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Full Length Article

Calorific Value of Cereals and Cereal by-products in Growing Male Broilers

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Abstract

An experiment was conducted to determine apparent metabolizable energy corrected for nitrogen (AMEn) of commonly used cereals and cereal by-products in poultry diet. Three samples each of corn, rice broken (RB), rice polishings (RP) and wheat bran (WB) were assayed for AMEn by substitution method using 21-days-old broilers. The 12 experimental diets (4 ingredients x 3 samples) were formulated by substituting the corn-soybean meal basal diet with 30% test ingredients. The acid insoluble ash was added at 1% of all diets. The 468 day-old male broiler chicks (Hubbard x Hubbard) were reared on basal diet from day 1 to 13 and thereafter, experimental diets were offered *ad libitum* to birds from 14 to 21days. Each diet was offered to 36 birds, equally distributed to six replicate pens. The basal diet continued to feed the birds of six replicates from day 14 to 21. The excreta samples were collected from day 19–21 to calculate AMEn. The average daily feed intake (ADFI), average daily gain (ADG) and feed conversion ratio (FCR) were calculated. Data regarding ADFI, ADG, FCR and AMEn were analyzed using GLM procedures of SAS while means were partitioned by t-test. The ADFI, ADG, FCR and AMEn remained unaltered (P>0.05) by feeding diets based on samples of same feed ingredient except the RP and WB. The birds fed RP and WB based diets showed varying (P<0.05) AMEn among the samples. The birds fed corn substituted basal diet had higher (P<0.05) ADG (56.03 g) followed by RB (50.04 g), WB (45.87 g) and RP (43.61 g) diets. The ADFI of broilers fed corn diets was highest (P<0.05) while it was lowest with RB based diets. The birds showed improved (P<0.05) FCR by feeding RB diet followed by corn, WB and RP diets. The average AMEn of RB and corn was 3372 and 3315 kcal/kg, respectively. In cereal by-products, the RP and WB had 1936 and 1760 kcal/kg AMEn, respectively. In conclusion, varying growth pattern of broilers was observed by feeding corn, RB, RP and WB substituted diets. The RB and RP's AMEn was higher in cereals and cereal by-products, respectively.

Keywords: Broiler; AMEn; Growth performance; Cereals; Cereal by-products

Introduction

The feed cost represents more than 70% share of total broiler production cost, out of which the major portion is used to supply required dietary metabolizable energy (Jiang, 2004; Donohue and Cunningham, 2009). Cereals and cereal by-products contribute a major energy share in poultry diets (Sibbald, 1982). These ingredients' inclusion level in diet is based on their available nutrients particular the metabolizable energy (ME). The ME intake influences the broiler's feed intake and growth performance (Leeson and Summers, 2001; Morris, 2004) that's why poultry diets are formulated to fulfill bird's ME requirement (Nadeem *et al*., 2005). Precise and accurate assessment of feed ingredient's ME is mandatory to prepare a balanced diet with a definite calorific concentration (Scott *et al*., 1998; Nadeem *et al*., 2005; Macleod *et al*., 2008). The feed ingredient's nutrient composition influences its calorific value (Toghyani *et al*., 2014) and this nutrient composition is affected by varying plant genetics, soil conditions, agronomic practices and climatic changes (Ravindran *et al*., 2014). The ME value differs not only between ingredients but also amid samples of same feed ingredient (Jiang, 2004) produced at different locations of the same country.

The term apparent ME (AME) is classically used to represent ME of an ingredient and is the difference in gross energy (GE) intake and energy voided through feces and urine. For comparative purposes, these AME values are corrected for N retention (AMEn) to convert all data on N equilibrium basis (Fisher, 2000; Leeson and Summers, 2001; Macleod, 2002). The N correction is generally made to determine the nutrients potential to provide energy not their ability to promote N retention (McNab, 2000). These AMEn values are more authentic and additive approach compared to AME values (Jiang, 2004).

The advanced countries have developed the database

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regarding AMEn values of feed ingredients produced in their respective regions. But, unfortunately, the same information of our locally available ingredients is limited. The partial available information was determined using adult cockerels or roosters (Nadeem *et al*., 2005; Pasha *et al*., 2008). But the ME values are influenced by age (Zelenka, 1968; Lodhi *et al*., 1969), species (Slinger *et al*., 1964; Fisher and Shannon, 1973) and strains (Foster, 1968; March and Biely, 1971) of birds. Even broiler classes varying in growth performance resulted in different AME values (Jorgensen *et al*., 1990; Ten Doeschate *et al*., 1993). Broilers showed varying, generally, greater AME values than cockerels (Bourdillon *et al*., 1990). Therefore, the feed ingredient's AME determined in older aged cockerels or roosters may not be equally useful in formulating precise and cost-effective growing broiler's diet. Therefore, the present study was planned to determine AMEn values of commonly used cereals and cereal by-products in growing male broilers.

Materials and Methods

Feed Ingredients

The two each cereals and cereal by-products determined for AMEn content included corn (*Zea mays* L.), rice broken (*Oryza sativa* L.), rice polishings (*Oryza sativa* L.) and wheat bran (*Triticum spp*.). The 3 samples of each feed ingredient were analyzed for AMEn value. These feed ingredients were assayed for dry matter (DM), crude protein (N x 6.25) by LECO® nitrogen analyzer (model FP-528, Leco Corporation, St. Joseph, MI), crude fat, crude fiber and ash content (AOAC, 2000) (Table 1).

