starch decreases back fat thickness and dressing percentage but has no effect on the longissimus muscle quality of growing–finishing pigs

L. Fang, X. Jiang, Y. Su*, W. Zhu

Laboratory of Gastrointestinal Microbiology, College of Animal Science and Technology, Nanjing Agricultural University, Nanjing, PR China

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ABSTRACT

This study was conducted to investigate the effects of long-term intake of raw potato starch (RPS) on carcass quality, luminal short chain fatty acid (SCFA) concentrations, the expression of host genes involved in fat metabolism in the liver, SCFA uptake, SCFA signaling and satiety regulation in the colonic mucosa of growing–finishing pigs. Thirty-six Duroc × Landrace × Large White growing barrows (70 days of age, 23.78 ± 1.87 kg) were randomly allocated to corn starch (CS) and raw potato starch (RPS) groups, each group consisting of six replicates (pen) with three pigs per pen. Pigs in the CS group were offered a corn–soybean based diet, while pigs in the RPS group were put on a diet in which 230 g/kg (growing) or 280 g/kg (finishing) purified corn starch was replaced with purified RPS during a 100-day trial. Results showed that long-term intake of RPS significantly increased the feed intake of the pigs, but had no effect on body weight, average daily gain or feed:gain ratio. Consumption of RPS significantly increased the weight of the stomach and large intestine and their percentage of body weight, the mucosa thickness of the cecum and colon, and SCFA concentrations in the colon of pigs. Long-term intake of RPS decreased back fat thickness and dressing percentage but had no effect on the longissimus muscle quality of growing–finishing pigs. The expression of genes *MCT1*, *FFAR2* and *FFAR3* in the colonic mucosa was significantly up-regulated in pigs fed with the RPS diet as compared to pigs fed with the CS diet. Consuming RPS significantly down-regulated the expression of genes *CPT1a* and *PPARα*, and up-regulated the expression of the *SREBP1c* gene in the livers of pigs. The results suggest that RPS modulates gut SCFA concentrations and the expression of host genes, which can change the adipose tissue patterning in pigs.

1. Introduction

The starch, acting as the major energy-producing component of the daily diet, is the main carbohydrate in pig nutrition; however, it can also have properties similar to dietary fiber. Starch that escapes digestion in the human and animal small intestine can enter the large intestine, where it is used as a substrate for bacterial fermentation (Englyst et al., 1992). In previous studies on humans, there was evidence that resistant starch (RS) fermentation could confer health benefits, helping to reverse infectious diarrhea (Niderman-Meyer et al., 2010), and prevent colorectal cancer (Young et al., 2005; Le Leu et al., 2009). In pigs, it was also found that diets high in RS modulated microbiota composition, short chain fatty acid (SCFA) concentrations, and gene expression in the intestine (Haenen et al., 2013);

* Corresponding author. Tel.: +86 25 84395523; fax: +86 25 84395314.
E-mail address: yong.su@njau.edu.cn (Y. Su).

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however, information on the effects of RS on animals at the extraintestinal level is relatively limited.

Recently, there has been increased interest in understanding the impact of RS on the adipose metabolism and adipose tissue patterning of humans and animals. It was reported that diets high in RS resulted in lower total body adiposity, subcutaneous and visceral fat with no change in the overall body weight of mice (So et al., 2007). Currently, the swine industry in China is focused on improving pork quality. Adipose tissue patterning including back fat thickness and intramuscular fat content is regarded as an important factor affecting pork quality. Martinez-Puig et al. (2006) found that consumption of raw potato starch (RPS) which is high in RS decreased lipogenesis in adipose tissues but not in the muscular tissues of growing pigs; however, back fat thickness and intramuscular fat content were not affected significantly throughout a 38-day trial. Thus, it is necessary to know whether resistant starch can affect carcass traits or the pork quality of finishing pigs after a long-term intake of RPS.

So far, the mechanism behind the relationship between RS and the adipose metabolism of rodents is that SCFA fermented from RS can increase endogenous secretions of the satiety-stimulating hormones glucagon-like peptide 1 (GLP-1) and peptide YY (PYY) in the gut (Keenan et al., 2006; Zhou et al., 2008). Nevertheless, it was also found that RS could increase the feed intake of aged mice after fasting for 12 h (Tachon et al., 2013). In pigs, a recent study showed that RS did not change the expression of genes involved in satiety regulation in intestinal mucosal tissue, though genes related to SCFA uptake and signaling were up-regulated (Haenen et al., 2013). Furthermore, a study of piglets showed that long-term ingestion of a rapidly digestible starch (high amylopectin ratio) significantly elevated the hepatic lipogenesis, which is associated with a higher serum insulin concentration and more lipogenic genes expressed in the liver (He et al., 2010). To date, it is not clear whether RS can affect the expressions of adipose metabolism-related genes in the livers of pigs or further changes in adipose tissue patterning.

