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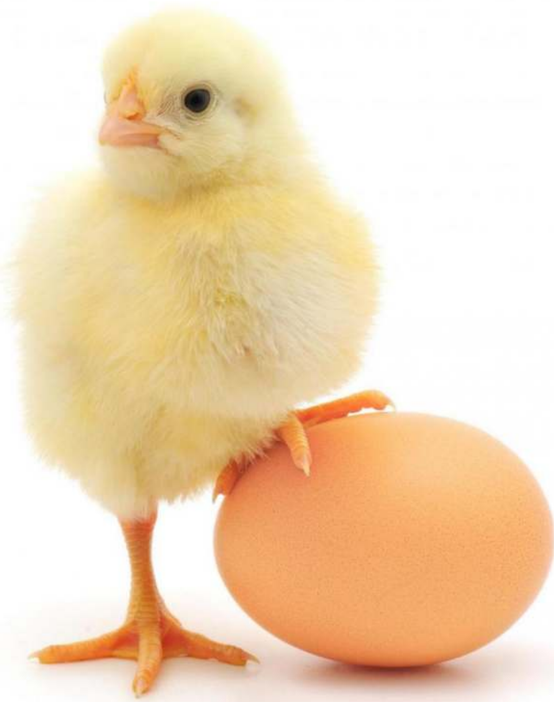

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Short Communication
Comparison of Energy Values Estimated by Direct and Indirect Methods for Broiler Chickens

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Abstract
Objective: The objective of this study was to compare energy values of wheat or barley derived from the direct and regression methods for broiler chickens. **Materials and Methods:** Seven diets consisted of a corn-soybean meal-based basal diet, 2 semi-purified diets mixed to contain wheat or barley as the sole source of energy and 4 test diets prepared by supplementing the basal diet with wheat or barley at 15 or 30%, respectively. Chromic oxide was used as an indigestible index to calculate the metabolizability. A total of 504 21-days-old male Ross 308 broiler chickens were allocated based on body weight into 7 treatments with 6 replicate cages and 12 birds per cage by using a randomized complete block design. From d 21, birds were fed the experimental diets for 5-d and excreta samples were collected from d 24-26. **Results:** The apparent metabolizable energy (AME) of the wheat using the direct method (2,934 kcal kg^{-1} DM) was not different from the value (3,026 kcal kg^{-1} DM) derived from the regression method. However, the AME of barley obtained from the direct method (2,730 kcal kg^{-1} DM) differed from the value (2,970 kcal kg^{-1} DM) measured by the regression method. **Conclusion:** The direct and regression methods gave different estimates of the AME in barley but not in wheat fed to broiler chickens.

Key words: Barley, broiler diet, direct method, metabolizable energy, regression method, wheat

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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

The main goal of poultry production is to provide cost-effective products as a source of nutrient for human. It is important to supply appropriate amount of feed ingredients to animals with accurate nutrient evaluation for efficient production. To provide right amount of energy to broilers, an accurate estimation of energy utilization of feed ingredients is needed.

Wheat and barley are widely used as energy sources for broiler diets. There are several methods to determine the apparent metabolizable energy (AME) in feed ingredient for broilers including direct and indirect method[1]. The direct method is widely used to determine the digestibility ofmetabolizable energy energy in feed ingredients because this method simply use one diet which contain feed ingredient as the sole source of energy. However, in some cases, the indirect method may be more suitable. This method needs to formulate a basal diet and a test diet in which a portion of the basal diet is replaced by the test feed ingredient due to poor palatability and antinutritional factors in the test ingredient[1]. Several studies were conducted to investigate the AME of wheat and barley for broilers by using direct method[2-4]. However, these ingredients contain antinutritional factors such as arabinoxylans and β-glucan which can have negative effects on metabolizable energy, therefore, the indirect method may be more suitable for determining the metabolizable energy. But, to our knowledge, there is a scarce data for the AME of wheat and barley using the indirect method and comparison between the values from two methods for broilers. Thus, the objective of this study was to compare energy values derived from the direct and indirect method for wheat and barley in broiler chickens.

