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Original Research Article

Dietary β-glucan supplementation improves growth performance, carcass traits and meat quality of finishing pigs

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ABSTRACT

This experiment was conducted to investigate growth performance, carcass traits and meat quality of finishing pigs with dietary β-glucan supplementation. A total of 96 healthy pigs (Duroc × Landrace × Yorkshire; initial average BW = 25 kg) were randomly allocated into 4 dietary treatments with 6 replicates per treatment and 4 pigs per replicate. The control group was fed a basal diet, and the experimental diets were supplemented with 50, 100 and 200 mg/kg *Agrobacterium* sp. ZX09 β-glucan, respectively. The experiment lasted 103 d. The basal diet supplemented with 100 mg/kg β-glucan significantly increased average daily gain and feed conversion ratio, probably due to the improved digestibility of dry matter, gross energy and crude protein ($P < 0.05$). Beta-glucan supplementation from 100 to 200 mg/kg of diet significantly increased carcass length ($P < 0.05$). The basal diet supplemented with 100 mg/kg β-glucan supplementation also significantly ($P < 0.05$) increased muscle pH, reduced drip losses and increased a^* values. The basal diet supplemented with 100 mg/kg β-glucan increased the content of intramuscular fat and changed the proportion of saturated fatty acid and unsaturated fatty acid, thereby improved the flavor of meat. In conclusion, the basal diet supplemented with 100 mg/kg *Agrobacterium* sp. ZX09 β-glucan improves growth performance, nutrient digestibility, carcass length, and pork quality of finishing pigs.

1. Introduction

In pig production, antibiotics are usually used as animal feed additives for the treatment of bacterial infections and growth promotion. However, the over-use of antibiotics has caused serious problems such as bacterial resistance, drug residue in pork product and environmental pollution, which is harmful for health of animals and human (Du et al., 2015). Therefore, developing a green, safe antibiotic alternative is a top priority.

Beta-glucan is a kind of functional polysaccharide which widely spreads in the cell wall of fungi, bacterial and cereal seeds (oats, rye and barley, etc). It has various biological functions such as promotion on immune function, anti-infection and glucose regulation (Xiong et al., 2015). One β-glucan molecule usually comprises β-1,3-linked glucopyranosyl residues with a small number of β-1,6-linked glucopyranosyl residues side chains. The special glycosidic bonds and intermolecular hydrogen bonds contribute a kind of unique helical molecular structure which is easily recognized and accepted by immune system. Plenty of research indicates that β-glucan could promote the growth performance of rats (Belobrajdic et al., 2015), chickens (Tian et al., 2016), fish (Jiang et al., 2016), pigs (Lee et al., 2017) and cattle (Ma et al., 2015), which is concerned with the function of promoting intestinal health and improving body's immunity. The β-glucan used in previous research is mainly from

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plant extracts, which is of low purity and contains a variety of polysaccharide components. The β-glucan applied in this experiment is a brand new β-glucan obtained from *Agrobacterium* sp. ZX09. It is a novel high purity and water-soluble polymer, which is composed of a linear chain of glucosyl residues linked through a repeat unit of 7 β-(1,3) and 2 α-(1,3) glucosidic bonds.

As a new β-glucan with specific molecular structure, its safety has been demonstrated in the acute and subchronic experiment (Zhou et al., 2013). Our experiment lasted for 114 d. We selected 96 growing-finishing pigs to do our trial. Most of researchers mainly concentrated on weaning pigs trials for 28 d. Hence, the aim of the present study was to evaluate the effects of dietary β-glucan supplementation on growth performance, carcass traits and meat quality of finishing pigs, and finally provide potential evidence for the appropriate dose of β-glucan in the diet formulation during fattening period.

2. Materials and methods

All experimental procedures in the present study were approved by the Animal Management Rules of the Ministry of Health of the People's Republic of China and the Animal Care and Use Committee of Sichuan Agricultural University. The number of project approval: 2016HH0004.

