Effect of replacement of de-hulled barley with water-soaked barley in corn–soybean meal-based diet on growth performance, blood characteristics, and meat quality in finishing pigs

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ABSTRACT

A total of 144 crossbred pigs [(Yorkshire Landrace) × Duroc] with an average initial body weight (BW) of 61.7 kg were used to assess the effect of replacement of de-hulled barley (DB) with water soaked barley (WB) in corn-soybean meal-based diet on growth performance, blood characteristics, and meat quality in finishing pigs according to their BW and sex (12 replicates per treatment and 4 pigs per pen). The dietary treatments were: DB, basal diet containing 5% DB; WB1, basal diet + 5% WB (0–8 weeks of feeding); WB2, basal diet + 5% WB (4–8 weeks of feeding). The end of week 4, the IgG concentration (p<.05) was higher in WB1 than DB and WB2. At the end of week 8, lymphocyte percent was higher (p<.05) in WB than WB1 whereas IgG concentration was higher in WB1 and WB2 than DB. The sensory evaluation of colour scored higher (p<.05) in WB1 and meat marbling scored higher (p<.05) in WB2 than in DB. A higher (p<.05) yellowness and drip loss (day 1 and day 5) was observed in DB than in WB1. In conclusion, replacement of DB with WB had a positive impact on blood characteristics and meat quality of finishing pigs.

1. Introduction

Barley is used in pigs’ diet as an energy source (Newman & Newman 2006). The high levels of available essential amino acids present in barley contribute to the formulation of low-cost diets that are nutritionally effective in maximizing carcass quality (Harrold 2010). However, hulled barley has higher fibre and lower digestible energy and crude protein (CP) content, compared to hullless barley (Qian et al. 2009), which may account for the relative poor growth performance of pigs fed a hulled barley diet than maize- and wheat-based diets. The nutritive value of barley can be improved by removal of hull as demonstrated by Wu et al. (2000). Although the technology for removing hull is well developed, the fragility of the grain and poor yield and the high cost of de-hulling limit its large utilization in pigs’ diet. The development of effective method such as soaking barley in water was found to improve the feeding value of barley as demonstrated by Fry et al. (1958), Svihus et al. (1997), Yan and Kim (2012), and Wang and Kim (2014).

The germination of seed in water-soaked barley (WB) is induced by an increase in temperature and humidity. This causes the embryo to synthesize phyto-hormone, gibberellic acid, which induces de novo synthesis of a-amylase and other hydrolyses (Jones 2005). These enzymes are capable of degrading starch, structural protein, and hull of barley. Soaking the barley in water degrades the cell wall extensively during malting compared to other grains as suggested by Etokakpan and Palmer (1990). Thus, recently developed technology involves the germination of barley through water soaking. The objective of the present experiment was to compare the effectiveness of the replacement of de-hulled barley (DB) with WB in corn–soybean meal-based diet during long and short time periods of feeding on growth performance, blood chemistry, and meat quality of finishing pigs.

2. Materials and methods

The experimental protocols describing the management and care of animals were reviewed and approved by the Animal Care and Use Committee of Dankook University.

2.1. Preparation of de-hulled and water-soaked barley

In the current study, DB and WB were provided by Designsolv Inc. (Guangzu, South Korea). Briefly, DB was processed by a full circle hammer mill with a 2.5-mm hammer mill grind screen. WB was then produced in jars according to patent 10-08717830 (2006). Briefly, viable hulled barley grains were steeped in water at a ratio of 1:3 (wt/wt) as follows: 19 h wet at 15–18°C, 22 h air rest at 24°C, 16 h wet at 15–18°C, 4 h air rest at 24°C, 3 h wet at 55°C, 3 h wet at 60°C, 3 h wet at 65°C, and air rest at 24°C until the moisture is less than 20%, and then ground to get the final WB.

