Effects of Brown Rice Particle Size on Growth Performance and Energy Digestibility in Finishing Pigs

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Introduction

It is generally agreed that reducing the mean particle size of cereal grains in the feed of pigs results in marked improvements in nutrient digestibility and growth efficiency of the animals (NATIONAL RESEARCH COUNCIL, 2012). However, this conclusion is primarily based on results obtained from studies on sorghum (OWSLEY et al., 1981) and corn (WONDRA et al., 1995).

Recently in a study on brown rice, YAMAMOTO et al. (2016) found that for each 1 mm reduction in mean particle size, the total tract energy digestibility increased by approximately 7.7%. This suggests that reducing the size of the brown rice particles fed to pigs improves growth efficiency due to the resulting increase in nutrient digestibility.

Effects of brown rice particle size on growth performance is still unknown. Therefore, we aimed to evaluate effect of brown rice particle sizes on growth efficiency.

Materials and Methods

The brown rice used in this study was of the Yumeaoba variety produced in Chiba prefecture in 2015. The brown rice was ground into three mean particle sizes using a roll mill (RMP30, Asano Engineering Co. LTD, Gifu, Japan). The targeted mean particle sizes were 1.6, 1.1, and 0.6 mm, designated coarse (C), medium (M), and fine (F), respectively. The mean particle size of corn was adjusted to that of the medium-sized (M) brown rice particles. The geometric means were calculated as described in FURUYA and KAJI (1987).

Thirty-two finishing pigs (16 barrows and 16 gilts, Yorkshire × Landrace × Duroc), with an average initial body weight (BW) of 90 kg, were allotted to four diet treatment groups, with eight pigs (four barrows and four gilts) per group. The pigs were placed in slatted-floor pens (R&D Center, Nosan Corporation) with free access to one of the four diets, a corn-based diet or a brown rice-based diet consisting of one of the three particle sizes, until reaching 108 kg BW. The diets were formulated to meet or exceed NATIONAL AGRICULTURE AND FOOD RESEARCH ORGANIZATION (2013) recommendations for all nutrients (Table 1). Drinking water was freely available.

Pigs and feeders were weighed at initiation and conclusion of the growth assay to determine average daily gain, average daily feed intake, and feed conversion ratio (feed/gain). From d 14 to 19 of the experiment, 2% celite® 545, a source of acid insoluble ash (AIA), was added to all diets and used as an indigestible marker. On d 19, fecal grab samples of pigs were collected from each pen. The fecal samples were dried in a forced air drying oven at 60°C and ground through a 1-mm screen prior to chemical analysis. To allow calculation of energy digestibility...
through the indirect ratio method, the concentrations of AIA (FURUYA et al., 2001), N (ASSOCIATION of OFFICIAL ANALYTICAL CHEMISTS 1990), and GE (by bomb calorimetry, Ca-4PJ ; Shimadzu ; Kyoto) in the feces and diets were determined. Daily intake of digestible energy was calculated by multiplying daily energy intake by energy digestibility.

Data were analyzed statistically using the GLM procedure of SAS9.4 (SAS Inst. Inc., Cary, NC). The average daily gain of the pigs and the total tract energy digestibility were compared using a one way ANOVA with Tukey test. An alpha level of 0.05 was used to assess significance among means.

Animal care of this experiment was followed the Guidelines for animal experiments by University of Gifu.

| Table 1. | Ingredient composition (%) and chemical composition of experimental diets on an as fed basis |
|-----------------|-------------------|-----------------|
| Item, % | Corn diet | Brown rice diets |
| Brown rice (F, M or C)¹ | 0.00 | 80.00 |
| Corn | 80.00 | 0.00 |
| Soybean meal | 17.35 | 17.35 |
| Limestone | 0.75 | 0.75 |
| Triphosphate carbonate | 1.00 | 1.00 |
| Sodium chloride | 0.30 | 0.30 |
| Vitamin premix 1² | 0.20 | 0.20 |
| Vitamin premix 2³ | 0.20 | 0.20 |
| Mineral premix ⁴ | 0.20 | 0.20 |

