SHORT COMMUNICATION

Effect of dietary β-glucan supplementation on growth performance, nutrient digestibility, and characteristics of feces in weaned pigs

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ABSTRACT

A total of 150 crossbred weaned pigs [(Yorkshire × Landrace) × Duroc] with an average body weight of 6.75 ± 0.49 kg were used in a 6-wk trial to determine the effects of dietary supplementation of β-glucan on growth performance, nutrient digestibility, and characteristics of feces (fecal score, microbiota, moisture, and pH) in weaned pigs. The corn-soybean meal based dietary treatments included: 1) antibiotic (30 ppm Tiamulin), 2) 0% β-glucan, 3) 0.1% β-glucan, 4) 0.2% β-glucan, and 5) 0.4% β-glucan. Dietary supplementation with β-glucan resulted in no significant differences in growth performance, nutrient digestibility, or characteristics of feces compared with that of Tiamulin supplementation. Pigs fed β-glucan exhibited a linearly increasing average daily gain and feed/gain ratio. Dietary supplementation of β-glucan linearly increased apparent total tract digestibility of dry matter and energy during 1–14 and 1–42 d as dietary β-glucan increased from 0.1 to 0.4%. In addition, pigs fed β-glucan had linearly decreasing coliform bacterial counts. In conclusion, dietary supplementation with β-glucan from rice bran improved growth performance, nutrient digestibility and coliform bacteria in weaned pigs, and β-glucan had the same effect as Tiamulin supplementation on growth performance, nutrient digestibility, and characteristics of feces. Thus, we suggest that β-glucan from rice bran can be used as an alternative to antibiotics, and will improve productivity of weaned pigs.

1. Introduction

Antibiotic supplementation in pig diets is well known to improve growth rate, feed utilization, and reduce mortality from clinical disease (Cromwell 2002). Because the use of antibiotics results in a reservoir of drug-resistant bacteria, the use of antibiotics in livestock diets as a growth promoter has been banned in many countries. Many researchers have focused on the development of alternatives to antibiotics, including probiotics (Simon 2010; Jacela et al. 2010b; Cho et al. 2011), prebiotics (Jacela et al. 2010b), enzymes (Thacker 2000; Adeola and Cowieson 2011), acidifiers (Kil et al. 2011), plant extracts (Jacela et al. 2010b; Liu et al. 2011), copper (Jacela et al. 2010a), and zinc (Jacela et al. 2010a) to maintain pig health and performance.

β-glucan, a polysaccharide of D-glucose monomers linked by β-glycosidic bonds, is present in cellulose in plants, bran of cereal grains, cell walls of baker’s yeast, certain fungi, mushrooms, and bacteria. It is well known that β-glucan activates the immune system by binding to receptors on the surface of innate immune cells and maintains normal blood cholesterol concentrations (Braaten et al. 1994; Brown and Gordon 2001; Vetvicka et al. 2007). In addition, it has been reported that pig fed dietary β-glucan exhibited increased plasma leucocytes counts, increased lymphocyte proliferation activity, decreased TNF-α concentration and fecal E. coli numbers, and benefited from the composition and metabolic activity of gastric microbiota, and caecal and colonic microbiota (Metzler-Zebeli et al. 2011; Zhou et al. 2013). However, β-glucan from different sources results in variable effects on growth and the immune response (Dritz et al. 1995; Decuypere et al. 1998; Fortin et al. 2003; Hisan and Sauerwein 2003).

In the present study, we used water soluble β-glucan from rice bran as a dietary supplementation and investigated the effects of their different concentrations on growth performance, nutrient digestibility, and fecal microbiota, score, moisture, and pH in weaned pigs.

2. Materials and methods

The animal care and used protocol were approved by the Animal Care and Use Committee of Dankook University.

2.1. Experimental design, animals and diets

A total of 150 crossbred weaned barrows [(Yorkshire × Landrace) × Duroc] with an average BW of 6.75 ± 0.49 kg were used in a 6-wk trial. The pigs were sorted into pens with five pigs per pens and six pens per treatments. The diets were based on corn-soybean meal. The dietary treatments were 1) 30 ppm Tiamulin (Yuhan Co., Ltd., Seoul, South Korea), 2) 0% β-glucan, 3) 0.1% β-glucan, 4) 0.2% β-glucan, and 5) 0.4% β-glucan. A tested product, β-glucan comprises 86% β-1, 3/1, 6-glucan (STR Biotech. Co., Ltd., Chuncheon, South Korea), which was added to basal diets from 0.1 to 0.4%.
environmentally controlled room with a slatted plastic floor requirement (Table 1) (NRC 2012). All pigs were housed in an
with 2% Cr2O3 (chromic oxide) as an indigestible marker for
and the feed/gain (F/G) ratio.
average daily gain (ADG), average daily feed intake (ADFI),
recorded on a pen basis during the experiment to calculate
d 42 of the experimental period, and feed consumption was
Individual pig BW was recorded at the beginning, d 7, d 21, and
2.2. Sampling and measurements

Provided per kg of complete diet: Cu, 12 mg; Zn, 85 mg; Mn, 8 mg; I, 0.28 mg; and Se, 0.15 mg.

