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Effects of fulvic acid on growth performance and meat quality in growing-finishing pigs

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ABSTRACT

An experiment was conducted to evaluate the effects of dietary fulvic acid (FA) on growth performance and meat quality in growing-finishing pigs. Two hundred and sixteen (30.0 ± 2.5 kg body weight) crossbred (Landrace × Yorkshire) castrated male pigs were randomly allotted to 6 dietary treatments with 6 replicates (pens) per treatment and 6 pigs per pen. The basal diet was supplemented with different levels of FA (0.0%, 0.1%, 0.2%, 0.4%, 0.6%, and 0.8%). Pigs were fed diets based on a 2-phase feeding program (phase 1 for 45 d, and phase 2 for 42 d). The results from the entire experimental period showed pigs fed diets supplemented with FA increased average daily gain (ADG) linearly and quadratically ($P < 0.05$) during phase 1 and the whole feeding period, respectively, whereas gain to feed ratio (G:F) was increased quadratically ($P < 0.05$). Dietary supplementation of FA did not affect ADG and average daily feed intake during phase 2, but G:F was increased quadratically ($P < 0.05$). The slaughter weight and hot carcass weight of pigs fed diets supplemented with FA increased linearly and quadratically ($P < 0.05$). The backfat thickness was reduced ($P < 0.05$) quadratically in response to dietary FA supplementation. Feeding diets supplemented with FA reduced pH in muscle (24 h) linearly ($P < 0.05$) and malonaldehyde (MDA) quadratically ($P < 0.05$), while a^* value, b^* value, and marbling increased linearly and quadratically ($P < 0.05$). The results of this study indicated that supplementation of diets with FA is an effective way to increase growth performance, reduce backfat thickness, and improve meat quality in growing-finishing pig. Broken-line regression analysis indicated that the optimum dietary FA supplementation to increase G:F and reduce backfat thickness and MDA under the current experimental conditions was 0.48–0.79%.

1. Introduction

Fulvic acid (FA) is a type of humic acid (HA) that is formed by the decomposition and transformation of plant and animal residues and microbial materials (Oades, 1988; Janos, 2003). The FA is obtained from peat and different types of coal such as weathered coal and lignite. Compared to other HA, the FA is soluble in both acid and alkali solutions, is lower in molecular weight, and has a greater biological activity. It also contains more oxygen-containing functional groups compared to other HA (Stevenson, 1994; Yong, 2001; Zhang et al., 2011). The FA can absorb strongly metal ions and organic compounds between humic substances and mineral oxides as natural sorbents (Chiou et al., 2000; Saito et al., 2005), and it can participate in redox reactions and increase metabolism. Many studies have indicated that utilizing FA in agriculture can accelerate seed germination and improve rhizome growth (Nardi et al., 2002; Zancani et al., 2009; Zancani et al., 2011), stimulate oxygen transport, accelerate respiration, promote the efficient utilization of nutrients by the plant, and improve land salinization (Anjum et al., 2011; Visser, 1988). These findings have prompted scientists' interests in the specific properties of FA and its possible benefits as a substitute for the antibiotics used to improve the growth and health of animals.

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In recent years, many reports have indicated that FA can form a film on the mucus epithelium of the gastrointestinal tract and protect against infections and toxins, thus, ensuring improved utilization of nutrients in animal feed (Islam et al., 2005; Trckova et al., 2005). Also, the FA has antimicrobial and anti-inflammatory properties (Van Rensburg et al., 2001). It has been shown that FA added to animal feed increased growth rate and product quality, and provided better resistance to viral infections (Banaszkiewicz and Drobnik, 1994; Karaoglu et al., 2004; Kucukersan et al., 2005; McMurphy et al., 2009; Písaříková et al., 2010) to improve feed conversion ratio and decrease the cost of feed to get greater profit in animal production (An et al., 2009; Gu et al., 2001; Wu et al., 2009).

Studies focusing on the applications of HA, FA, and the weathered coal have been conducted extensively in China since the beginning of the 1980s. However, the use of FA as a dietary supplement for pigs has not been well-studied, particularly in growing-finishing period. Therefore, the objective of this research was to test the effects of different levels of FA supplemented diets on growth performance, carcass traits and meat quality to explore the effective dose of dietary FA supplementation in growing-finishing pigs.

