ISSN 1682-8356
ansinet.com/ijps

INTERNATIONAL JOURNAL OF

# POULTRY SCIENCE

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OPEN ACCESS International Journal of Poultry Science

ISSN 1682-8356
DOI: 10.3923/ijps.2019.618.625

# Research Article
# Nutritional Value of Fermented Rice Bran for Broiler Chickens: Apparent Metabolizable Energy and Growth Performance

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## Abstract

**Background and Objectives:** The inclusion level of rice bran in broiler diets is limited due to its anti-nutritional factors such as phytic acid and fibre. Thus, this study was designed to evaluate the effect of solid fermentation of rice bran on the nutrient composition and feeding value for broilers. **Materials and Methods:** Experiment I: The apparent metabolisable energy of fermented rice bran (FRB), unfermented rice bran (UFRB) and yellow corn (as a reference) was determined using 64 growing broilers (28-35day). The assay diets were developed by substituting yellow corn, FRB and UFRB at 500 and 250 g $kg^{-1}$ (w/w), respectively, of the basal diet. All diets were offered *ad libitum* to four cages containing 4 birds per cage. Experiment II: The feeding value of fermented rice bran was investigated. The experiment was designed using completely randomized design with six treatments and four replicates (10 birds/cage). A total of 240 day-old broilers were randomly distributed to 24 experimental units. The assay diets (0-250 g $kg^{-1}$ FRB) were offered *ad libitum* to broilers from 0-21day. Data were analysed using ANOVA. **Results:** In experiment I, the results showed that the AME/n values of FRB were found to be higher ($p<0.05$) than the AME/n values of UFRB but it was comparable ($p>0.05$) to the AME/n values of yellow corn. In the experiment II, the different inclusion level of FRB significantly ($p<0.01$) affected the body weight gain (BWG) and feed intake of broilers but it did not affect ($p>0.05$) feed per gain and mortality rate. The BWG of birds fed on diets containing 0-150 g $kg^{-1}$ of the FRB was lower ($p<0.05$) than those fed on diets containing 100-250 g $kg^{-1}$ of the FRB. Birds given diets containing 100-250 g $kg^{-1}$ FRB had similar ($p>0.05$) BWG. **Conclusion:** FRB is a good source of energy and amino acids and can be included up to 250 g $kg^{-1}$ in broiler ration without a negative impact on the performance.

Key words: Apparent metabolizable energy, broiler feed, fermented rice bran, growth performance, yellow corn

Citation: Catootjie L. Nalle and Marlin R.K. Yowi, 2019. Nutritional value of fermented rice bran for broiler chickens: Apparent metabolizable energy and growth performance. Int. J. Poult. Sci., 18: 618-625.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

One of the main products obtained from rice milling processing is rice bran. This product consists of a multilayered structure (the pericarp, nucleus, seed coat and aleurone) and about 8-10% of the whole product weight[1,2]. The nutritional value of rice bran was affected by several factors such as the variety of rice and processing methods[2-5]. Rice bran has been widely used as an alternative energy source in the poultry diet due to its availability and low price. However, the inclusion level of this ingredient is still limited due to their anti-nutritive contents which are fiber (cellulose and hemicelluloses), phytic acid, trypsin inhibitor, haemagglutinin-lectin protein, polyphenols, tannins, oxalates, saponins[5-7]. In a review by Medugu *et al.*[8], it was reported that rice bran can be included 10, 20 and 25% in broiler starter, finisher and layer diets, respectively. The nutrient quality of rice bran can drop easily during the storage due to the presence of lipase, lipoxygenase and peroxidize, enzymes that rapidly hydrolyze oil into free fatty acid (FFA) and glycerol[9,10]. The hydrolyzing of rice bran oil ameliorates acidity and causes odor and rancid flavour.

Kaur *et al.*[7] reported that phytic acid and dietary fiber were the main anti-nutritive factors found in rice bran. The soluble fiber content of rice bran was 2.28-3.15%, insoluble fiber 16.49-23.36% and total dietary fiber 18.77-42.62%, the phytic acid content of rice bran was 5.05-8.48%[2,7]. It has been well documented that feeding birds with a high content of fiber resulted in lowering nutrient digestibility, growth performance, increasing digesta viscosity and wet litter[11-13]. Adeola and Cowieson[14] explained that phytic acid caused the limitation of nutrient utilization as a result of the binding of 6 phosphate groups which makes the P unavailable to the animal. Reddy[15] reported that 64-85.7% of the phosphorus in rice bran is phytic acid. Garcia *et al.*[2] found that the phytic phosphorus in rice bran range from 1.43-2.38%. Furthermore, the binding of phytic acids and minerals (Fe, Zn and Ca) results in insoluble salt that is poorly digested[16]. A review conducted by Amerah[17] clearly explained that the interaction between phytate and protein in the upper digestive tract at low pH is responsible for the compromising effect of phytate on Na, Ca, amino acids and energy digestion. Phytic acid combines with protein and starch resulting in reduced bioavailability of these nutrients[2]. The presence of phytic acid in diets has been shown to impair the growth performance of birds[18].