2.1. Study design and diets

A randomized complete block design was adopted in this experiment. A total of 96 healthy pigs (Duroc × Landrace × Yorkshire; initial average BW = 25 ± 0.2 kg; ratio of barrows to gilts = 3:1) were selected and randomly allocated into 4 dietary treatments, each treatment had 6 replicates and 4 pigs (3 males and 1 female) per replicate. The corn-soybean based diets were formulated in accordance with NRC (2012) as basal diets. Beta-glucan (effective content ≥ 90%) at levels of 50, 100 and 200 mg/kg were added to the basic feed, respectively. The experiment lasted 103 d and was divided into 3 stages: 25 to 50 kg, 50 to 75 kg and 75 to 110 kg. The composition and nutrient levels of basal diets are presented in Table 1.

2.2. Feeding and management

The experiment was conducted in Danling Pig Farm in Meishan, Sichuan. The experiment was divided into 3 stages (25 to 50 kg for 35 d, 50 to 75 kg for 28 d and 75 to 110 kg for 40 d, a total of 103 d). Pigs were fed 3 times (08:00, 14:00 and 20:00) per day. The room temperature (T) varied with different periods and BW. It followed the following formula: T = 26 − 0.06BW. Pigs were fed *ad libitum*. Feed consumption, waste and remaining amount were recorded. Pigs were weighed in each stage of the experiment, and the digestibility was determined at last 4 d of each stage. At the end of final stage, one barrow from each pen was selected for carcass and meat quality assay.

2.3. Production characteristics

Pigs were weighed at the start of each phase and the end of the experiment. Average daily gain (ADG) was computed per period. During that time, feed consumption per pen was measured and average daily feed intake (ADFI) was recorded. Feed conversion ratio (FCR) during a period was calculated by dividing the feed intake of a pen through the weight gain of pigs in the pen.

Table 1
Composition and nutrient levels of basal diets for pigs (as fed basis, %).

Item	Diets		
	25 to 50 kg	50 to 75 kg	75 to 110 kg
Ingredients			
Corn	67.47	72.04	73.00
Soybean meal	23.50	19.20	17.76
Wheat bran	5.00	5.00	6.00
Soybean oil	1.00	1.00	1.00
L-lysine	0.36	0.31	0.20
DL-methionine	0.06	0.03	0.01
L-threonine	0.10	0.08	0.03
L-tryptophan	0.01	0.01	0.00
Choline chloride	0.15	0.15	0.15
Limestone	0.60	0.50	0.55
Calcium phosphate	1.10	1.00	0.62
Salt	0.25	0.35	0.35
Microelement premix[1]	0.35	0.30	0.30
Decavitamin[2]	0.05	0.03	0.03
Total	100.00	100.00	100.00
Nutrient levels[3]			
DE, Mcal/kg	3.30	3.31	3.31
CP	16.61	15.04	14.49
Ca	0.67	0.58	0.51
TP	0.56	0.53	0.47
AP	0.33	0.31	0.25
Lys	0.98	0.85	0.74
Met	0.28	0.24	0.21
Thr	0.60	0.52	0.46
Try	0.17	0.15	0.14

DE = digestible energy; CP = crude protein: Ca = calcium; TP = total protein; AP = avialable phosphorus.
[1] Microelement premix provided the following per kilogram of diet: Fe 100 mg, Cu 8 mg, Mn 4 mg, Zn 100 mg, Se 0.3 mg, I 0.3 mg.
[2] Decavitamin provided the following per kilogram of diet: vitamin A 17,500 IU, vitamin D 5,000 IU, vitamin E 37.5 IU, vitamin K 5 mg, vitamin B_1 5 mg, vitamin B_2 12.5 mg, vitamin B_6 7.5 mg, vitamin B_{12} 0.05 mg, niacin 50 mg.
[3] Nutrient levels were calculated levels.

2.4. Nutrient digestibility

The apparent digestibility of dry matter, crude protein and gross energy was determined by the method of acid insoluble ash (AIA) (Furuya et al., 2001). The moisture, crude protein and energy of the feed and fecal sample were analyzed according to the Association of Official Analytical Chemist (1990). Apparent digestibility of nutrient (%) = [1 − (AIA content in feed × Nutrient content in fecal)/(AIA content in fecal × Nutrient content in feed)] × 100.