In this study, we hypothesize that diet high in RS can increase gut SCFA concentration, modulate host gene expression, and eventually influence the adipose metabolism and pork quality. Therefore, by using raw potato starch to substitute about half of the corn starch in the diet, the present study aimed to investigate the effects of a long-term intake of RS on growth performance, carcass quality, expression of host genes involved in adipose metabolism in the liver, SCFA uptake, SCFA signaling and satiety regulation in the colonic mucosa of growing–finishing pigs.

2. Materials and methods

2.1. Animals, housing, and diets

This study was approved by the Nanjing Agricultural University Animal Care and Use Committee. The treatment, housing, husbandry and slaughtering conditions conformed to the Experimental Animal Care and Use guidelines of China. All pigs were raised on a commercial farm in the Jiangsu province of China. Thirty-six Duroc × Landrace × Large White growing barrows (70 days of age, 23.78 ± 1.87 kg) were randomly allocated to two groups, each group consisting of six replicates (pen) with three pigs per pen. Pigs in the control group were offered a corn–soybean based diet, while 230 g/kg purified corn starch (CS) was replaced with purified RPS in the RPS diet group. Diets were formulated (Table 1) according to the nutrient requirements of the National Research Council (1998). When animals reached the age of 120 days, diets were adapted to the nutrient requirements of the animals (finishing diet) and the amount of purified starch increased to 280 g of CS or RPS per kilogram of feed. Pigs had unlimited access to feed in a mash form and water throughout the experimental period, which consisted of two 50-day trials consuming the growing diet (days 0–50) and finishing diet (days 51–100), respectively. Individual body weight was registered on days 0, 50 and 100 for calculation of average daily gain (ADG). The feed intake of pigs in each pen was recorded during each period for calculation of average daily feed intake (ADFI). Feed efficiency (feed: gain) was expressed as ADFI:ADG.

2.2. Slaughtering and sampling

On day 100, one pig from each pen was randomly selected for slaughtering when pigs approached target slaughter weight (105 to 110 kg). Feed was withheld from the pigs 12 h before slaughter. Pigs were weighted and transported (10 km) to a local commercial slaughterhouse, and slaughtered via electrical stunning followed by exsan-

Table 1
Composition and analyzed nutrient contents of experimental diets (as-fed basis).

Diets	Growing pigs		Finishing pigs	
	CS	RPS	CS	RPS
Ingredients (g/kg)				
Corn starch	230.0	–	280.0	–
Raw potato starch	–	230.0	–	280.0
Corn	360.0	360.0	360.0	360.0
Wheat bran	90.0	90.0	120.0	120.0
Soybean meal	250.0	250.0	210.0	210.0
Extruded soybean	30.0	30.0	–	–
Soybean oil	8.00	8.00	–	–
Dicalcium phosphate	9.80	9.80	8.80	8.80
Limestone	7.80	7.80	7.70	7.70
Salt	3.00	3.00	3.00	3.00
Vitamin and mineral premix[a]	10.0	10.0	10.0	10.0
L-Lysine	1.00	1.00	0.50	0.50
L-Methionine	0.40	0.40	–	–
Nutrient analysis (g/kg)				
Crude protein	174.5	174.5	147.3	147.3
Starch	505.6	504.5	550.2	549.5
Resistant starch	6.40	133.5	5.20	153.5
Ash	72.1	73.2	61.0	61.6
Neutral detergent fiber	95.77	95.78	102.5	102.6

CS, corn starch; RPS, raw potato starch.

[a] This mineral and vitamin premix (1%) supplies per kg diet as follows: VA 11 000 IU, VD3 1 000 IU, VE 16 IU, VK1 1 mg, VB1 0.6 mg, VB2 0.6 mg, D-pantothenic acid 6 mg, nicotinic acid 10 mg, VB12 0.03 mg, folic acid 0.8 mg, VB6 1.5 mg, choline 800 mg, Fe 165 mg, Zn 165 mg, Cu 16.5 mg, Mn 30 mg, Co 0.15 mg, I 0.25 mg, Se 0.25 mg.