One of the nutritional strategies that can be suggested to overcome the problem related to NSP and phytic acid contents in rice bran is by using solid-state fermentation (SSF) technology for microbial enzyme production. In a review by Kapilan[19], solid-state fermentation (SSF) was defined as the microbial cultivation process in the absence or near absence of free water in the substrate. Furthermore, the growth of filamentous fungi in SSF bioreactors is a benefit because the solid medium simulates its natural habitat. This advantage is extended to the production of enzymes, providing greater productivity than the submerged fermentation process (using liquid substrate). Moreover, the enzymes produced by SSF are more concentrated and downstream processing (DSP) costs are minimized. Besides, SSF also is the way for the production of phenolic compounds and enhance antioxidant activity in foods[2]. SSF of rice bran with *Rhizopus orizae* is shown to be an effective method to intensify rice bran antioxidant properties which are capable of reducing or preventing other molecules from oxidizing. Research regarding the effect of solid-state fermentation with *Aspergillus niger* on the nutritional quality and feeding value of rice bran is still limited. That is the reason why this experiment has been conducted.

## MATERIALS AND METHODS

- **Experiment I: Apparent Metabolizable Energy Determination**

**Ingredients:** Rice bran, yellow corn and *Aspergillus niger* were obtained from the commercial supplier. Rice bran was then fermented using *Aspergillus niger* powder. The fermentation of rice bran was carried out by mixing 1000 g of rice bran with 200 mL of clean water. Then, the *Aspergillus niger* powder (3 g $kg^{-1}$) spread equally on the top of the mixture. The mixture was then packed into a plastic bag and kept for 21 days in a dark room at the ambient temperature. On Day 21, the fermented rice bran was unpacked, spread equally into a tarpaulin and then sun-dried for 2 days. The fermented rice bran (FRB) was then included in assay diets. Yellow corn was ground using hammer mill (3 mm screen size) before being included in the assay diets.

**Metabolizable energy assay:** A yellow corn-soybean meal basal diet was formulated (Table 1) to meet the nutrient requirements for growing broilers. The crude protein content of the basal diet was calculated to be 18%. Then, three assay diets were developed by substituting, 250 g $kg^{-1}$ (w/w) of the basal diet with the FRB and unfermented rice bran (UFRB). While, yellow corn assay diets were formulated by substituting 500 g yellow corn $kg^{-1}$ (w/w) of the basal diet. Day-old chicks (Cobbs, mix male and female) were raised in a floor pen and offered a commercial broiler starter diets containing 230 g $kg^{-1}$ crude protein till day 21. Feed and water were provided *ad libitum*. On day 21, 64 birds of equal body weight were selected and randomly allotted to 16 cages

Table 1: Treatment diets for metabolizable energy determination (Experiment 1)

| Diets | Treatments |
|---|---|
| BD | Basal diet (yellow corn-soybean meal) |
| BDRB | Basal diet (yellow corn-soybean meal)+25% unfermented rice bran |
| BDFRB | Basal diet (yellow corn-soybean meal)+25% fermented rice bran |
| BYC | Basal diet (yellow corn-soybean meal)+50% yellow corn (reference) |

Table 2: Basal diet composition (g $kg^{-1}$ air-dry basis, Experiment 1 and 2)

| Ingredients | |
|---|---|
| Yellow corn | 594.6 |
| Soybean meal | 351.8 |
| Vegetable oil | 17.8 |
| Dicalcium phosphate | 21.7 |
| Limestone | 7.8 |
| Salt | 2.0 |
| Sodium bicarbonate | 2.3 |
| Trace mineral-vitamin premix | 3.0 |

Sanmix, PT Sanbe Farma, per kg provided: Vit A: 1250000 IU, Vit D3: 250000 IU, Vit E: 750 IU, Vit K: 200 mg, Vit B1: 150 mg, Vit B2: 500 mg, Vit B6: 500 mg, Vit B12: 1012 mcg, Vit C: 3000 mg, Ca-d-pantothenate: 500 mg, Niacin: 3500 mg; Methionine: 3500 mg, Lysine: 3500 mg, Manganese: 10000 mg, Iron: 2500 mg, Iodine: 20 mg, Zn: 10000 mg, Cobalt: 20 mg, Copper: 300 mg, Antioxidant: 1000 mg