2.5. Carcass traits

Before slaughtered, pigs were injected anesthetic (200 mg sodium barbital per kg BW). The animals were killed one by one. Carcasses were evaluated post chilling. Time post-mortem was about 20 min. Carcass weight, carcass length, backfat thickness and carcass yield were measured and calculated in the slaughter spot by the previous method (Li et al., 2018). Briefly, average fat thickness was measured manually at the thickest shoulder, the last rib and the junction of the waist and the sacrum of the carcass midline. Carcass length was measured as the distance between the anterior edge of pubic symphysis to the midpoint of the first rib and sternum. The longitudinal dorsal muscles at the last rib in a vertical direction were used to measure the loin muscle area according to the following equation: Loin muscle area (cm^2) = Loin muscle height (cm) × Loin muscle width (cm) × 0.7. At 45 min and 24 h post mortem, the pH was measured by pH-STAR (SFK-Technology, Denmark) in the loin around the 13th costa of both carcass sides.

We cut the meat into 2-cm thick slices and trim it to a 5 cm × 3 cm cuboid. One chop was obtained per analysis. A piece of

the loin of the right side anterior to the anterior last costa was removed and sliced. One slice was used for Commission Internationale de ÍEclairage lab (CIELAB) color coordinates analysis by HunterLab Miniscan EZ portable colorimeter (HunterLab Company, USA). The second slice was used to evaluate drip losses as the proportionate weight loss after hanging the sample in a plastic bag for 14 h at 4 °C (Chevalier et al., 1999). The third slice of 2.54-cm thickness was collected and put into a water bath until the center temperature of the pork slices reached 71 °C (Li et al., 2018). With a 1.27-cm inner diameter sampler, at least 3 meat pillars were taken from the meat along the direction of muscle fibers. The shear force of each meat pillar was measured by a shear force tester (Texture Analyzer). Finally, the average value of shear force is obtained. Immediately after the pig was slaughtered, we conducted the cooking process. Cooking losses were defined as the weight loss during cooking process. The final slice was taken to determine the content of intramuscular fat (IMF) by the Soxhlet method (ISO, 1973) and analyze the fatty acid (FA) profile (Rey and Lopez-Bote, 2001).

2.6. Statistical analysis

The data were analyzed by one-way analysis of variance (ANOVA) using the GLM procedure of SAS (release 9.0; SAS Institute). If a significant treatment effect was observed, the significance between the treatment differences was identified by Duncan's multiple comparisons test. Results were expressed as means ± SEM. A probability value of $P < 0.05$ was considered statistically significant.

3. Results

3.1. Effects of β-glucan on growth performance

Beta-glucan shows a significant effect on growth performance of finishing pigs. As illustrated in Table 2, dietary addition of 100 mg/kg β-glucan significantly increased the average daily gain (ADG) and decreased the feed to gain ratio (F:G) at 50–75 kg stage and through the whole fattening period ($P < 0.05$); β-glucan supplemented at 50 and 100 mg/kg significantly increased the ADG and decreased the F:G at 75–110 kg stage ($P < 0.05$). Overall, addition of 100 mg/kg β-glucan could significantly increase the body weight gain and improve FCR.

Table 2
Effects of β-glucan on growth performance of fattening pigs (kg).

Stage	Item	Control	β-glucan supplemental level, mg/kg		
			50	100	200
25 to 50 kg	ADFI	1.72 ± 0.47	1.67 ± 0.11	1.79 ± 0.46	1.66 ± 0.55
	ADG	0.84 ± 0.19	0.81 ± 0.25	0.83 ± 0.27	0.78 ± 0.41
	F:G	2.03 ± 0.45	2.08 ± 0.31	2.13 ± 0.47	2.12 ± 0.47
50 to 75 kg	ADFI	2.74 ± 0.89	2.68 ± 0.68	2.82 ± 0.49	2.77 ± 0.68
	ADG	0.93 ± 0.41^{a}	0.93 ± 0.36^{a}	1.08 ± 0.23^{b}	0.99 ± 0.32^{ab}
	F:G	2.98 ± 0.12^{a}	2.91 ± 0.10^{a}	2.62 ± 0.70^{b}	2.81 ± 0.53^{ab}
75 to 110 kg	ADFI	3.13 ± 0.50	3.11 ± 0.34	3.09 ± 0.23	3.12 ± 0.27
	ADG	0.94 ± 0.50^{a}	1.09 ± 0.24^{ab}	1.16 ± 0.50^{b}	1.07 ± 0.45^{ab}
	F:G	3.37 ± 0.13^{a}	2.79 ± 0.91^{b}	2.73 ± 0.79^{b}	3.09 ± 0.96^{ab}
25 to 110 kg	ADFI	2.58 ± 0.38	2.63 ± 0.64	2.69 ± 0.75	2.66 ± 0.56
	ADG	0.92 ± 0.18^{a}	0.97 ± 0.18^{a}	1.10 ± 0.18^{b}	0.96 ± 0.35^{a}
	F:G	2.76 ± 0.82^{a}	2.73 ± 0.61^{a}	2.50 ± 0.49^{b}	2.73 ± 0.56^{a}