2.2. Chemical analyses

The chemical compositions of WB and DB were analysed in triplicate before initiation of the experiment (Table 1). The amino

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2.3. Animals and experimental design

A total of 144 crossbred pigs [(Yorkshire × Landrace) × Duroc] with an average initial body weight (BW) of 61.7 ± 1.27 kg were allocated to one of three treatments according to their BW and sex (two barrows and two gilts) with 12 replicates per treatment and 4 pigs per pen. The dietary treatments were: DB, corn–soybean meal-based basal diet + 5% DB (0–8 weeks of feeding); WB1, basal diet + 5% WB1 (0–8 weeks of feeding); WB2, basal diet + 5% WB (4–8 weeks of feeding). WB as a replacement to DB was fed for long (0–8 weeks) and short (4–8 week) periods to evaluate the effect of feeding periods of WB on the parameters measured. Barley was supplemented at the expense of corn at both feeding periods. All nutrients in diets were formulated to either meet or exceed the recommendation of NRC (2012) for finishing pigs. Composition of the experimental diet is presented in Table 2. All pigs were housed in a temperature- and humidity-controlled room. The experiment lasted for 8 weeks. Each pen was equipped with a one-sided, stainless-steel self-feeder and a nipple drinker that allowed pigs ad libitum access feed and water.

2.4. Growth performance and nutrients digestibility

Body weight and feed consumption were measured at the beginning and on 4th and 8th weeks of the experimental period to monitor the average daily gain (ADG), average daily feed intake (ADFI), and gain/ feed (G/F) ratio. Chromium oxide (Cr₂O₃) was added to the diet at 0.20% as an indigestible marker 7 days prior to faecal collection on 4th and 8th weeks to calculate the digestibility coefficient. Faecal grab samples were then collected randomly from at least two pigs in each pen. Feed and faecal samples were dried for 72 h at 70°C, after which they were finely ground to be able to pass through a 1-mm screen and then frozen and stored in a refrigerator at −20°C until analysis. DM, N, E were analysed according to the AOAC (1995). Chromium levels were determined via UV absorption spectrophotometry (Shimadzu, UV-1201, Japan).

Table 1. Nutrient composition of water-soaked and de-hulled barley (g/kg DM basis).

| Item                      | De-hulled barley | Water-soaked barley |
|---------------------------|------------------|---------------------|
| Dry matter                | 896.0            | 922.0               |
| Crude protein             | 98.0             | 148.0               |
| Crude fat                 | 21.0             | 22.1                |
| Crude fibre               | 56.0             | 98.6                |
| Crude ash                 | 24.0             | 41.7                |
| Neutral detergent fibre   | 199.0            | 298.0               |
| Acid detergent fibre      | 80               | 152.0               |
| β-glucan                  | 73.8             | 21.6                |
| Gross energy (kcal/kg)    | 3567.0           | 4210                |
| Essential AA              |                  |                     |
| Arginine                  | 4.9              | 4.9                 |
| Histidine                 | 2.5              | 5.4                 |
| Isoleucine                | 3.6              | 4.2                 |
| Leucine                   | 6.8              | 13.1                |
| Lysine                    | 3.9              | 5.1                 |
| Methionine                | 1.8              | 2.0                 |
| Phenylalanine             | 4.9              | 6.4                 |
| Threonine                 | 3.6              | 5.5                 |
| Tryptophan                | 2.9              | 15.5                |
| Valine                    | 5.2              | 6.7                 |
| Fatty acid (g/kg) total fatty acid |         |                     |
| Myristic acid             | 12.1             | 12.0                |
| Palmitic acid             | 221.0            | 201.0               |
| Stearic acid              | 13.0             | 12.1                |
| Oleic acid                | 125.5            | 103.0               |
| Linoleic acid             | 527.2            | 670.2               |
| Linolenic acid            | 62.0             | 59.2                |
| Mineral composition       |                  |                     |
| Calcium                   | 0.7              | 1.3                 |
| Phosphorous               | 3.4              | 3.5                 |
| Potassium                 | 4.8              | 10.8                |
| Sodium                    | 0.1              | 0.30                |
| Chlorine                  | 1.2              | 7.50                |
| Magnesium (mg/kg)         | 1.1              | 3.30                |
| Manganese (mg/kg)         | 16.0             | 19.6                |
| Zinc (mg/kg)              | 30.7             | 43.3                |
| Copper (mg/kg)            | 9.5              | 4.5                 |
| Iron (mg/kg)              | 158.2            | 170.2               |

Table 2. Composition of basal finishing pig diet (as fed basis).