(4 birds per cage). On Day 21-28, the birds were fed on a commercial broiler finisher diets containing 180 g $kg^{-1}$ crude protein. Then, four replicate cages were randomly allocated to each assay diet. The AME was determined using the classical total excreta collection method. The assay diets (mash form), were fed to birds from Day 28. The measurement of feed intake and excreta output per cage was conducted from Day 32-35. The excreta collected from each cage were subsequently pooled, mixed, sub-sampled and oven-dried (60°C). The dried excreta samples, together with samples of the diets and feed ingredients (FRB, UFRB and yellow corn), were then ground using a sample mill (0.5 mm sieve) and put into an airtight plastic containers for further analysis in the laboratory. Composition of basal diet is shown in Table 2.

- **Experiment 2: Feeding value experiment**

**Birds and housing:** A total of one day old 240 broiler chicks (Cobbs, mix male and female) obtained from local commercial hatchery were individually weighed and randomly assigned to24 pens (10 birds each pen). The initial body weight of birds for each pen is similar. The size for each pen was 80×80 cm and rice hulls were used for pen litter. The Electric bulb (75 watt) was used as artificial heat for chicks (0-7 days) in each pen. Temperature and relative humidity inside the housing were controled by using thermo-higrometer.

**Assay diets:** The nutrient composition and amino acid content of fermented rice bran (FRB) used for the assay diet formulation were presented in Table 3 and 4. Iso-energetic and iso-nitrogenous diets containing 0-250 g FRB $kg^{-1}$ were formulated (Table 5) using chemical composition in Table 3, 4 and 6. Each of the experimental diets in mash form was randomly assigned to four pens containing 10 chicks each. The assay diets were given *ad libitum* and water were provided during the experimental period (21 day). Body weights and feed intake were recorded on Day 21, while mortality was recorded daily. The weight of the dead birds was recorded and that data were used to correct feed per gain. The feed per gain was determined using formula: feed per gain/weight gain plus dead bird's weight.

**Chemical analysis:** The dry matter content of feed ingredients, diets and excreta was measured in a convection oven at 105°C[20]. Gross energy was determined using an adiabatic oxygen calorimeter (Gallenkamp Autobomb, London, UK) standardized with benzoic acid. Nitrogen content was determined using the Kjeldahl method. Amino acids were determined by hydrolyzing the samples with 6N HCl (containing phenol) for 24 h at 110±2°C in glass tubes sealed under vacuum. Amino acids were detected on a Waters ion-exchange HPLC system and the chromatograms were integrated using dedicated software (Millenium, Version 3.05.01, Waters, Millipore, Milford, MA) with the amino acids identified and quantified using a standard amino acid mixture. The HPLC system consisted of an ion-exchange column, two 510 pumps, Waters 715 ultraWISP sample processor, a column heater, a post-column reaction coil heater, a ninhydrin pump and a dual-wavelength detector. Amino acids were eluted by a gradient of pH 3.3 sodium citrate eluent to pH 9.8 sodium borate eluent at a flow rate of 0.4 mL $min^{-1}$ and a column temperature of 60°C. Cysteine and methionine were analysed as cysteic acid and methionine sulphone, respectively, by oxidation with performic acid for 16h at 0°C and neutralization with hydrobromic acid before hydrolysis.

**Calculations:** The AME values of the test diets and unfermented and fermented rice bran were calculated using the following formulas:

$$\text{AME diet (MJ kg}^{-1}) = \frac{(\text{Feed intake} \times \text{GEdiet}) \times (\text{excreta output} \times \text{GE excreta})}{\text{Total feed intake}}$$

$$\text{AME UFRB or FRB (MJ kg}^{-1}) = \frac{\text{AME of UFRB or FRB diet-(AME basal diet} \times 0.75)}{0.25}$$

$$\text{AME yellow corn (MJ kg}^{-1}) = \frac{\text{AME yellow corn diet-(AME basal diet)}}{0.50} \times 0.50$$

Correction for zero nitrogen retention was made using a factor of 36.54 kJ per gram nitrogen retained in the body[21].