All diets were formulated to meet or exceed the NRC nutrition requirement (Table 1) (NRC 2012). All pigs were housed in an environmentally controlled room with a slatted plastic floor, which proved 0.26 m² of space per pig. Each pen was equipped with a self-feeder and nipple waterer to allow ad libitum access to feed and water throughout the experimental period.

2.2. Sampling and measurements

Individual pig BW was recorded at the beginning, d 7, d 21, and d 42 of the experimental period, and feed consumption was recorded on a pen basis during the experiment to calculate average daily gain (ADG), average daily feed intake (ADFI), and the feed/gain (F/G) ratio.

During the experimental period, pigs were fed diets mixed with 2% Cr2O3 (chromic oxide) as an indigestible marker for the determination of apparent total tract digestibility (ATTD) for dry matter (DM) and nitrogen (N). On d 7, d 21, and d 42, fecal samples were collected from at least two pigs in each pen via rectal massage. All feed and fecal samples were freeze-dried, finely ground, passed through a 1-mm screen, and analyzed for DM, N, and energy. DM and N concentrations were determined by the Kjeldahl method according to the AOAC (2007). Gross energy was determined using a Parr 6100 oxygen bomb calorimeter (Parr instrument Co., Moline, IL, USA). Chromium was analyzed via UV absorption spectrophotometry (Shimadzu UV-1201, Shimadzu, Kyoto, Japan).

Fecal scores were determined twice each day on d 7, d 14, d 21, d 28, d 35, and d 42, the score scale was (1) hard and dry pellet, but small mass, (2) hard and formed stool, (3) soft and formed stool but moist, (4) soft and unformed stool, and (5) watery, liquid stool. The fecal moisture contents were determined by randomly collecting feces from each pen at wk 6 via massaging the rectum. The fecal samples were dried at 60°C for 72 h to allow determination of fecal moisture content. Fecal pH was determined with pH-meter (model 720P, IsteK, Inc., Seoul, Korea) by diluting 10 g of feces collected at wk 6.

Fecal samples were collected via rectal massage from two pigs in each pen, pooled, placed on ice for transportation to the laboratory, and analyzed for microfloral counts. Viable counts of bacteria in the fecal samples were determined by plating serial 10-fold dilutions (in 1% peptone solution) onto Lactobacilli medium III agar plates (Medium 638, DSMZ, Braunschweig, Germany), MacConkey agar plates (Difco Laboratories, Detroit, MI), and Salmonella-Shigella (SS) agar (Difco Laboratories, Detroit, MI) to isolate Lactobacillus, coliform bacteria, and Salmonella, respectively. The lactobacilli medium III agar plates were then incubated for 48 h at 37°C under anaerobic conditions. The MacConkey and SS agar plates were incubated for 24 h at 37°C under aerobic conditions. The coliform bacteria and Lactobacillus colonies were counted immediately after removal from the incubator and the results were presented as log10 colony-forming units (CFU) per gram.

### 2.3. Statistical analysis

All data were analyzed using the mixed procedures for repeated measures (PROC MIXED) in SAS software (version 9.0, SAS Institute, Cary, NC, USA) with the following statistical model of

\[ Y_{ijk} = \mu + t_i + r_k + e_{ijk}, \]

where \( Y_{ijk} \) was an observation on the dependent variable, \( \mu \) was the overall population mean, \( t_i \) was the fixed effect of treatments, \( r_k \) was the pen as a random effect, and \( e_{ijk} \) was the random error associated with the observation \( ijk \). Orthogonal contrasts used to separate treatments means were antibiotic vs. \( \beta \)-glucans (0.1, 0.2, and 0.4%). Furthermore, means were separated using orthogonal polynomial contrasts to examine effects of \( \beta \)-glucan diets. For statistical analysis, the pen means served as the experimental unit. Variability in the data was expressed as the pooled standard error of the mean (SEM). \( P \) values < 0.05 were considered statistically significant.

### 3. Results

#### 3.1. Growth performance

Effects of dietary \( \beta \)-glucan supplementation on growth performance are shown in Table 2. In phase 1, supplementation of \( \beta \)-glucan linearly increased ADG and the F/G ratio (\( P = 0.009 \) and 0.003, respectively). In phase 2, supplementation of \( \beta \)-glucan linearly increased the F/G ratio (\( P = 0.04 \)). Overall, supplementation of \( \beta \)-glucan linearly increased ADG and the F/G ratio (\( P = 0.009, 0.022 \), respectively). Levels of ADG, ADFI, and F/G did not differ between supplementation with \( \beta \)-glucan and Tiamulin.