| Ingredients (%)          | De-hulled barley | Water-soaked barley |
|--------------------------|------------------|---------------------|
| Maize                    | 59.56            | 62.56               |
| De-hulled barley         | 5.00             | 0.00                |
| Water-soaked barley      | 0.00             | 5.00                |
| Soybean meal , 46% CP    | 20.10            | 20.1                |
| Maize glucan             | 0.83             | 0.83                |
| Limestone                | 1.44             | 1.44                |
| Tallow                   | 3.67             | 3.67                |
| Molasses                 | 6.00             | 3.00                |
| Sodium chloride          | 0.11             | 0.11                |
| L-Lysine-6Cl (72%)       | 0.69             | 0.69                |
| C₆H₆-Methionine (98%)    | 0.30             | 0.30                |
| Vitamin-mineral premix    | 0.30             | 0.30                |
| Chromic oxide            | 2.00             | 2.00                |
| Analyzed composition (g/kg) | 888.40           | 887.2               |
| Dry matter               | 162.00           | 164.0               |
| Neutral detergent fibre  | 122.40           | 101.35              |
| Acids detergent fibre    | 62.70            | 54.5                |
| β-glucan                 | 63.20            | 43.2                |
| Total lysine             | 9.20             | 9.5                 |
| Methionine + Cysteine    | 61.00            | 62.0                |
| Calcium                  | 7.00             | 7.5                 |
| Total phosphorus         | 6.20             | 6.9                 |

*Provided per kg of complete diet: vitamin A, 9000 IU; vitamin D₃, 1200 IU; vitamin E, 40 IU; vitamin K₃, 3.0 mg; vitamin B₂, 5.2 mg; vitamin B₆, 2.6 mg; vitamin B₁₂, 26 g; niacin, 32 mg; d-pantothenic acid (as dicalcium pantothenate), 20 mg; provided per kilogram of complete diet: Cu (as CuSO₄·5H₂O), 15 mg; Mn (as Fe₃O₄·H₂O), 70 mg; Zn (as ZnSO₄), 50 mg; Mn (MnO₂), 50 mg; I (as KI), 0.5 mg; Co (as CoSO₄·5H₂O), 0.3 mg; and Se (as Na₂SeO₃·5H₂O), 0.2 mg.
following the method described by Williams et al. (1962). The apparent total tract digestibility (ATTD) of DM and N was calculated using indirect-ratio methods using the following formula:

\[
\text{Apparent total tract digestibility} = 1 - \left( \frac{\text{Nf} \times \text{Cd}}{\text{Nd} \times \text{Cf}} \right),
\]

where Nf = nutrient concentration in faeces (% DM), Nd = nutrient concentration in diet (% DM), Cf = chromium concentration in diet (% DM), and Cd = chromium concentration in diet (% DM).

### 2.5. Blood characteristics

At the end of 4 and 8 weeks, six pigs were randomly chosen from each treatment and bled via jugular venipuncture to obtain blood samples. Blood samples were collected into vacuum tubes containing no additives and tubes containing K₃EDTA (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ, USA) to obtain serum and whole blood, respectively. The red blood cells (RBC), white blood cells (WBC), and lymphocyte counts of the whole blood samples were determined using an automatic blood analyser (ADVIA 120, Bayer, Tarrytown, NY, USA). The serum was separated by centrifugation for 30 min at 2000×g at 4°C and then stored at −4°C for determination of IgG levels using an automatic biochemistry blood analyser (HITACHI 747, Hitachi, Tokyo, Japan). Glucose concentrations were determined using a spectrophotometric procedure (Sigma 1990).

### 2.6. Meat quality

At the end of the experiment, five pigs for each treatment were slaughtered at a local commercial slaughterhouse. After chilling at 2°C for 24 h, one 2.54-cm thick longissimus muscle (LM) sample was obtained at the 10th rib (right side of the carcass). Sensory evaluation (colour, marbling, and firmness scores) was evaluated according to the National Pork Producers Council standards (NPPC 2000). The colour of each sample was determined using a Chromameter (Model CR-410, Minolta Co., Japan) and is reported in the International Commission on Illumination system values of lightness (L*), redness (a*), and yellowness (b*). Colour was measured on each loin meat sample in duplicate with one reading in the anterior and one reading in the posterior portion of the meat. All colour readings were taken on the skin surface in an area free of obvious colour defects (over scald, bruises, and blood accumulation). Waterholding capacity (WHC) was estimated by determining expressible juice using a modification of the filter paper press method described by Wierbicki and Deatherage (1958) as follows. A meat sample weighing between 0.2 g was placed on a 11 cm diameter filter paper between plexiglass plates and pressed at 3000 psi for 2 min. The outline area of the expressible juice and the meat film was traced, and the two areas were determined using a compensating polar planimeter. Expressible juice, as a percentage, was calculated as follows:

\[
\text{Expressible juice %} = \frac{100 \times (\text{total juice area} - \text{meat film area})}{\text{water/square inch filter paper}} \times \frac{\text{total moisture (mg) of original sample}}{\text{sample wt in (mg)} \times \% \text{ moisture}}.
\]

Higher expressible juice percentage is related to lower WHC.