Table 3: The chemical composition (g kg$^{-1}$ DM) of rice bran (unfermented and fermented) and yellow corn used in assay diets in both experiments

| | Unfermented rice bran | Fermented rice bran | Yellow corn |
|---|---|---|---|
| Dry matter | 897.5 | 883.9 | 883.1 |
| Crude protein | 74.1 | 119.6 | 91.7 |
| Crude lipid | 44.2 | 55.7 | 14.4 |
| Crude fiber | 314.8 | 244.0 | 22.9 |
| NFE | 305.8 | 339.4 | 736.9 |
| ADF | 430.9 | 328.6 | 165.6 |
| NDF | 616.8 | 530.8 | 365.3 |
| Minerals | 158.6 | 125.2 | 17.2 |
| Ca | 15.3 | 12.1 | 11.5 |
| P | 6.4 | 10.6 | 5.5 |
| Gross energy | 3693.0 | 4044.0 | 3763.0 |

Table 4: Amino acid concentration (g kg$^{-1}$) of rice bran (unfermented and fermented) and yellow corn used in assay diets in both experiments

| | Unfermented rice bran | Fermented rice bran | Yellow corn |
|---|---|---|---|
| **Essential amino acid** | | | |
| Arginine | 2.0 | 0.9 | 1.6 |
| Histidine | 1.0 | 1.1 | 0.9 |
| Isoleusine | 0.9 | 1.0 | 1.2 |
| Leusine | 1.0 | 2.7 | 0.6 |
| Lysine | 0.9 | 1.2 | 1.0 |
| Methionine | 0.9 | 1.0 | 0.8 |
| Phenylalanine | 2.4 | 0.9 | 1.8 |
| Threonine | 1.1 | 1.0 | 1.1 |
| Valine | 2.9 | 1.5 | 2.1 |
| **Non essential amino acid** | | | |
| Alanine | 2.6 | 1.9 | 3.2 |
| Aspartic acid | 4.6 | 2.2 | 5.0 |
| Cystine | 0.8 | 0.3 | 0.7 |
| Glycine | 1.4 | 1.8 | 1.3 |
| Glutamic acid | 11.8 | 4.6 | 1.2 |
| Proline | 1.5 | 0.5 | 3.9 |
| Serine | 5.4 | 0.5 | 1.7 |
| Tyrosine | 1.6 | 0.4 | 1.2 |

Table 5: Assay diets (experiment II)

| | Fermented rice bran level (g kg$^{-1}$ as fed) | | | | | |
|---|---|---|---|---|---|---|
| Feed ingredients | 0 | 50 | 100 | 150 | 200 | 250 |
| Yellow corn | 534.90 | 503.50 | 454.40 | 408.00 | 380.40 | 332.60 |
| Fermented rice bran | 0.00 | 50.00 | 100.00 | 150.00 | 200.00 | 250.00 |
| Soybean meal (44% CP) | 297.60 | 275.30 | 276.40 | 274.40 | 257.50 | 255.00 |
| Meat and Bone Meal | 50.00 | 57.50 | 57.00 | 57.00 | 57.10 | 57.10 |
| Local fish meal (39% CP) | 50.00 | 52.50 | 52.50 | 52.50 | 52.50 | 52.50 |
| Vegetable oil | 44.50 | 40.80 | 41.00 | 40.90 | 36.40 | 37.90 |
| DL-methionine (99%) | 2.00 | 2.20 | 2.20 | 2.30 | 2.40 | 2.70 |
| L-Lysine HCl (99%) | 0.10 | 0.60 | 0.60 | 0.80 | 1.20 | 1.50 |
| Limestone | 9.00 | 6.60 | 6.30 | 4.50 | 3.10 | 1.80 |
| Dicalcium phosphate | 6.00 | 5.10 | 3.70 | 3.70 | 3.50 | 3.00 |
| Salt | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 | 2.50 |
| Sodium bicarbonate | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 | 0.40 |
| Vitamin-mineral premix | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| Amount | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 | 1,000 |
| Calculated nutrient composition | | | | | | |
| AME (kcal kg$^{-1}$) | 3,103 | 3,103 | 3,103 | 3,103 | 3,103 | 3,103 |
| Crude protein (g kg$^{-1}$) | 224 | 223 | 225 | 227 | 225 | 225 |
| Lysine (g kg$^{-1}$) | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 | 12.5 |
| Met+Cys (g kg$^{-1}$) | 9.80 | 9.84 | 9.74 | 9.71 | 9.69 | 9.71 |
| Ca (g kg$^{-1}$) | 10.3 | 10.3 | 10.3 | 10.3 | 10.3 | 10.3 |
| Av P (g kg$^{-1}$) | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 |