#### 3.2. Nutrient digestibility

Effects of dietary \( \beta \)-glucans supplementation on ATTD are shown in Table 3. In wk 1, supplementation of \( \beta \)-glucan linearly increased the ATTD of dry matter (\( P = 0.002 \). In addition, pigs

| Table 1. Feed compositions of control diet (as-fed basis). |
|----------------|----------------|
| **Item**       | **Phase I (d 1–14)** | **Phase II (d 15–42)** |
| Extruded corn  | 44.49           | 61.97           |
| Soybean meal (48% CP) | 21.20          | 27.80           |
| Fish meal (66% CP)  | 3.50            | -               |
| Soy oil         | 2.55            | 1.05            |
| Lactose         | 8.30            | -               |
| Whey            | 10.00           | 5.00            |
| Decalci Phosphate| 1.50            | 1.50            |
| Sugar           | 3.00            | -               |
| Lysin-HCl       | 0.39            | 0.46            |
| DL-Methionine   | 0.30            | 0.24            |
| L-Threonine     | 0.19            | 0.20            |
| Choline chloride| 0.10            | 0.10            |
| Vitamin a       | 0.10            | 0.10            |
| Vitamin E       | 0.10            | 0.10            |
| Mineral b       | 0.20            | 0.20            |
| L-Lysine-HCl    | 0.98            | 1.13            |
| Salt            | 0.20            | 0.25            |
| Total           | 100             | 100             |
| **Calculated energy content** |
| Metabolizable energy, kcal/kg | 3540          | 3410           |
| Crude protein   | 20.24           | 19.10           |
| Lysin           | 1.48            | 1.37            |
| Methionine + Cysteine | 0.96          | 0.84            |
| Calcium         | 0.94            | 0.89            |
| Total Phosphorus| 0.74            | 0.69            |
| Avail Phosphorus| 0.53            | 0.42            |
Beta-glucan increased in apparent total tract digestibility of energy (linear, $P = 0.015$; quadratic, $P = 0.037$). Dietary supplementation of beta-glucan linearly increased the ATTD of dry matter ($P = 0.001$) and nitrogen ($P = 0.03$) in wk 3. In wk 6, dietary supplementation of beta-glucan linearly increased the ATTD of dry matter ($P = 0.009$) and energy ($P = 0.004$). Dry matter, nitrogen, and energy with dietary beta-glucan supplementation did not differ compared to Tiamulin supplementation.

### 3.3. Characteristics of feces

Effects of dietary supplementation of beta-glucans from rice bran on characteristics of feces (fecal score, microbiota, moisture, and pH) are shown in Table 4. Dietary beta-glucan supplementation linearly decreased coliform bacteria counts ($P = 0.033$). Dietary beta-glucan supplementation did not affect fecal score, *Lactobacillus*, coliform bacteria and *Salmonella* counts, moisture, and pH compared to that with Tiamulin supplementation.

### 4. Discussion

Because of the limitation of antibiotics, there have been increasing efforts to minimize their use as growth promoters in livestock. Alternatives to antibiotics, such as probiotics and prebiotics, have attracted considerable attention. Among these, prebiotics, primarily derived from nondigestible oligosaccharides, inulin, and beta-glucan, are nondigestible food substances that selectively stimulate the growth of favourable species of bacteria in the gut (Kaplan and Hutkins 2000; Smiricky-Tjardes et al. 2003; Loh et al. 2006; Arena et al. 2014). Supplementation with beta-glucan is the most desirable alternative to antibiotics because it is well established that beta-glucan activates the immune system and maintain normal blood cholesterol concentration (Braaten et al. 1994; Brown and Gordon 2001; Vetvicka et al. 2007). In the present study, beta-glucan supplementation in pig diets improved ADG and F/G. Many studies have reported relatively positive effects of beta-glucan supplementation on pig performance, although its functions in growth improvement remain controversial. In agreement with the present data, beta-glucan supplementation enhanced growth performance in pigs (Dritz et al. 1995; Hahn et al. 2006; Li et al. 2006). Dritz et al. (1995) reported that pigs fed diets containing 0.025% beta-glucan had higher ADG and ADFI and were heavier on d 28 after weaning than pigs fed the control diet. In addition, they reported that supplementation with beta-glucan increased growth performance and.

