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Effects of dietary ramie powder at various levels on carcass traits and meat quality in finishing pigs

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ABSTRACT

This study investigated the effects of ramie (0, 3, 6, 9, or 12%) included in finishing diets on carcass traits and meat quality of Xiangcun black pigs. Results showed that ramie decreased (linear, $P < .05$) backfat depth while it increased (linear, $P < .05$) loin-eye area. A quadratic effect of shear force in *longissimus thoracis* (LT) was observed, and the lowest value was noted in the 6% ramie group. Protein content in LT was linearly increased by ramie (linear, $P < .01$). Meanwhile, dietary ramie linearly decreased lipogenic genes mRNA levels and fiber cross-sectional area, but it linearly increased total fiber number of LT. These results suggest that ramie included in the diet < 9% is an effective feed crop to partly improve carcass trait and muscle chemical composition without negatively affecting growth performance, and the underlying mechanism may be due to the changed lipogenic potential and myofiber characteristics induced by ramie.

1. Introduction

Production of soybean meal, which is widely used in the Chinese pig industry as a source of protein, has declined in recent years whereas demand has continued to increase. The increasing shortage of local supply for soybean meal has led to a soaring price of soybean meal, thus resulting in a reducing profit in pig production. On the other hand, due to the growing focus on the relationship between nutrition and health, consumers are increasingly demanding high-quality meat products (Franco, Vazquez, & Lorenzo, 2014). Consequently, it is absolutely imperative to look for alternative feed sources to reduce use of soybean meal and beneficially regulate meat quality of pigs (Hanczakowska, Świątkiewicz, & Grela, 2015).

Recently, ramie (*Bochmeria nivea*), well known as "China grass", has attracted growing interest as an unconventional feed source for livestock (Kipriotis, Heping, Vafeiadakis, Kiprioti, & Alexopoulou, 2015). Ramie leaves and tender tops, unlike the stems and roots, are relatively low in fiber, but their crude protein (CP) content is relatively high (slightly > 20% of dry matter, DM) and they are a rich source of amino acids (especially lysine) (Jang & Yoon, 2006). Thus, there is an urgent need to evaluate their effects as alternative protein feed *in vivo* trials. Xiangcun black pig, as a lean-meat breed of swine in Southern China, has strong adaptability and resistance, and is playing an increasing significant role in pork industry. Therefore, Xiangcun black pig was selected as an animal model in the present study to evaluate the growth effect of finishing pigs fed the ramie meal.

It is commonly known that intramuscular fat (IMF) is regarded as an important factor influencing meat quality as it contributes to the pork tenderness and flavor. A study reported by Lee, Kim, and Lee (2014) has found the administration of ramie leaf extract could improve serum lipid profile and reduce adipose tissue weight in the *db/db* obesity mice. However, whether and how lipid metabolism can be regulated by ramie in pigs, is still not clear. In addition, data available in the previous literature indicate that muscle fiber characteristics is associated with

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many aspects of meat quality that are represented by shear force (a reflection of tenderness) and water holding capacity (Joo, Kim, Hwang, & Ryu, 2013; Ryu & Kim, 2005). To our knowledge, there was no relevant research that was conducted to test whether ramie treatment can change meat quality and, if so, whether lipid metabolism or/and myofiber characteristics of muscle can be changed by ramie, which may be involved in regulation of the process. In view of the foregoing, we hypothesized that dietary ramie inclusion may affect meat quality traits of Xiangcun Black finishing pigs through influencing lipid metabolism and myofiber characteristics. The present study was conducted to test this hypothesis.

2. Materials and methods

All experiment procedures in the present study were approved by the Animal Care Committee of the Institute of Subtropical Agriculture, the Chinese Academy of Sciences.

2.1. Preparation of ramie powder

The leaves and tender tops of fresh ramie were purchased from Institute of Bast Fiber Crops, Chinese Academy of Agricultural Sciences (Changsha, Hunan, China). The ramie (*Boehmeria nivea* cv. Zhongzhu No.1) was cut at about 60 cm height and immediately dried at 60 °C for 4 d by placing in a heat drier room. The leaf-stem ratio of dry ramie was 3.65. Finally, the dried stems and leaves were crushed to ramie powder using a grinder equipped with a sieve that had holes of 1.5 mm in diameter, then kept in a well-closed and light-resistant place.

2.2. Animals and experimental diets

A total of 180 finishing pigs (Xiangcun Black pigs, a Chinese native breed) with similar initial BW (70.71 ± 1.21 kg) were assigned into five treatment groups in a completely randomized design. Each treatment consisted of six replicates (pens) with six pigs each. The control diet was based on corn, soybean meal, and wheat bran. The pigs were provided with a control diet or a diet in which corn, soybean meal, and wheat bran were partly replaced by 3, 6, 9, or 12% ramie powder. All diets were formulated to contain similar levels of CP and to meet recommendations of Chinese National Feeding Standard for Swine (2004) as shown in Table 1. Diets were offered to pigs as pellets. The pigs were hand-fed three times/d (7:30, 11:30 and 17:30 h) in feeding troughs to make sure fresh feed was available and *ad libitum*. Water was provided *ad libitum*. The feeding experiment lasted for 50 d following a 7 d of adaptation period. The pigs were weighed at the beginning and the termination of the experiment and feed consumption of the pigs were determined weekly throughout the trial.