Table 6: AME and AMEn values (MJ $kg^{-1}$ DM±SD) of rice bran (unfermented and, fermented) and yellow corn (as a reference)[1]: Experiment 1

| | Unfermented rice bran | Fermented rice bran | Yellow corn | p-value |
|---|---|---|---|---|
| AME | 8.50±0.53[b] | 12.67±0.86[a] | 13.15±0.21 | 0.00048 |
| AMEn | 7.98±0.53[b] | 11.52±0.88[a] | 12.21±0.18[a] | 0.00054 |

[a,b]Means of the column with the superscripts significant difference (p<0.05), 1 Each value is the average of 4 replicates (4 birds/replicate)

Table 7: Growth performance of broilers starter (0-21 d) fed diets containing different level of fermented rice bran

| FRB Inclusion level (g $kg^{-1}$) | WG (g $bird^{-1}$±SE) | FI (g $bird^{-1}$±SE) | FCR (g $g^{-1}$) (g $g^{-1}$±SE) | Mortality (%) (%±SE) |
|---|---|---|---|---|
| 0 | 472±26.72[b] | 798.0±12.61[c] | 1.794±0.15[ab] | 2.5±0.01 |
| 50 | 478±24.63[b] | 918.0±9.12[b] | 2.049±0.25[a] | 0.0±0.00 |
| 100 | 558±20.23[a] | 969.0±17.70[ab] | 1.871±0.54[ab] | 0.0±0.00 |
| 150 | 589±27.70[a] | 950.0±18.85[b] | 1.687±0.35[b] | 0.0±0.00 |
| 200 | 594±25.4[a] | 1,004.0±12.20[ab] | 1.850±0.32[ab] | 2.5±0.01 |
| 250 | 587±20.65[a] | 1,069.0±18.66[a] | 1.824±0.24[ab] | 2.0±0.01 |
| Probability p>FRB level | *** | *** | NS | NS |

[a,b]Means of the column with the superscripts significant difference (p<0.001), ***NS: Not significant (p>0.05). [1]each value is the saverage of 4 replicates (10 birds/replicate)

**Statistical analysis:** The pen means were used to derive performance and apparent metabolizable energy (AME) data. The data were analyzed by one-way analysis of variance (ANOVA) using the General Linear Model procedure of SAS[22]. Significant differences between means were subjected to Fisher's Least Significant Difference Test (LSD) at 5% probability.

## RESULTS

**AME determination:** The apparent metabolizable energy (AME) values of the fermented and unfermented rice bran and yellow corn were summarized in Table 6. The AME and AMEn values of the fermented rice bran (FRB), unfermented rice bran (UFRB) and yellow corn were found to be significantly different (p<0.01). The AME and AMEn values of FRB were significantly higher (p<0.05) than the AME and AMEn values of UFRB. No significant differences were found between the AME and AMEn values of the fermented rice bran and yellow corn. The AME and AMEn values of fermented rice bran determined were 12.67 and 11.52 MJ $kg^{-1}$ DM, respectively. Whereas, the AME and AMEn values of unfermented rice bran were only 8.50 and 7.98 MJ $kg^{-1}$ DM, respectively. Compared to yellow corn, the AME and AMEn values of yellow corn were found to be 13.15 and 12.21 MJ $kg^{-1}$ DM, respectively, which were slightly higher than those found in FRB.

**Feeding value experiment:** The body weight gain, feed intake, feed conversion ratio and mortality rate during the experimental period (0-21 day) were presented in Table 7. Overall, the graded inclusion level of the fermented rice bran (FRB) in the diets significantly (p<0.01) affected weight gain and feed intake of broilers but it did not affect (p>0.05) feed per gain and mortality rate. Group of birds fed on diets containing 100-250 g $kg^{-1}$ of the FRB had similar (p>0.05) weight gain but they were higher (p<0.05) than those fed on diets containing 0-50 g FRB $kg^{-1}$. The improvement in BWG of birds received diets containing 100-250 g $kg^{-1}$ of FRB was probably due to the increase of feed intake (Table 7). The body weight gain of birds fed on control diets and FRB diets (50 g $kg^{-1}$) were 472 and 478 g $bird^{-1}$. While, the range of BWG of birds received diets containing 100-250 g FRB $kg^{-1}$ were between 558-594 g $bird^{-1}$.

With regards to feed intake, broilers fed on diets containing 50-250 g $kg^{-1}$ of FRB had higher (p<0.05) feed intake compared to those fed on control diets. This result suggests that the FRB diets were more palatable than the control diets. No differences (p>0.05) were found in feed per gain of birds in all treatments, however, the lowest feed per gain was found in group of birds fed diets containing 150 g $kg^{-1}$ fermented rice bran, which was 1.687. Birds fed on diet containing 0-250 g $kg^{-1}$ fermented rice bran had comparable (p>0.05) mortality rate.