### Table 2. The effects of beta-glucan from rice bran on growth performance in weaned pigs*.

| Items, % | Ant* | 0 | 0.1 | 0.2 | 0.4 | SEMb | P-value | beta-glucan effect |
|---------|------|---|-----|-----|-----|------|---------|-------------------|
| ADG, g  | 251  | 242| 244 | 255 | 262 | 5.42 | 0.940   | 0.009            |
| ADFI, g | 285  | 285| 280 | 277 | 284 | 3.03 | 0.332   | 0.075            |
| F/G     | 1.135| 1.178|1.148 |1.086 |1.084 |0.02 | 0.642   | 0.003            |

*Each mean represented by six replications per treatment ($n = 6$).

*Antibiotic (30 ppm Tiamulin).

bStandard error of means.

cAverage daily gain.

dAverage daily feed intake.

### Table 3. Effects of beta-glucan from rice bran on apparent total tract nutrient digestibility in weaned pigs*.

| Items, % | Ant* | 0 | 0.1 | 0.2 | 0.4 | SEMb | P-value | beta-glucan effect |
|---------|------|---|-----|-----|-----|------|---------|-------------------|
| Dry matter | 84.32 | 82.22 | 82.52 | 82.77 | 83.96 | 0.44 | 0.540 | 0.002 |
| Nitrogen | 68.04 | 78.78 | 79.29 | 79.64 | 79.83 | 0.42 | 0.470 | 0.237 |
| Energy | 84.43 | 82.23 | 82.63 | 82.93 | 83.37 | 0.45 | 0.470 | 0.237 |

*Each mean represented by six replications per treatment ($n = 6$).

*Antibiotic (30 ppm Tiamulin).

bStandard error of means.
susceptibility to Streptococcus suis infection via a complex interaction between growth performance and disease susceptibility in nursery pigs. In another study, Li et al. (2006) discussed the effects of β-glucan, extracted from Saccharomyces cerevisiae, on growth performance and the immunological and somatotrophic responses of pigs challenged with Escherichia coli lipopolysaccharide. β-glucan is considered a biological response modifier that exert a variety of biological and immunopharmaceutical properties. These immunomodulators have the capacity to stimulate both innate and specific immunity (Vetvicka et al. 2014). Weaned piglets experience biological stress including physiological, environmental and social challenges that results in intestinal, immunological, and behavioural changes. Therefore, the period after weaning is an extremely important time in the life of pigs. The findings of the current study suggest that β-glucan inclusion in the diet might improve both the growth and F/G in weaned pigs.

In previous reports, the digestibility of DM, GE, CP, EE, Ca, and P linearly increased in weaned pigs as the dietary concentrations of β-glucan increased (Hahn et al. 2006). However, a few studies have reported inconsistent results; specifically, β-glucan supplementation showed no effect on the digestibility of DM, GE, CP, ash, or P in growing or finishing pigs (Bae et al. 1999; Ko et al. 2000). Consumption of nonstarch polysaccharides such as β-glucan has been associated with decreased nutrient digestibility (Lynch et al. 2007). However, β-glucan has been shown to have prebiotic properties because they have the ability to pass undigested through the gastrointestinal tract, where they act as a substrate for microbial fermentation and selectively stimulate the growth and activity of a small number of beneficial bacteria (Gibson 2004). Prebiotics have been found to enhance the ATTD of DM, N, and other minerals (Scholz-Ahrens et al. 2001; Zhao et al. 2015), which is believed to be caused by improvements in the intestinal environment. β-glucan may have different effects on growth performance and immune function depending upon processing methods in weaned piglets. β-glucan from different sources may also vary in structure, chemical composition, or both, which may influence its activity and the amount that should be added for a growth response (O’Shea et al. 2010). In the present study, inclusion of β-glucan derived from rice bran appeared to elevate the ATTD of DM, N, and energy.

Dietary β-glucan decreased the numbers of coliform bacteria in feces in the present study. Similarly, piglets receiving feed supplemented with β-glucan for 2 weeks after weaning showed decreased susceptibility to enterotoxigenic E. coli, which is a major cause of diarrhea in neonatal, suckling, and newly weaned piglets (Stuyven et al. 2009). Shen et al. (2012) suggested that β-glucan might exert favourable effects on intestinal functions and health by increasing Lactobacillus and Bifidobacterium and decreasing Enterobacteriaceae. Therefore, decreased fecal E. coli numbers in this study caused by dietary β-glucan supplementation may be related to improvement of the intestinal environment, although no significant difference was detected in Lactobacillus and Salmonella populations.

In conclusion, the present study indicated that dietary supplementation of β-glucan from rice bran improved growth performance, nutrient digestibility, and fecal microbiota in weaned pigs. In addition, β-glucan had the same effect as antibiotic supplementation on growth performance, nutrient digestibility, and characteristics of feces. Thus, we suggest that β-glucan from rice bran could have alternative antibiotic effects and improve productivity of weaned pigs.

Disclosure statement

No potential conflict of interest was reported by the authors.

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