ADFI = average daily feed intake; ADG = average daily gain; F:G = feed intake to body gain ratio.
$^{a, b}$ Within a row, means with different superscripts differ at $P < 0.05$.

3.2. Effects of β-glucan on nutrient digestibility

Nutrient digestibility during fattening period is shown in Table 3. Addition of 100 mg/kg β-glucan dramatically increased the digestibility of dry matter, gross energy and crude protein. Compare with the control group, β-glucan has no effect on the digestibility of dry matter, gross energy or crude protein at 25 to 50 kg BW stage. Addition of 100 mg/kg β-glucan could significantly increase the digestibility of dry matter, gross energy and crude protein at 50–75 kg BW stage ($P < 0.05$). Dietary supplementation of 50 and 100 mg/kg β-glucan significantly increased the digestibility of dry matter and gross energy at 75 to 110 kg BW stage ($P < 0.05$), and the digestibility of crude protein showed no significant difference.

3.3. Effects of β-glucan on carcass traits

Beta-glucan had a significant effect on the carcass length of finishing pigs (Table 4). The carcass length was significantly longer in 100 and 200 mg/kg groups than in the control group ($P < 0.05$), and it was also longer in the 50 mg/kg group than in the control group, but not significantly ($P > 0.05$). The carcass length in 100 mg/kg group was significantly longer than that in 50 mg/kg group ($P < 0.05$). However, when compared with 200 mg/kg group, the difference was not significant ($P > 0.05$). No differences in carcass weight, backfat thickness and carcass yield were found in fattening pigs fed different levels of β-glucan ($P > 0.05$).

3.4. Effects of β-glucan on meat quality

Beta-glucan had effects on the meat quality of finishing pigs. As revealed in Table 5, addition of β-glucan showed certain effects on muscle pH. The muscle pH in 100 mg/kg group was significantly higher than that in the control group ($P < 0.05$). Addition of 100 mg/kg β-glucan could rapidly reduce the drip losses of meat ($P < 0.05$), indicating that water-holding capacity of muscle may be enhanced, whereas 50 and 200 mg/kg β-glucan had no significant effect on the drip losses. For the pork color, although β-glucan had no effects on lightness (CIELAB L^*-coordinate), it dramatically affected redness (CIELAB a^*-coordinate) and yellowness (the CIELAB b^*-coordinate) at 45 min post mortem ($P < 0.05$). The a^*-value (45 min) in 100 mg/kg group was significantly higher than that in the control group ($P < 0.05$). The addition of β-glucan effectively reduced b^*-value (45 min) ($P < 0.05$), and no significant differences were observed among β-glucan treatments. Beta-glucan had no effects on values of L^*, a^* and b^* at 24 h post mortem ($P > 0.05$).

3.5. Effects of β-glucan on inosine monophosphate (IMP) and fatty acid composition

Beta-glucan could change the content of IMP and fatty acid proportion. Inosine monophosphate is the main marker of good quality. As illustrated in Table 6, a dosage of 50 to 100 mg/kg of β-glucan supplemented in the diets increased the content of IMP ($P < 0.05$). No differences in the fatty acid profile among treatments were observed ($P > 0.05$), except for margaric acid, linoleic acid, arachidic acid, cis-11-gadoleic acid and eicosadienoic acid. Pigs in supplemental groups had higher content of margaric acid, linoleic acid and arachidic acid ($P < 0.05$). No significant difference among supplemental treatments were detected ($P > 0.05$).

4. Discussion

A novel high purity, water-soluble extracellular β-glucan of specific molecular weight was used in the present study. To the best of our knowledge, it is the first in literature to investigate whether

Table 3
Effects of β-glucan on nutrient digestibility (%).