## DISCUSSION

As shown in Table 3., with the exception of minerals and calcium, the overall nutrient content of fermented rice bran was better than the nutrient content of unfermented rice bran and yellow corn. The crude protein contents and crude lipid increased by 61.40 and 26,01%, respectively. The nitrogen free extract (NFE), phosphor and gross energy contents increased by 11.28, 36 and 9.50%, respectively. The fermentation of rice bran using *Aspergillus niger* reduced the fibre content (crude fibre, NDF and ADF) of rice bran. The NDF content of rice bran decreased from 616.8-530 g kgv DM after fermentation, while the ADF content decreased from 430.9-328.8 after being

fermented with *Aspergillus niger*. The Lysine, methionine and cystein contents of the fermented rice bran was found to be slightly higher than that of unfermented rice bran.

**AME determination:** The present study demonstrated that there was a significant increase in the apparent metabolizable energy (AME/n) value of rice bran after fermentation. The AME/n value of fermented rice bran was found to be similar with the AME/n value of yellow corn.

The improvement of the AME/n of fermented rice bran was probably due to the decrease of fiber and phytic acid contents. It has been well documented that the AME value of feed ingredients was affected by fiber content[13]. As can be seen in Table 3., the neutral detergent fibre (NDF) content of fermented rice bran was 13.96% lower than the NDF content of the unfermented rice bran. The decrease in the fibre content of rice bran after fermentation was probably due to the presence of fibre degrading enzymes which were produced by *Aspergillus niger* during the fermentation. Previous researchers reported that *Aspergillus niger* produced several enzymes such as NSP degrading enzymes (pectinases, cellulase, endoglucanase and xylanase) and phytase[23-25]. Cellulases are a complex of enzymes that act synergistically to degrade insoluble cellulose into soluble fermentable sugars, whereas xylanase plays an important role to break down hemicellulose in the plant cell wall, as this group of branched polysaccharides connects strongly with each other and the surface of cellulose microfibrils, forming crosslinks via hydrogen bonds that hinders the action of cellulases[24]. Besides, xylanases are responsible for xylan hydrolysis, which is the polysaccharide component of hemicelluloses.

When broiler chickens administered with basal diets containing fermented rice bran, the viscosity of small intestine decreased and this condition supported the accessibility of pancreatic enzymes (protease, lipase and amylase) to attack the target substrates (protein, fat and starch). As a result, the digestibility and nutrient absorption in the small intestine of broilers increased. *Aspergillus niger* in fermented rice bran also play an important role in improving fibre digestibility in the small intestine, which in turn, increase the AME/n values of fermented rice bran. It was reported by Lawal *et al.*[26] that *Aspergillus niger* has the potential of splitting the β-1,4 linkage in the hemicellulolytic xyloglucans in the gut contents, thereby reducing gut viscosity and improving nutrient absorption.

It is generally known that rice bran is rich in phytic acid. This anti-nutritional factor has been reported to negatively influence the energy digestibility and AME value[18]. Previous researchers claimed that phytic acid inhibits the action of enzymes such as α-amylase, trypsin, lipase, acid phosphatase and pepsin which leads to a deficient digestion and absorption of nutrients[18,25]. In a review conducted by Woyengo and Nyachoti[18], it was clearly explained that phytic acid may decrease energy digestibility by reducing the digestibility of energy generating molecules such as carbohydrates, lipids and protein. Furthermore, phytic acid reduces the absorption of carbohydrates likely by reducing the activity of digestive carbohydrases. Phytic acid reduce activity of digestive carbohydrates by binding to: (1) The digestive enzymes, (2) Dietary protein that is closely associated with starch and (3) Starch through phosphate linkage. The reduced glucose absorption partly explain the reduce energy digestibility by phytic acid.

The phytic acid content of rice bran (fermented and unfermented) used in the present study was not determined. However, based on the above explanation the lower value of AME/n of unfermented rice bran obtained in the present study was probably due to the presence of phytic acid in rice bran. As well as the improvement of the apparent metabolizable energy of fermented rice bran was also probably owing to the reduction of phytic acid content of rice bran during fermentation. Phytic acid can only be hydrolyzed by phytase which is an acid phosphohydrolase. This enzyme hydrolyses the phytate phosphate to inorganic phosphate and myo-inositol phosphate derivates[25]. *Aspergillus niger* used as a substrate in the fermentation process of the present study was known to have the ability to produce several enzymes including phytase. Thus, it can be concluded that phytase produced by *Aspergillus niger* during the fermentation of rice bran might reduced the phytic acid content of rice bran. As a result, the digestibility of nutrients and the AME/n values of fermented rice bran increased.