The pH of each sample was measured at 20 min postmortem with a pH metre with a pH electrode (NWK biner pH, K-21, Landsberg, Germany). For 10 s, the electrode was inserted approximately 2.5 cm below the surface of the anterior portion of the meat. The electrode was calibrated at 20°C in buffers with pH 4.00 and 7.00. The longissimus muscle area (LMA) was measured by tracing the LM surface at the 10th rib, which was also conducted using the aforementioned digitizing area-line sensor. A 4.5 g meat sample (1.5-cm-diameter core of approximately 4 cm in length) was acquired from the loin meat samples for drip loss test, placed perpendicular to the length of the muscle, and suspended in a plastic bag for 7 days. The sample was measured for weight at 1, 3, 5, and 7 days. To determine the cooking loss, two 25 mm slices of the LM sample were weighed and then placed in individual polyethylene bags. The samples were then cooked for 60 min in a water bath at 70°C. After cooking, the fluid was poured from the bags and the samples were refrigerated (0–1°C) overnight. The following morning, the samples were patted dry with paper towels and then reweighed to determine the cooking loss, which was expressed as a percentage of the uncooked sample weight.

### 2.7. Statistical analyses

All data generated in this experiment were subjected to the general linearized model procedures of SAS (SAS Institute 1996) as a randomized complete block design. Each pen served as the experimental unit. Additionally, Tukey’s test was used to compare the means of the treatments. Variability in the data was expressed as the pooled standard error (SE) and a p < .05 was considered to be statistically significant.

### 3. Result

The analysed composition of the experimental diet in the present study indicated that WB contains higher energy and CP than that in DB (Table 1).

As shown in Table 3, there was no difference in ADG, ADFI, and growth: feed ratio (G/F) among dietary treatments (p > .05). There was also no difference in dry matter, nitrogen, and gross energy digestibility among dietary treatments (p > .05) (Table 4).

The replacement of DB with WB did not have a significant difference (p > .05) on the WBC, RBC, and glucose concentration at week 4 and week 8. There was also no difference (p > .05) in lymphocyte concentration among dietary treatments at week 4. But, at the end of week 8, lymphocyte was higher (p < .05) in DB than in WB1 treatment. At the end of week 4, WB1 treatment improved the IgG concentration (p < .05) compared with those in DB and WB2. Moreover, WB1 and WB2 treatments had higher (p < .05) IgG than in DB treatment at the end of week 8 (Table 5).

With regard to meat quality, the sensory evaluation of colour scored higher (p < .05) in WB1 treatment than in the DB and WB2 treatments. Moreover, meat marbling scored higher (p < .05) in WB2 treatment than in the DB treatment. A higher (p < .05) yellowness was observed in DB treatment than the WB1 treatment. There was no difference in cooking loss, pH, WHC, and LMA among dietary treatments (p > .05). The
Table 3. Effect of replacement of de-hulled barley with water-soaked barley in con–soybean meal-based diet on growth performance in finishing pigs.

| Items (ppm) | DB | WB1 | WB2 | SE  |
|------------|----|-----|-----|-----|
| 0–4 week   |    |     |     |     |
| ADG (g)    | 847 | 876 | 846 | 19  |
| ADFI (g)   | 2527 | 2557 | 2514 | 65  |
| G/F        | 0.335 | 0.343 | 0.337 | 0.006 |
| 4–8 week   |    |     |     |     |
| ADG (g)    | 902 | 944 | 971 | 26  |
| ADFI (g)   | 2806 | 2964 | 2965 | 66  |
| G/F        | 0.321 | 0.318 | 0.327 | 0.008 |
| Overall    |    |     |     |     |
| ADG (g)    | 875 | 910 | 909 | 14  |
| ADFI (g)   | 2667 | 2761 | 2740 | 29  |
| G/F        | 0.328 | 0.330 | 0.332 | 0.006 |

Notes: DB, basal diet + 5% de-hulled barley; WB1, basal diet + 5% water-soaked barley (0–8 weeks); WB2, basal diet + 5% water-soaked barley (4–8 weeks); ADG, average daily gain; ADFI, average daily feed intake; G/F, feed efficiency. *Standard error (pooled).