2. Materials and methods

2.1. Fulvic acid

The FA used in the current experiment was extracted from weathered coal obtained (Yongye Nongfeng Bio-tech. Co. Ltd., Inner Mongolia, China). The analyses of FA were conducted following the methods reported by Klymenko et al. (2010). Two liters of 0.1 M NaOH solution was poured over 400 g of air-dried weathered coal, and the mixture was stirred for 24 h. The dark supernatant containing humic and fulvic acids was acidified to pH 2.0 with concentrated sulfuric acid to separate the humic acid fraction. Filtration was used to separate the FA solution. Then, 4 M NaOH solution was added to the FA-containing extract to achieve a pH of 7. The resulting solution was used as a preparation of FA. The measured effective content of FA was 12.05%.

2.2. Experimental design, animals, and diets

A total of 216 crossbred (Landrace × Yorkshire) castrated male pigs with an average initial BW of 30.0 ± 2.5 kg were used in the current experiment. At the beginning of the experiment, pigs were assigned to 6 dietary treatments on the basis of initial BW. There were 6 pens per treatment and 6 pigs per pen. The dietary treatments included the following: basal control diet supplemented with 0.0%, 0.1%, 0.2%, 0.4%, 0.6%, or 0.8% FA. The pigs were allowed ad libitum access to feed and water throughout the experiment. All of the experimental diets were formulated to meet or exceed the recommended requirements of the NRC (1998) for a 2-phase feeding program (Table 1). Pigs were fed phase 1 and 2 diets for 45 and 42 d, respectively, until they reached a BW of 90 kg. All procedures involving pigs were approved by the Animal Care and Use Committee of Heilongjiang Province, China.

Table 1
Formula and chemical composition of experiment diet (as-fed basis).[a]

Item	Phase 1	Phase 2
Ingredients (%)		
Maize	63.80	65.00
Soybean meal (46% CP)	23.30	17.20
Wheat bran	10.00	15.00
Monocalcium phosphate	0.50	0.40
Limestone	1.00	1.00
Salt	0.30	0.30
Premix[b]	1.00	1.00
Choline chloride (50%)	0.10	0.10
Total	100.00	100.00
Chemical composition[c]		
ME (MJ/kg)	13.59	13.54
Crude protein (%)	16.40	14.52
Ca (%)	0.56	0.52
P (%)	0.22	0.19
Lys (%)	0.85	0.72

[a] A 2-phase feeding program was used. The duration of each phase differed depending on the growth rate of the pigs.
[b] Supplied per kilogram diet: vitamin A, 8000 IU; vitamin D_3, 2000 IU; vitamin E, 30 IU; vitamin K_3, 1.5 mg; vitamin B_1, 1.6 mg; vitamin B_6, 1.5 mg; vitamin B_{12}, 12 μg; niacin, 20 mg; d-pantothenic acid, 15 mg; Zn (ZnO), 80 mg; Fe ($FeSO_4 \cdot 7H_2O$), 100 mg; Cu ($CuSO_4 \cdot 5H_2O$), 20 mg; Mn ($MnSO_4 \cdot H_2O$), 25 mg; I (KI), 0.3 mg; and Se ($NaSeO_3 \cdot 5H_2O$), 0.2 mg.
[c] Calculated values.

2.3. Sampling and measurements

Individual BW and feed consumption per pen were measured after 45 and 42 d to monitor the average daily gain (ADG), average daily feed intake (ADFI), and gain to feed ratio (G:F). At the end of the experiment, 1 pig from each pen was selected randomly and a total of 36 pigs were transported to the abattoir for slaughter. The carcasses were placed in a conventional chiller at 4 °C. After a 24 h chill period, longissimus muscle (LM) samples, including lean and fat, were obtained from the left sides of the carcasses between the 10th and 11th ribs. At the same time, abdominal fat (leaf fat) was stripped from the left side of the carcass and weighted. Backfat thickness was measured at the first, 10th, and last ribs, and average was recorded. The longissimus muscle area (LMA) was measured by taking a digital image of the exposed surface of the muscle area at the 10th rib. The images were standardized using a fixed camera and 2 rulers, and the LMA was calculated using imaging software (Pomar et al., 2001).

Before the meat quality was evaluated, the meat samples were thawed at ambient temperature. The pH of LM was measured at 24 h post-mortem by a portable pH-Meter (pH-Meter, EL2; Mettler-Toledo, Shanghai, China). The color measurement of lightness (L^*), redness (a^*), and yellowness (b^*) values were determined (Minolta Chroma Meter, CR-301; Konica Minolta, Tokyo, Japan). Marbling score data were obtained according to published pork quality standards (NPPC, 2000). Drip loss was measured using the plastic bag and approximately 20 g of meat samples at 4 °C for 24 h to determine drip loss percentage as described by Honikel (1998). Cooking loss was determined by calculating the weight loss during cooking. Meat