**Feeding value experiment:** During the experimental period (0-21 day), all birds were healthy. The birds fed fermented rice bran diets had similar weight gain, feed intake and feed per gain with the control diets. However, numerically the range of the weight gain of birds fed on diets containing fermented rice bran was 478-594 g bird$^{-1}$, while the body weight gain of birds fed on the control diet was only 472 g bird$^{-1}$. The similar trend was also found in the feed consumption. Group of birds fed on the fermented rice bran diets were higher (918-1069 g bird$^{-1}$) than those in the control group (798 g bird$^{-1}$). This result indicated that diets containing fermented rice bran were more palatable than the control diets. The feed conversion ratio of control diet was slightly lower (1.794) than the feed conversion ratio of the fermented

rice bran diets (1.687-2.049). The lowest feed conversion ratio was found in group of birds fed on diets containing 150 g $kg^{-1}$ of fermented rice bran.

It is interesting to note from the present study that fermented rice bran can be included up to 25% into broiler ration without detrimental effect on the production performance. The ability of birds to eat higher level of fermented rice bran without negative impact was probably due to the decrease in the antinutrient content including fibre and phytic acid. Thus, as explained before that the reduction in fibre and phytic acid content leads to the improvement in nutrient digestibility and absorption so the growth performance will be better.

In a review by Medugu *et al.*[8], it was reported that normally rice bran (raw or crude) can only be included up to 20% in broiler diets due to its high fiber and phytic acid. As reported by previous researchers[11-13] that feeding birds with high content of fiber resulted in lowering nutrient digestibility, growth performance, increasing digesta viscosity and wet litter. Adeola and Cowieson[14] explained that phytic acid caused the limitation of nutrient utilization as a result of the binding of 6 phosphate groups which makes the P unavailable to the animal. Thus, the present result indicated that 25% inclusion level of fermented rice bran in broiler ration without negative impact on the production performance was due to the reduction of fiber and phytic acid after solid-state fermentation (Table 3). The reduction of fiber and phytic acid content in fermented rice bran leads to the improvement of starch, protein, minerals and lipid digestibility as well as nutrient absorption.

## CONCLUSION

It was evident from the present study that the AME and AMEn values of fermented rice bran were comparable to that of yellow corn but it was higher than unfermented rice bran. Feeding birds with fermented rice bran in maize-soy basal diets had beneficial effect on weight gain and feed intake during 21 day feeding trial but it did not change feed per gain and mortality rate of birds. Thus, when the diets were balanced to meet nutrient requirements for broilers, the inclusion of fermented rice bran up to 250 g $kg^{-1}$ could beneficially support good production performance of starter broilers.

## SIGNIFICANCE STATEMENT

This study discovered the nutritional value of fermented rice bran for broiler chickens that can be valuable for feed industry to maximize the use of rice bran in broiler diet without any detrimental effects. This study will help the researcher to reveal the crucial role of fermentation process in improving the nutritional value of rice bran that many researchers could not explore. Thus, a new theory regarding the fermentation of rice bran using *Aspergillus niger* and the feeding value of fermented rice bran may be developed to maximize the potential use of rice bran in broiler diet.

## ACKNOWLEDGMENTS

The authors would like to thank the Directorate General of Higher Education of the Republic of Indonesia that provided funding for this research.