MATERIALS AND METHODS

Birds, diets and management: A total of 800 one-day-old male Ross 308 broiler chickens were weighed and tagged individually. The birds were provided *ad libitum* access to water and feed from day 0-21. The environment of the cages was maintained with continuous lighting. The birds were fed a commercial pre-starter diet until d 6 and starter diet from day 7-21. The composition of pre-starter diet was at least of 21.5 and 0.6% for CP and Ca, respectively and at most of 1.4% of P with 3,000 MEn (Nitrogen-corrected metabolizable energy) kcal kg^{-1}. The starter diet contained at least of 20.5% of CP with 3,100 MEn kcal kg^{-1}, without changing Ca and P amounts from the pre-starter diet. Broilers were adapted to the experimental diets for 5 days from d 21-26. On day 21, a total of 504 birds were assigned to 1 of 7 treatments using a randomized complete block design as 6 cages per treatment and 12 birds per cage.

The 7 experimental diets were formulated on a corn-soybean meal-based basal diet and 2 semi-purified diets which consisted of each wheat or barley as the sole source of energy in mixed diet and 4 test diets by replacing the energy sources in basal diet with wheat or barley at 15 or 30%, respectively (Table 1). Every diet met or exceeded the requirements of the broilers between 0-3 weeks of age for all nutrients as recommended by the NRC[5]. Chromic oxide was

Table 1: Ingredient composition of experimental diets fed to broilers

				15% of ingredient		30% of ingredient	
Items	Wheat	Barley	Basal diet	Wheat	Barley	Wheat	Barley
Ingredient (%)							
Ground corn	-	-	57.2	47.7	47.7	38.2	38.2
Soybean meal (48% CP)	-	-	34.5	30.3	30.3	26.2	26.2
Wheat	95.0	-	-	15.0	-	30.0	-
Barley	-	95.1	-	-	15.0	-	30.0
Soybean oil	-	-	3.0	1.8	1.8	0.5	0.5
L-Lysine•HCl	-	-	0.3	0.2	0.2	0.2	0.2
DL-Methionine	-	-	0.2	0.2	0.2	0.1	0.1
Monocalcium phosphate	1.6	1.4	1.6	1.6	1.6	1.6	1.6
Limestone	2.0	2.1	1.8	1.8	1.8	1.8	1.8
Vitamin-mineral premix[1]	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Sodium chloride	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Chromic oxide	0.5	0.5	0.5	0.5	0.5	0.5	0.5

[1]Provided per kilogram of diet: Vitamin A: 8,000 IU, Vitamin D_3: 1,500 IU, Vitamin E: 4 IU, Vitamin K_3: 660 µg, Thiamine nitrate: 485 µg, Riboflavin: 2.5 mg, Pyridoxine hydrochloride: 1 mg, Vitamin B_{12}: 6 mg, Nicotinic acid: 10 mg, Calcium pantothenate: 4 mg, Folic acid: 300 µg, Choline chloride: 175 mg, Mn: 60 mg as manganese sulfate Zn: 45 mg as zinc sulfate, Fe: 20 mg as ferrous sulfate and ferric oxide, Cu: 2.5 mg as copper sulfate, I: 1.25 mg as calcium iodate, Co: 500 µg as cobaltous carbonate, and Se: 250 µg as sodium selenite

used as an indigestible index to calculate the metabolizability. Two semi-purified diets were used for direct method and basal diet and 4 test diets were used for regression method to calculate apparent metabolizable energy (AME).

Individual body weight of broilers and group feed intake were recorded on day 21 and 26 to determine body weight gain, feed intake and feed efficiency. Excreta samples were collected twice daily at 0900 and 1700 from day 24-26. Waxed paper was put under the cages during excreta collection periods and excreta were collected. The collected excreta samples were pooled by each cage and maintained in a frozen condition at -20°C until further analyses.

Chemical analyses: Wheat and barley ingredients and experimental diets were analyzed for dry matter (DM) and crude protein (CP) by proximate analysis[6] methods. Frozen excreta samples were dried in a forced-air drying oven at 105°C for 24 h for DM analysis. Experimental ingredients, diets and excreta samples were analyzed for gross energy (GE) using a bomb calorimeter (C2000; IKA, Staufen, Germany). The chromium concentrations in diets and excreta were determined according to the procedure of Fenton and Fenton[7].

Calculations and statistical analyses: The metabolizability of energy for wheat and barley was estimated using the index method according to Kong and Adeola[1] with chromium as the index. Regression of AME for barley and wheat ingredients was analyzed by using SLOPE function of Microsoft Office Excel (Microsoft Corp., Redmond, WA). The PROC TTEST of SAS (SAS Inst. Inc., Cary, NC, USA) was used to compare the AME derived direct and regression methods for broilers. Each cage was an experimental unit and statistical significance was set at 0.05.