Table 4. Effect of replacement of de-hulled barley with water-soaked barley in con–soybean meal-based diet on nutrient digestibility in pigs.

| Items (%)  | DB | WB1 | WB2 | SE  |
|------------|----|-----|-----|-----|
| Dry matter |     |     |     |     |
| Week 4     | 78.04 | 78.45 | 78.74 | 0.22 |
| Week 8     | 75.86 | 76.11 | 76.32 | 0.33 |
| Nitrogen   |     |     |     |     |
| Week 4     | 77.22 | 77.63 | 77.94 | 0.66 |
| Week 8     | 75.64 | 75.95 | 75.70 | 0.16 |
| Energy     |     |     |     |     |
| Week 4     | 76.57 | 76.76 | 76.95 | 0.15 |
| Week 8     | 75.30 | 75.57 | 75.77 | 0.20 |

Notes: DB, basal diet + 5% de-hulled barley; WB1, basal diet + 5% water-soaked barley (0–8 weeks); WB2, basal diet + 5% water-soaked barley (4–8 weeks). *Standard error (pooled).

Table 5. Effect of replacement of de-hulled barley with water-soaked barley in con–soybean meal-based diet on blood characteristics in finishing pigs.

| Items   | DB | WB1 | WB2 | SE  |
|---------|----|-----|-----|-----|
| WBC, 10^3/mm | | | | |
| Week 4 | 14.76 | 15.20 | 14.59 | 1.04 |
| Week 8 | 20.46 | 20.76 | 20.62 | 1.62 |
| RBC, 10^6/mm | | | | |
| Week 4 | 6.70 | 6.88 | 6.69 | 0.14 |
| Week 8 | 6.90 | 6.61 | 6.77 | 0.15 |
| Lymphocyte (%) | | | | |
| Week 4 | 66.56 | 61.12 | 65.22 | 2.83 |
| Week 8 | 65.26 a | 59.52 b | 61.88 ab | 1.20 |
| Glucose (mg/dL) | | | | |
| Week 4 | 8.76 | 77.4 | 76.2 | 4.3 |
| Week 8 | 83.6 | 8.2 | 78.0 | 9.0 |
| IgG (mg/dL) | | | | |
| Week 4 | 793.2 b | 928.8 a | 811.8 b | 19.3 |
| Week 8 | 799.8 b | 1013.2 a | 942.4 a | 42.2 |

Notes: Means in the same row with different letters (a and b) differ (p < .05). DB, basal diet + 5% de-hulled barley; WB1, basal diet + 5% water-soaked barley (0–8 weeks); WB2, basal diet + 5% water-soaked barley (4–8 weeks). *Standard error (pooled).

Table 6. Effect of replacement of de-hulled barley with water-soaked barley in con–soybean meal-based diet on meat quality in finishing pigs.

| Items (ppm) | DB | WB1 | WB2 | SE  |
|------------|----|-----|-----|-----|
| Sensory evaluation | | | | |
| Colour | 1.97 b | 2.17 a | 1.83 b | 0.05 |
| Marbling | 2.08 b | 2.24 ab | 2.38 a | 0.07 |
| Firmness | 1.95 | 1.87 | 2.05 | 0.09 |
| Meat colour | | | | |
| L* (lightness) | 57.06 | 54.71 | 57.96 | 1.06 |
| a* (redness) | 18.61 | 18.44 | 18.78 | 0.28 |
| b* (yellowness) | 12.63 a | 10.41 b | 11.56 ab | 0.56 |
| Cooking loss (%) | 28.90 | 29.40 | 27.25 | 0.69 |
| pH at 24 h | 5.72 | 5.71 | 5.69 | 0.08 |
| WHC (%) | 60.40 | 58.93 | 56.24 | 2.93 |
| LMA* (cm²) | 51.36 | 52.92 | 51.79 | 0.76 |
| Drip loss (%) | 8.70 a | 4.67 b | 6.67 ab | 1.10 |
| Day 1 | 14.87 | 11.26 | 13.01 | 1.38 |
| Day 5 | 17.09 a | 12.15 b | 13.89 ab | 1.35 |
| Day 7 | 17.54 | 16.01 | 15.24 | 1.47 |

Notes: Means in the same row with different letters (a and b) differ (p < .05). DB, basal diet + 5% de-hulled barley; WB1, basal diet + 5% water-soaked barley (0–8 weeks); WB2, basal diet + 5% water-soaked barley (4–8 weeks). *Standard error (pooled).