Chemical composition⁵

| Item, % | Corn diet | Brown rice diets |
|-----------------|-------------------|-----------------|
| CP, % | 14.3 | 12.4 |
| GE, kcal/kg | 3790 | 3673 |
| DE, kcal/kg | 3396 | 3435 |
| Available lysine, % | 0.70 | 0.72 |

1 F, M and C indicates fine, medium and coarse, respectively.
2 Provided the following quantities of vitamins per kilogram of complete diet : Vitamin A, 10,000,000IU as vitamin A acetate ; vitamin D₃, 20,000,000IU as D-activated animal sterol ; vitamin E, 10 g as dl-alpha tocopherol acetate.
3 Provided the following quantities of vitamins per kilogram of complete diet : Thiamin, 1000 mg as thiamin mononitrate ; riboflavin, 7000 mg ; pyridoxine, 500 mg as pyridoxine hydrochloride ; D-pantothenic acid, 10,900 mg as calcium pantothenate ; nicotinic acid, 6,000 mg as nicotinic acid amide ; choline, 576,000 mg as choline chloride.
4 Provided the following quantities of minerals per kilogram of complete diet : Cu, 10,000 mg as copper sulfate ; Fe, 50,000 mg as iron sulfate ; I, 1,000 mg as calcium iodate ; Mn, 50,000 mg as manganese sulfate ; Zn, 60,000 mg as zinc carbonate.
5 Chemical composition for DE and available lysine were based on National Agriculture and Food Research Organization (2013).

Results and Discussion

Particle size distribution and geometric mean particle size of corn and brown rice were shown in Table 2. The obtained geometric mean particle sizes for corn and brown rice F, M and C were 1.12, 0.66, 1.13 and 160 mm, respectively. Both the ground corn and brown rice particles were within 0.06 mm of the targeted particle sizes.

Results of growth performance and energy digestibility are shown in Table 3. There were tendency to increase average daily gain and to decrease feed conversion ratio according to the reduction of brown rice particle sizes, but no significant differences were observed. The average daily gain of barrows tended to be higher than that of gilts (P <
Figure 1A illustrates the relationship between brown rice particle size and feed conversion ratio. The slope of the line, 0.28, shows increase of feed conversion ratio for each 1 mm increase in particle size. This results indicates that feed conversion ratio from brown rice-based diets maybe improved by approximately 10% for each 1 mm reduction of particle size.

Energy digestibility from diet F which was prepared with finely ground brown rice particles, was significantly higher than that diet M, with medium-sized particles (P < 0.05). In addition, energy digestibilities from diet C and control diet were significantly lower than diet M (P < 0.05). The increases in energy digestibility with reduced particle size are consistent with other research reports on sorghum-based diet (OWSLEY et al., 1981), corn-based diet (WONDRa et al., 1995) and brown rice-based diet (YAMAMOTO et al., 2016).

The NATIONAL RESEARCH COUNCIL (2012) suggests that for corn and sorghum, each 1 mm reduction in mean particle size increases the apparent total tract energy digestibility by approximately 8.6 percentage units. The relationship between the particle size of brown rice and energy digestibility in the present study is shown in Figure 1B. The slope of the line, 9.2, shows the increase in digestibility (in percentage units) for each 1-mm reduction in particle size.

Table 2. Percentage of corn or brown rice retained on sieves with different-sized openings and the geometric mean of each particle size grouping

| Criterion                                      | Corn       | Brown rice |
|------------------------------------------------|------------|------------|
| Size of sieve opening, μm                      | Fine (F)   | Medium (M) | Coarse (C) |
| 3,500                                         | —          | —          | —          |
| 2,800                                         | 3.0a       | —          | 0.1        | 0.1        |
| 2,000                                         | 11.3       | —          | 0.8        | 31.8       |
| 1,400                                         | 25.9       | 0.1        | 34.8       | 43.9       |
| 1,000                                         | 23.2       | 8.6        | 39.4       | 13.9       |
| 1,550                                         | 23.5       | 68.5       | 16.7       | 5.8        |
| 1,210                                         | 11.2       | 18.2       | 6.4        | 3.5        |
| 88                                            | 1.9        | 4.6        | 1.8        | 1.0        |
| Geometric mean, mm                            | 1.12       | 0.66       | 1.13       | 1.60       |

*Values are the percentage of a 100-g sample retained on the sieve after shaking for 1 min.