RESULTS

The analyzed compositions of DM, GE and CP for wheat used in current study were 88.45%, 3,932 kcal kg^{-1} and 10.53%, respectively. Analyzed chemical constituent of DM was 90.45%, GE was 4,016 kcal kg^{-1} and CP was 10.24% for the barley.

The AME of the semi-purified diets which contained each wheat or barley as sole source of energy in mixed diets were 2,788 kcal kg^{-1} DM for wheat and 2,596 kcal kg^{-1} DM for barley diet. The sole wheat diet consisted of 95.03% wheat in mixed diet, therefore, AME of wheat ingredient was 2,934 kcal kg^{-1} DM by using direct method. Also, sole barley diet was formulated to contain 95.08% of barley in mixed diet, thus, the AME of barley ingredient through direct method converted to 2,730 kcal kg^{-1} DM. The results of regressions indicated that the AME value for wheat and barley was 3,026 and 2,970 kcal kg^{-1} DM, respectively (Fig. 1).

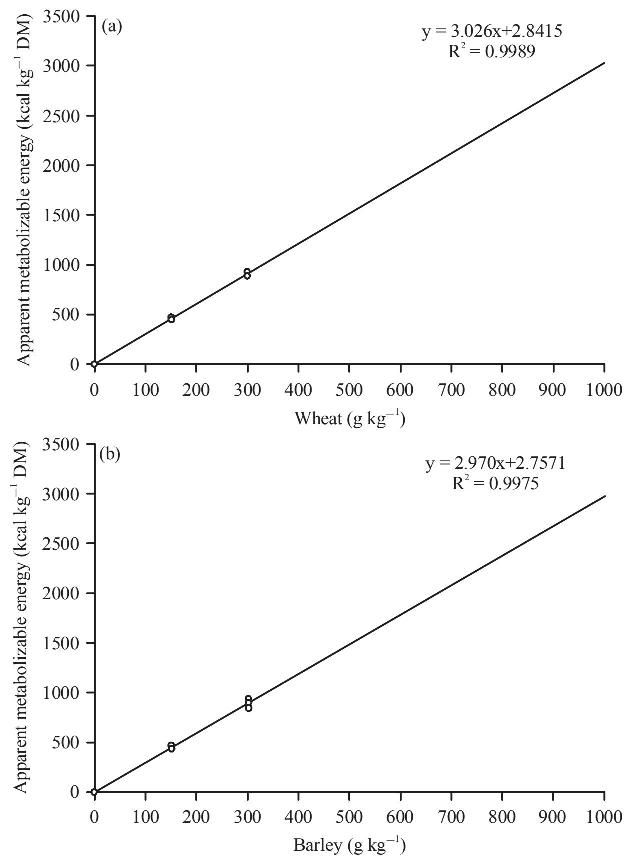

Fig. 1(a-b): Apparent metabolizable energy (AME) of (a) Wheat and (b) Barley Fed to broilers
Data express the regression of AME over ingredient consumption for broilers fed 0, 15, or 30% of wheat or barley. The slope of the regression line shows that the AME for wheat and barley equals 3,026 and 2,970 kcal kg^{-1} dry matter (DM), respectively

Comparison of AME values estimated by direct and regression methods was conducted into wheat and barley for broilers (Table 2). The AME of wheat from direct method was not different from that obtained by regression method ($p = 0.363$). There was significant difference between the AME derived from two different methods ($p = 0.007$).

DISCUSSION

The AME can be determined directly or indirectly for swine and poultry[1]. With direct method, energy contents in mixed diet were provided from only one feed ingredient to estimate the metabolizable energy (ME). Also, energy value for

Table 2: Comparison of apparent metabolizable energy (AME) estimated by direct and regression methods for wheat and barley in broilers (n = 6)

	Method			
Items	Direct	Regression	Standard error	p-value
Wheat				
AME (kcal kg^{-1} DM)[1]	2,934	3.026	92	0.363
Barley				
AME (kcal kg^{-1} DM)	2,730	2.970	54	0.007

[1]DM: Dry matter

test ingredient can be calculated by the difference of basal diet and test diet which is formulated by replacing the basal diet with test ingredient by using indirect method such as regression method.