Stage	Item	Control	β-glucan supplemental level, mg/kg		
			50	100	200
25 to 50 kg	Dry matter	74.71 ± 0.33^{ab}	74.50 ± 0.39^{b}	76.95 ± 0.79^{a}	75.29 ± 0.27^{ab}
	Gross energy	74.88 ± 0.21	74.29 ± 0.28	75.15 ± 0.39	74.99 ± 0.65
	Crude protein	67.88 ± 0.73	65.56 ± 1.00	67.93 ± 0.46	69.03 ± 0.72
50 to 75 kg	Dry matter	74.28 ± 0.72^{b}	75.99 ± 1.01^{b}	80.76 ± 0.59^{a}	75.11 ± 0.98^{b}
	Gross energy	73.93 ± 0.75^{b}	74.72 ± 0.70^{b}	80.69 ± 0.58^{a}	74.79 ± 0.25^{b}
	Crude protein	64.12 ± 1.12^{a}	67.61 ± 1.27^{ab}	73.15 ± 0.72^{b}	67.29 ± 1.15^{ab}
75 to 100 kg	Dry matter	85.14 ± 0.35^{b}	87.23 ± 0.19^{a}	87.38 ± 0.45^{a}	86.21 ± 0.50^{ab}
	Gross energy	73.93 ± 0.75^{b}	74.72 ± 0.70^{b}	80.69 ± 0.58^{a}	74.79 ± 0.25^{b}
	Crude protein	79.65 ± 0.67	81.02 ± 0.38	81.04 ± 1.13	80.69 ± 1.02

[a, b] Within a row, means with different superscripts differ at $P < 0.05$.

Table 4
Effects of β-glucan on carcass traits.

Item	Control	β-glucan supplemental level, mg/kg		
		50	100	200
Carcass weight, kg	81.57 ± 1.12	81.02 ± 1.03	81.04 ± 1.41	79.94 ± 1.79
Carcass length, cm	104.15 ± 0.96^{b}	106.05 ± 1.21^{b}	109.18 ± 0.89^{a}	108.97 ± 0.95^{a}
Backfat thickness, mm	18.13 ± 1.08	18.66 ± 0.69	18.56 ± 1.31	16.78 ± 1.02
Carcass yield, %	70 ± 0.6	71 ± 0.7	71 ± 0.6	70 ± 0.9

[a, b] Within a row, means with different superscripts differ at $P < 0.05$.

Table 5
Effects of β-glucan on meat quality.

Item	Control	β-glucan supplemental level, mg/kg		
		50	100	200
Eye muscle area, cm^2	42.85 ± 2.94	46.37 ± 3.60	42.12 ± 1.64	42.60 ± 1.69
Muscle pH (45 min)	6.27 ± 0.08^{b}	6.38 ± 0.14^{ab}	6.58 ± 0.09^{a}	6.52 ± 0.09^{ab}
Muscle pH (24 h)	5.91 ± 0.05	5.76 ± 0.04	5.85 ± 0.03	5.90 ± 0.07
Cooking loss, %	37.00 ± 0.90	37.70 ± 0.50	36.60 ± 0.90	37.90 ± 0.90
Drip losses, %	3.40 ± 0.30^{a}	2.90 ± 0.20^{ab}	2.50 ± 0.10^{b}	2.80 ± 0.40^{ab}
Shear force, N	3.04 ± 0.33	3.38 ± 0.26	3.56 ± 0.51	3.82 ± 0.56
L^* (45 min)	38.13 ± 0.63	38.24 ± 0.22	38.38 ± 0.48	37.72 ± 0.36
a^* (45 min)	3.71 ± 0.24^{b}	3.87 ± 0.41^{ab}	4.60 ± 0.25^{a}	3.63 ± 0.19^{b}
b^* (45 min)	2.24 ± 0.11^{a}	1.68 ± 0.13^{b}	1.70 ± 0.15^{b}	1.62 ± 0.22^{b}
L^* (24 h)	52.71 ± 0.89	54.16 ± 0.51	53.27 ± 0.88	52.25 ± 0.70
a^* (24 h)	6.79 ± 0.64	7.33 ± 0.41	8.18 ± 0.50	7.31 ± 0.55
b^* (24 h)	5.59 ± 0.47	4.86 ± 0.23	4.95 ± 0.47	5.02 ± 0.38

[a, b] Within a row, means with different superscripts differ at $P < 0.05$.
L* = lightness; a* = redness; b* = yellowness.