## REFERENCES

1. Sharma, R., T. Srivastava and D.C. Saxena, 2015. Studies on rice bran and its benefits-A review. Int. J. Eng. Res. Applic., 5: 107-112.
2. Garcia, M.C., M.D.T. Benassi and M.S. Soares Júnior, 2012. Physicochemical and sensory profile of rice bran roasted in microwave. Ciênc. Tecnol. Aliment., 32: 754-761.
3. Faria, S.A.D.S.C., P.Z. Bassinello and M.D.V.C. Penteado, 2012. Nutritional composition of rice bran submitted to different stabilization procedures. Braz. J. Pharm. Sci., 48: 651-657.
4. Rafe, A., A. Sadeghian and S.Z. Hoseini-Yazdi, 2016. Physicochemical, functional and nutritional characteristics of stabilized rice bran form tarom cultivar. Food Sci. Nutr., 5: 407-414.
5. Shaheen, M., I. Ahmad, F.M. Anjum, Q.A. Syed and M.K. Saeed, 2015. Effect of processed rice bran on growth performance of broiler chicks from Pakistan. Bulg. J. Agric. Sci., 21: 440-445.
6. Khan, S.H., M.S. Butt, F.M. Anjum and A. Jamil, 2009. Antinutritional appraisal and protein extraction from differently stabilized rice bran. Pak. J. Nutr., 8: 1281-1286.
7. Kaur, S., S. Sharma and H.P.S. Nagi, 2011. Functional properties and anti-nutritional factors in cereal bran. Asian J. Food Agro-Ind., 4: 122-131.
8. Medugu, C.I., A.O. Raji, J.U. Igwebuike and E. Barwa, 2011. Alternative cereal grains and cereal by-products as sources of energy in poultry diets-A review. Res. Opin. Anim. Vet. Sci., 1: 530-542.
9. Bhosale, S. and D. Vijayalakshmi, 2015. Processing and nutritional composition of rice bran. Curr. Res. Nutr. Food Sci. J., 3: 74-80.
10. Oliveira, M.D.S., E.P. Cipolatti, E.B. Furlong and L.D.S. Soares, 2012. Phenolic compounds and antioxidant activity in fermented rice (*Oryza sativa*) bran. Ciênc. Tecnol. Aliment., 32: 531-537.

11. Krás, R.V., A.M. Kessler, A.M.L. Ribeiro, J.D. Henn, L. Bockor and A.F. Sbrissia, 2013. Effect of dietary fiber, genetic strain and age on the digestive metabolism of broiler chickens. Rev. Bras. Cienc. Avic., 15: 83-90.
12. Liu, H.Y., E. Ivarsson, L. Jonsson, L. Holm, T. Lundh and J.E. Lindberg, 2011. Growth performance, digestibility and gut development of broiler chickens on diets with inclusion of chicory (*Cichorium intybus* L.). Poult. Sci., 90: 815-823.
13. Nalle, C.L., 2009. Nutritional evaluation of grain legumes for poultry. Ph.D. Thesis, Massey University, Palmerston North, New Zealand.
14. Adeola, O. and A.J. Cowieson, 2011. Board-invited review: Opportunities and challenges in using exogenous enzymes to improve nonruminant animal production. J. Anim. Sci., 89: 3189-3218.
15. Reddy, N.R., 2002. Occurrence, Distribution, Content and Dietary Intake of Phytate. In: Food Phytates, Reddy, N.R. and S.K. Sathe (Eds.). CRC Press, Boca Raton, Florida, pp: 25-51.
16. Gupta, R.K., S.S. Gangoliya and N.K. Singh, 2015. Reduction of phytic acid and enhancement of bioavailable micronutrients in food grains. J. Food Sci. Technol., 52: 676-684.
17. Amerah, A.M., 2015. Interactions between wheat characteristics and feed enzyme supplementation in broiler diets. Anim. Feed Sci. Technol., 199: 1-9.
18. Woyengo, T.A. and C.M. Nyachoti, 2012. Review: Anti-nutritional effects of phytic acid in diets for pigs and poultry-current knowledge and directions for future research. Can. J. Anim. Sci., 93: 9-21.
19. Kapilan, R., 2015. Solid state fermentation for microbial products: A review. Arch. Applied Sci. Res., 7: 21-25.
20. AOAC., 2005. Official Methods of Analysis of AOAC International. 18th Edn., AOAC International, Gaithersburg, MD., USA., ISBN-13: 978-0935584752.
21. Hill, F.W. and D.L. Anderson, 1958. Comparison of metabolizable energy and productive energy determinations with growing chicks. J. Nutr., 64: 587-603.
22. SAS., 1997. SAS/STAT User's Guide: Statistics. Version 6.12. SAS Institute, Cary, NC., USA..
23. Martos, M., A. Baumann, N. Cruz, R. Hours and O. Garro, 2012. Partial characterization of enzymatic activities produced bya wild strain of *A. niger*. J. Microbiol. Biotechnol. Food Sci., 2: 917-932.
24. Farinas, C.S., L.M. Scarpelini, E.A. Miranda and V.B. Neto, 2011. Evaluation of operational parameters on the precipitation of endoglucanase and xylanase produced by solid state fermentation of *Aspergillus niger*. Braz. J. Chem. Eng., 28: 17-26.
25. Santos, T., 2011. Optimisation of phytase production by *Aspergillus niger* using solid state fermentation. Master Thesis, National University of Ireland, Galway, Ireland.
26. Lawal, T.E., S.G. Ademola, A. Owoseni, O.E. Atobatele and L.O. Oriye, 2013. Use of *Aspergillus niger* for improving the feeding value of rice offal. Afr. J. Bitechnol., 12: 3083-3087.