2.3. Slaughter procedure and sample collection

At the end of the experiment, one pig with medium weight per pen (6 pigs/treatment) were selected. Pigs were slaughtered by exsanguination after electrical stunning at a local commercial slaughter house. Samples of skeletal muscle tissue including *longissimus thoracis* (LT) muscle and *biceps femoris* (BF) muscle for the analysis of quantitative real-time PCR were immediately and aseptically excised from the right side of the carcasses, and flash frozen using liquid N_2, then stored at −80 °C, while those for determination of the chemical composition were stored at −20 °C. Fresh samples of LT (1 cm^3) were fixed in 4% paraformaldehyde in PBS (pH 7.3) for paraffin sections and hematoxylin and eosin staining.

2.4. Carcass traits measurements

At slaughter, hot carcass weight (HCW) was recorded after evisceration so that carcass yield could be calculated. The other carcass traits measurements (obtained from the left side of the carcass) included carcass length, average backfat depth (average of first- and last-rib, and last-lumbar depth on the split carcass), and loin-eye area. Fat-free lean index (FFLI) was calculated using National Pork Producers Council (2000) guidelines, FFLI = (8.588 + (0.465 × 2.2046 × HCW, kg) − (21.896 × 0.0394 × 10th-rib fat depth, mm) + (3.005 × 0.155 × 10th-rib loin-eye area, cm^2))/(2.2046 × HCW, kg). Weights of heart, liver, and two kidneys at slaughter were also recorded.

Table 1
Ingredient and chemical composition of experimental diets. (as-fed basis)[a].

Item	Ramie inclusion level (%)				
	0	3	6	9	12
Ingredient, %					
Corn	67.52	67.50	67.48	67.70	67.90
Soybean meal	18.00	17.22	16.42	15.80	15.20
Wheat bran	12.00	10.00	8.05	5.40	2.70
Ramie	0.00	3.00	6.00	9.00	12.00
$CaHPO_4$	0.50	0.62	0.70	0.80	0.90
Limestone	0.68	0.36	0.05	0.00	0.00
Salt	0.30	0.30	0.30	0.30	0.30
Premix[b]	1.00	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00
Chemical composition[c]					
Digestible energy, MJ/kg	13.72	13.73	13.73	13.73	13.73
Crude protein, %	14.54	14.46	14.48	14.53	14.54
Crude fiber, %	3.71	4.43	5.24	5.98	7.15
Calcium, %	0.52	0.55	0.53	0.66	0.78
Total phosphorus, %	0.46	0.45	0.49	0.47	0.46
Available phosphorus, %	0.20	0.22	0.23	0.24	0.24

[a] Basal diet formulated according to the Chinese National Feeding Standard for Swine.
[b] Supplied, per kilogram of diet: 19.8 mg $CuSO_4 \cdot 5H_2O$; 0.20 mg KI; 400 mg $FeSO_4 \cdot 7H_2O$; 0.56 mg $NaSeO_3$; 359 mg $ZnSO_4 \cdot 7H_2O$; 10.2 mg $MnSO_4 \cdot H_2O$; 5 mg vitamin K (menadione); 2 mg vitamin B_1; 15 mg vitamin B_2; 30 μg vitamin B_{12}; 5400 IU vitamin A; 110 IU vitamin D_3; 18 IU vitamin E; 80 mg choline chloride; 20 mg antioxidants; 100 mg Fungicide.
[c] The contents of total energy, crude protein, crude fiber, calcium and total phosphorus were analyzed.

2.5. Meat quality measurements

The pH values at 45 min and 24 h postmortem were determined on LT muscle using a portable pH meter (pH-STAR, SFK-Technology, Denmark) which was calibrated at the beginning of each measuring day using pH 4.6 and 7.0 buffers. Meat color, cooking loss, and shear force of LT samples were measured as previously outlined (Rossi et al., 2013; Stein et al., 2006). Meat color attributes including lightness (L*), redness (a*) and yellowness (b*) were performed at 24 h postmortem on LT samples, allowing 10–15 min for the color to develop after cutting, and using a hand-held colorimeter (CR-410, Minolta Camera, Co., Osaka, Japan) calibrated against a standard white plate (8 mm diameter aperture, d/0 illumination system). For cooking loss determination, a fresh 25 mm thick slice from each sample was weighed (130 ± 5 g), placed in a plastic bag and cooked to an internal temperature of 70 °C in a 75 °C water bath. Internal temperature was monitored during cooking with a hand-held temperature probe. Cooked samples were allowed to cool for 30 min, blotted dry and weighed. The difference between pre- and post-cooking weights was used to calculate the percentage loss during cooking. Cooking loss measurement was made in duplicate. The shear force was determined in samples cooled at 4 °C for 24 h after heat-treatment and measured using a texture analyzer (TA-tx2i Texture Analyzer, Stable Micro Systems, Godalming, UK) equipped with a Warner–Bratzler shear force device (200 mm/min crosshead speed). A cylindrical core borer was used to cut 3 samples from each of the cooked steaks with a diameter of 1.27 cm and length of approximately