β-glucan isolated from *Agrobacterium* sp. ZX09 could improve growth performance in fattening pigs and modulate its effects on meat quality. It is confirmed that β-glucan derived from *Agrobacterium* sp. ZX09 effectively improved growth performance of finishing pigs, indicating that it may shorten the duration of the fattening period to allow pigs to reach an optimal slaughter weight.

Beta-glucan is a kind of natural immune enhancer, which enhances the non-specific immunological function to improve animal's health and growth performance. In this experiment, the ADFI and ADG of fattening pigs presented earlier increase along with the increased addition level of β-glucan, possibly due to high nutrient digestibility during fattening period. In this experiment, 100 mg/kg glucan can significantly improve the digestibility of dry matter, gross energy and crude protein. According to the research conducted by Dritz et al. (1995), β-glucan could significantly increase the ADG and reduce the mortality of piglets. Besides, β-glucan could effectively improve the intestinal structure of pigs (Metzler-Zebeli et al., 2012). However, the results are inconsistent with previous studies (Hester et al., 2012), which indicated that 100 mg/kg β-glucan had no effects on non-immunochallenged piglets. An alternative explanation for this discrepancy involves in the differences of optimum concentration, purity, molecular weight, conformation, chemical modification and solubility of β-glucan in the diet formulation. Current report strongly demonstrates that optimal dosage of β-glucan derived from *Agrobacterium* sp. ZX09 was 100 mg/kg of diet for fattening pigs, while the optimal doses of β-glucan previously applied were various and their sources were mainly obtained from cell wall of *Saccha-romycetes cerevisiae* (Shao et al., 2016; Tian et al., 2016) and purified from oat (Suchecka et al., 2016, 2017). Beta-glucan purity obtained from *Agrobacterium* sp. ZX09 is higher (>90%) than that from *Saccha-romycetes cerevisiae* and oat (60% to 80%), thereby existing more sensitive biological activities (Wang et al., 2008).

Despite faster growth in the dietary group supplemented with 100 mg/kg β-glucan, no significant differences were seen in carcass weight and fat thickness. The 100 mg/kg β-glucan supplementation group had longer carcass length, which suggests that the faster growth shows a better carcass trait. But the mechanisms are not known and need further research. The intramuscular fat content was higher in pigs fed 50 and 100 mg/kg β-glucan. An increase in intramuscular fat level enhances the consumer's acceptability of pork up to a level of 3.5% (Fernandez et al., 1999). Several studies

Table 6
Effects of β-glucan on the proportion of inosine monophosphate (IMP) and fatty acid (%).

Item	Control	β-glucan supplemental level, mg/kg		
		50	100	200
IMP, mg/g	1.221 ± 0.035[b]	1.451 ± 0.024[a]	1.465 ± 0.026[a]	1.385 ± 0.045[ab]
Decanoic acid	0.134 ± 0.011	0.126 ± 0.010	0.132 ± 0.005	0.136 ± 0.012
Lauric acid	0.093 ± 0.005	0.086 ± 0.006	0.090 ± 0.004	0.067 ± 0.009
Myristic acid	1.594 ± 0.097	1.522 ± 0.049	1.618 ± 0.065	1.550 ± 0.079
Palmitic acid	27.523 ± 1.101	27.484 ± 0.506	27.558 ± 0.298	27.405 ± 0.153
Gaidic acid	3.590 ± 0.312	4.020 ± 0.353	3.966 ± 0.198	3.736 ± 0.165
Margaric acid	0.203 ± 0.108[b]	0.244 ± 0.018[a]	0.299 ± 0.015[a]	0.241 ± 0.010[a]
Heptadecenoic acid	0.083 ± 0.009	0.088 ± 0.015	0.079 ± 0.008	0.074 ± 0.005
Stearic acid	13.901 ± 0.898	13.357 ± 0.956	14.123 ± 0.304	13.320 ± 0.567
Oleic acid	46.675 ± 0.674	45.543 ± 0.895	45.315 ± 0.371	45.679 ± 0.787
Linoleic acid	4.781 ± 0.406[b]	5.460 ± 0.377[a]	5.470 ± 0.352[a]	5.161 ± 0.253[a]
Arachidic acid	0.125 ± 0.023[b]	0.153 ± 0.008[a]	0.168 ± 0.012[a]	0.130 ± 0.014[ab]
Cis-11-gadoleic acid	0.462 ± 0.035[b]	0.593 ± 0.017[a]	0.591 ± 0.021[a]	0.643 ± 0.039[a]
Eicosadienoic acid	0.113 ± 0.009[b]	0.152 ± 0.008[a]	0.144 ± 0.011[a]	0.151 ± 0.081[a]
Arachidonic acid	0.186 ± 0.029	0.245 ± 0.023	0.193 ± 0.019	0.215 ± 0.024
Saturated fatty acid	43.271 ± 0.683	42.972 ± 1.176	43.918 ± 0.627	42.849 ± 0.652
Unsaturated fatty acid	55.890 ± 0.834	56.110 ± 0.946	55.744 ± 0.569	55.677 ± 0.677
Monounsaturated fatty acid	50.810 ± 0.798	50.244 ± 1.209	49.941 ± 0.654	50.150 ± 0.610
Polyunsaturated fatty acid	5.080 ± 0.240	5.866 ± 0.411	5.803 ± 0.317	5.527 ± 0.197
Total fatty acid	99.161 ± 0.533	99.082 ± 0.336	99.662 ± 0.085	98.526 ± 0.679