The CP and GE value of wheat used in this study were 10.53% and 4,446 kcal kg^{-1} DM. Analyzed GE of wheat in the present research was similar to the value from previous studies, such as 4,409 kcal kg^{-1} DM[8], 4,466 kcal kg^{-1} DM[9] and 4,456 kcal kg^{-1} DM[3,10]. However, the value in this study was greater than GE of soft wheat reported by Sauvant *et al.*[11] as 18.2 MJ kg^{-1} DM (4,348 kcal kg^{-1} DM) and 4,212 kcal kg^{-1} DM by Jaworski *et al.*[12] and lower than 4,972 kcal kg^{-1} DM (soft red) by NRC[13]. The concentration of CP from the current study was in agreement with Hew *et al.*[8] (10.32%) and Sauvant *et al.*[11] (10.5%) (soft wheat). However, Pedersen *et al.*[9] and Jaworski *et al.*[12] showed the greater CP in wheat than the value from this study, which were 12.44 and 11.33%, respectively, Bolarinwa and Adeola[3,10] reported the CP in wheat as 9.5% which is lower than the current value. Analyzed GE and CP of barley in present research were 4,441 kcal kg^{-1} DM and 10.24%, respectively. Sauvant *et al.*[11] showed the nutrient value in barley as 18.3MJ kg^{-1} DM (4,381 kcal kg^{-1} DM) for GE and 10.1% for CP. Also, there were other studies which reported GE and CP concentrations in barley, 4,470 kcal kg^{-1} DM and 12.92%[9], 4,569 kcal kg^{-1} DM and 9.94%[3] and 4,490 kcal kg^{-1} DM and 9.94%[10], respectively. Genetic and environmental factors such as cultivar, whether, origin and soil condition might cause the variation of nutritional compositions in wheat and barley[14]. The nutrient compositions of wheat can be different according to the cultivars such as hard red and soft white[5,13]. Also, nutrient contents in barley can vary depending on the presence of hull such as hulled and hulless barley.

The AME values of wheat fed to broilers estimated in the present study using direct and regression method were 2.934 and 3,026 kcal kg $^{-1}$ DM, respectively. Farrell[2] reported the AME values of Australian wheat were ranging from 3,050-3,770 kcal kg^{-1} DM. Bolarinwa and Adeola[3] showed ME value was 3,513 kcal kg^{-1} of DM and MEn was 3,372 kcal kg^{-1} DM in wheat fed to broiler chickens. Roudi *et al.*[4] investigated ME for 57 samples of wheat grains using mathematical prediction model varied from 1,896-3,733 kcal kg^{-1} of DM. The NRC[5] and Sauvant *et al.*[11] suggested the available energy value as nitrogen-corrected AME, which were 3,506 kcal kg^{-1} DM (soft white) and 13.94 MJ kg^{-1} DM (3,330 kcal kg^{-1} DM), respectively. The AME of wheat derived from the direct method was not different with that of regression method in current research. The AME for barley in this report were 2,730 vs. 2,970 kcal kg^{-1} DM determined by the direct and regression method, respectively. The ME and MEn value were 2,894 and 2,841 kcal kg^{-1} of DM for barley reported by Bolarinwa and Adeola[3]. The nitrogen-corrected AME was estimated as 2,966 kcal kg^{-1} DM by NRC[5] and as 12.57 MJ kg^{-1} DM (3,003 kcal kg^{-1} DM) by Sauvant *et al.*[11]. The previous research conducted with pigs showed that ME using direct method does not differ from the energy values determined by the regression method for barley and wheat[10]. In the current study, however, there was a difference between direct and regression method-derived AME in barley. In theory, regression method can be used as the alternative method of direct method when the direct method is not suitable due to high anti-nutritional factors in feed ingredient. The direct method-derived AME of barley in the present study was slightly lower compared to the previous data. The β-glucan component in barley increase the mucosal viscosity in small intestine and consequently decrease nutrient digestion and absorption[15]. Sole barley diet which was used for direct method might have underestimated nutrient digestibility and subsequently lower AME of broiler, thus, these results showed discrepancy between two AME values derived from different methods.

CONCLUSION

There was no difference between the AME obtained by the direct method and that of regression method in wheat (2,934 vs. 3,026 kcal kg^{-1} DM). In barley, however, the AME determined by the direct method differed from the value obtained by the regression method (2,730 vs. 2,970 kcal kg^{-1} DM).

SIGNIFICANCE STATEMENT

This study discovers the AME of wheat and barley using the direct and indirect methods and differences between the values derived from two methods. The results from the current study will help poultry nutritionists and feed companies to improve the accuracy of feed formulation for broiler chickens.

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