Table 3. Effect of particle size on growth performance and energy digestibility in corn and brown rice diets

| Item                                          | Corn       | Brown rice |
|-----------------------------------------------|------------|------------|
| Daily gain1 kg/head Gilts                     | 1.01±0.09  | 1.18±0.06  | 1.12±0.09  | 1.01±0.19  |
| Daily gain1 kg/head Barrows                   | 1.10±0.11  | 1.25±0.06  | 1.14±0.09  | 1.17±0.01  |
| Feed intake2 kg/d                             | 3.30       | 3.29       | 3.26       | 3.20       |
| Feed conversion ratio2                        | 3.18       | 2.75       | 2.89       | 3.01       |
| Energy digestibility1, %                      | 78.5±4.6a  | 90.4±1.0c  | 86.9±1.4b  | 81.8±4.2a  |
| DE intakeb, Mcal/d                            | 9.82       | 10.92      | 10.41      | 9.61       |

1Values are means±standard deviations.
2Values are shown as a group data.
Means in the same row followed by different superscripts differ (P < 0.05).
It is generally accepted that pigs eat to meet their energy needs. Therefore, when allowed to feed *ad libitum*, voluntary feed intake decreases as the energy density of the diet increases. Wondra et al. (1995) reported that due to the resulting increase in energy digestibility when corn particle size is reduced, average daily feed intake decreased and gain/feed increased with reduced particle size. However, in the present study, we observed the opposite effect. As shown in Table 3, daily feed intake increased slightly as the particle sizes of the brown rice decreased. Daily intake of digestible energy for diet F, diet M and diet C was 10.92, 10.41, and 9.61 Mcal, respectively. The increase in DE intake with reduced particle size is not explained by the generally accepted idea that pigs eat to meet their energy needs. These observations suggest that the effects of energy digestibility on the voluntary feed intake for the brown rice-based diets need to be explored further.

In conclusion, reducing brown rice particle sizes may be beneficial method for improvement of growth performance of finishing pigs as increases energy digestibility.

References

ASSOCIATION of OFFICIAL ANALYTICAL CHEMISTS : 1990, Official Methods of Analysis, 15th edn. Association of Official Analytical Chemists, Washington, DC.

FURUYA, S., and Y. KAJI : 1987, Ileal digestibilities of amino acids in corn, rice, barley, naked barley and wheat for growing pigs. Jpn. J. Zootech. Sci., 58, 228–235.

FURUYA, S., A. YAMAMOTO, M. ITOH and Y. AOKI : 2001, Use of acid-insoluble ash added with celite as a marker for determining digestibility in pigs. Jpn. J. Swine Sci., 8, 171–176.

NATIONAL AGRICULTURE AND FOOD RESEARCH ORGANIZATION : 2013, Japanese feeding standard for swine (2013), Japan Livestock Industry Association, Tokyo.

NATIONAL RESEARCH COUNCIL : 2012, Nutrient requirements of swine, 11th edn. National Academy Press, Washington, DC.

OWSLEY, W.F., D.A. KNABE, T.D. TANKSLEY, JR. : 1981, Effect of sorghum particle size on digestibility of nutrients at the terminal ileum and over the total digestive tract of growing-finishing pigs. J. Anim. Sci., 52, 557–565.

WONDRA, K.J., J.D. HANCOCK, K.C. BEHNKE, R.H. HINES and C.R. STARK : 1995, Effects of particle size and pelleting on growth performance, nutrient digestibility, and stomach morphology in finishing pigs. J. Anim. Sci., 73, 757–763.

YAMAMOTO, A., K. ONO, K. MACHINO, E., TAKASU and N. IMAEDA : 2016, Effect of particle size of brown rice on digestibility of energy and crude protein in growing-finishing pigs. Jpn. J. Swine Sci., 53, 137–142.