4. Discussion

Despite its high level of amino acid and phosphorous content, barley contains higher non-starch polysaccharides. Despite its high level of amino acid and phosphorous content, barley contains higher non-starch polysaccharides, thereby improving the nutrient utilization. Previous studies reported that WB improved nutrient digestion and feed efficiency of broiler chicks due to the reduction of β-glucans in barley grain (Fry et al. 1958; Svihus et al. 1997). In the present study, the growth performance and nutrient digestibility were not affected by the replacement of DB with 5% WB in pigs’ diet. In contrast, a previous study by Wang and Kim (2014) demonstrated that the inclusion of 15% WB in the diet significantly improved the growth performance and nitrogen digestibility. However, 10% inclusion of hydrolysed barley did not improve growth performance as reported by Yan and Kim (2012). Kong and Adeola (2012) fed a barley–corn–soybean meal-based diet to growing pigs supplemented with beta glucanase. There was no effect of glucanase on ATTD and AID of DM, GE, and N. The possible/potential reason for no improvement on growth performance and nutrient digestibility in the present study could be due to the low inclusion level of WB.

Regarding blood characteristic, lymphocyte concentration was significantly higher in DB than in WB on week 8 of the experiment. In WB, the level of β-glucans in the current study was higher than WB (63 vs 43 g/kg), which agrees with the result of Baidoo and Liu (1998) who reported that the level of β-glucans
in DB ranged from 40 to 70 g/kg. A report by Kim et al. (1996) indicated that β-glucans derived from mushroom influenced the acquired immune response in vitro by increasing lymphocyte proliferation. Thus, the increase in lymphocyte concentration might have been influenced by higher β-glucan concentration in DB compared to WB. The IgG concentration was significantly higher in WB1 and WB2 during week 4 and week 8 of the experiment compared to DB. β-glucanase is reported to be the most important hydrolytic enzyme for increasing resistance against microbial infection, indicating better immune response because the induction of β-1,3-glucanase in various plants like barley, wheat, rice, and sorghum in response to fungal pathogens clearly demonstrates the involvement of the enzyme in defence response (Salim et al. 2011; Gupta et al. 2013). The possible/potential reason for the increased level of immunoglobulin G, an antibody, in WB, is due to the presence of β-glucanase enzymes that might have improved the beneficial micro-organism in the gastrointestinal tract, thereby improving the immunity to fight against antigens produced by bacterial and viral infections even during week 4 in WB1. Other blood characteristics such as WBC, RBC, and glucose were not affected by the dietary replacement of DB with WB.

Research has shown that consumers most readily judge meat quality on the basis of their appearance, flavour, and texture. Among all sensory attributes of meat, colour is considered one of the most important physical traits because once colour is considered unacceptable, all other sensory attributes do not matter much to consumers (Mancini & Hunt 2005; Bekhitt et al. 2007) influencing their purchasing decisions (McKenna et al. 2005). Based on sensory evaluation, the score on colour for WB was higher than that for DB in this study. However, based on meat colour evaluation by instrumentation, yellowness of meat was found to be higher in DB compared to WB. In contrast to the present finding, Wang and Kim (2014) demonstrated no changes in yellowness of meat in WB compared to DB. The difference in finding could be due to the inclusion level of DB or WB in the diet.

The eating quality of meat has long been associated positively with the marbling of meat although it accounts for only a small part among the palatability characteristics. In the present study, WB1 and WB2 had higher marbling scores than DB. Fortin et al. (2003) reported that pigs fed a high β-glucan diet had the lowest chemical fat content and low marbling scores. The reason for the high marbling scores in WB could be due to the lower β-glucan content than in DB.

In the present study, the drip loss, a measure of water-holding property of lean muscle, was higher in DB than in WB. However, drip loss was not influenced in the pigs fed 15% DB and 15%WB in the diet (Wang & Kim 2014). The difference in result may be the low inclusion level of WB in the diet. Other characteristics of meat were not affected by WB inclusion in the diet.

5. Conclusion
In conclusion, WB at both feeding times did not have any impact on growth performance and nutrient digestibility compared with DB. However, the replacement of DB with 5% WB1 in finishing pigs’ corn–soybean meal-based diet showed a positive influence on improving the immune status as well as the quality of meat.

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Disclosure statement
No potential conflict of interest was reported by the authors.

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