[a, b] Within a row, means with different superscripts differ at $P < 0.05$.

suggest a favorable relationship between intramuscular fat and the juiciness and the tenderness of pork (Hodgson et al., 1991).

When the muscle pH of living animals is neutral, the protein molecules with net negative charge can absorb large quantities of water. The accumulation of lactic acid in the muscles will lead to the decrease of muscle pH at slaughter. The rate of decline of muscle pH is highly relevant to the drip losses and shear force of meat. In the present study, addition of 100 mg/kg β-glucan can significantly raise the muscle pH and reduce the drip losses when compared with the control group, suggesting a lower risk for PSE (pale, soft and exudative) in those animals. Also, this means β-glucan may be able to delay pH decline and enhance water holding capacity of muscle after slaughter.

Pork color is an important indicator to evaluate muscular appearance. It is influenced by several factors including post mortem glycolysis rate, intramuscular fat content, pigment level and oxidative status of the pigment (Van Oeckel et al., 1999). The current results on a* value and b* value agree with the research conducted by of Cho et al. (2013). The darker (redder) color of glucan fed animals may be attributed to increased fast twitch muscle fibers in type-a/type-b or an increased mean fiber cross-sectional area, as was detected by Petersen et al. (1998).

Intramuscular fat content is a relevant meat quality trait in fresh pork, since it strongly influences the technological feasibility for dry curing and the sensory quality of the final products (Lopez-Bote et al., 2002). High level of IMP in longissimus dorsal muscle of 50 and 100 mg/kg glucan fed pigs was observed. After slaughter, the oxygen delivery to muscle tissue will be ceased and the energy supplied by phosphocreatine and glycolysis will be used for adenosine triphosphate (ATP) synthesis. Along with the depletion of phosphocreatine and glycolysis, ATP is stopped being synthesized and begin to be degraded into IMP (Zhang et al., 2015). The fatty acid profile is another physical base of meat flavor. The higher level of saturated fatty acid and monounsaturated fatty acid, the higher score in tenderness, juiciness, flavor and overall liking (Picard et al., 2015). If the level of polyunsaturated fatty acid is higher, the carcass fat will become soft and acidic, which would affect the meat quality and produce peculiar smell. The present study suggests that the proportions of margaric acid, linoleic acid and arachidic acid were increased 32.1%, 14.4% and 25.6%, respectively at the β-glucan level of 100 mg/kg. And there is also a corresponding increase in the percentages of cis-11-gadoleic acid and eicosadienoic acid. Thus, β-glucan supplementation increased the content of IMP, changed the proportions of saturated and unsaturated fatty acid to improve the meat flavor.

5. Conclusion

The supplementation of dietary β-glucan improves the growth performance, nutrients digestibility and carcass traits of finishing pigs to a certain degree. Meat quality changes were minimal. Under the current experimental condition, the optimal dosage of *Agrobacterium* sp. ZX09 β-glucan applied in the fattening period seems to be recommended as 100 mg/kg in the diet.

Conflicts of interest

The authors declare that they have no conflict of interest.

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