Test Diets

The 12 experimental diets (4 ingredients x 3 samples) were formulated by substituting the corn-soybean meal basal diet (Table 2) with 30% test ingredient (Table 3). The Celite® (acid insoluble ash) was added at 1% of each diet (Dourado *et al*., 2010). The vitamins and minerals supplementation was similar across all diets. The feed ingredients' AMEn was determined by substitution method according to Macleod *et al.* (2008) using 3-weeks old male broilers as used by Woyengo *et al.* (2010).

Bird's Management

The 468 day-old male broiler chicks (Hubbard x Hubbard) were arranged from hatchery (SB Hatchery, Rawalpindi, Pakistan) and reared in cages. All chicks were raised under same managemental conditions. The room temperature was kept at 32±1°C during 1st week and gradually reduced to 24°C by the end of 3rd week. The birds were provided continuous fluorescent light during the experimental period. Chicks were vaccinated against Newcastle disease, Infectious Bronchitis and Infectious Bursal disease. The fresh water's *ad libitum* supply was available to chicks round the clock. All chicks were offered *ad libitum* corn-soybean basal diet in crumble form to fulfill their nutritional requirements (NRC, 1994) for first 13 days of age. On day 14th, chicks were fasted overnight, individually weighed and randomly distributed to 78 replicate pens, each containing 6 birds. The difference in mean body weight of chicks between replicates was ± 10 g. The each of the basal diet as well as experimental diets was fed *ad libitum* to six randomly selected replicates from 14 to 21 days of age.

Excreta Collection

The excreta samples from each replicate were collected 4 times a day, for 3 days (day 19 to 21). Feed and feather particles were removed from dropping samples as much as possible. The collected dropping samples were labeled according to diet and replicate and were refrigerated. After collection period, frozen samples were thawed, pooled replicate wise, homogenized and dried in hot air oven at 55°C for 72 h. Dried samples were ground in laboratory rotor mill (model ZM-200, Retsch GmbH, Haan, Germany) to pass through 0.5 mm sieve and stored for further analyses.

Chemical Analysis

The experimental and basal diets and excreta samples were analyzed for DM (AOAC, 2000), nitrogen content by LECO® nitrogen analyzer (model FP-528, Leco Corporation, St. Joseph, MI) and gross energy using C2000 IKA adiabatic oxygen bomb calorimeter (GMBIT and CO KGD-79219, IKA Works Inc., Wilmington, NC). The acid insoluble ash of diets and dropping samples was determined by procedure reported in AOAC (2000).

Calculations

The average daily feed intake (ADFI), average daily gain (ADG) of broiler chicks was recorded from day 14 to 21 and feed conversion ratio (FCR) was calculated. The AMEn value of all the test ingredient samples was calculated by data of diets and excreta analyses using following equations:

$$AME_n = GE_{Diet} - \frac{GE_{excreta} \times AIA_{Diet}}{AIA_{Excreta}} - 8.22 \times N_{Retained}$$

Where, AMEn (kcal/kg) = N-corrected apparent metabolizable energy

GE_{Diet} and $GE_{Excreta}$ (kcal/kg) = Gross energy content of diet and excreta, respectively

AIA_{Diet} and $AIA_{Excreta}$ (%) = Acid insoluble ash in diet and excreta, respectively

8.22 (kcal/kg) = Energy value of uric acid

$N_{Retained}$ (g/kg) = N Retained by the birds per kg of feed intake

The retained N content was calculated by the following equation:

$$N_{Retained} = N_{Diet} - \frac{N_{excreta} \times AIA_{Diet}}{AIA_{Excreta}}$$

Where, N $_{Diet}$ and N $_{Excreta}$ (%) = N content of diet and excreta, respectively

AMEn of test ingredients was determined by the following formula:

$$AMEn_{Ingredient} = AMEn_{Basal} + [\frac{AMEn_{test} - AMEn_{Basal}}{Proportion\ of\ test\ ingredient\ in\ test\ diet}]$$

Statistical Analysis

Data regarding ADFI, ADG, FCR and AMEn were analyzed using GLM procedures of SAS (SAS, 1999). In case of significance, treatment means were compared by t-test.

Results

The nutrient composition of feed ingredients is given in Table 1. The ingredient composition of basal diet as well as experimental diets is mentioned in Table 2 and 3, respectively. The ADFI, ADG and FCR in broilers remained same (P>0.05) fed diets based on different samples of same feed ingredients (Table 4). The AMEn of corn and RB was similar (P>0.05) between different samples; however, this AMEn varied (P<0.05) between samples of cereal by-products (RP and WB) (Table 4). The ADFI, ADG, FCR and AMEn was different (P<0.05) between different feed ingredients (Table 5). The greater (P<0.05) ADG in broilers was recorded by feeding corn diet (56.03 g) followed by RB (50.04 g), WB (45.87 g) and RP (43.61 g) diets. The more (P<0.05) ADFI was recorded when basal diet was substituted with corn while it was lowest with RB (Table 5). The improved (P<0.05) FCR in broilers was observed by feeding RB (1.94) diets followed by corn (2.02), WB (2.33) and RP (2.50).

The variation in different ingredient's AMEn was significant. The more (P<0.05) AMEn was recorded for RB (3372 kcal/kg) followed by corn (3315 kcal/kg), RP (1936 kcal/kg) and WB (1760 kcal/kg).

Discussion

The nutrient composition of feed ingredients was concordant with published values (Sauvant *et al*., 2004; Nadeem *et al*., 2005; Rostagno *et al*., 2005). The more (P<0.05) ADG in broilers fed corn substituted diets might be attributed to increased feed intake. The reduced ADFI of RP and WB diets might be because of more dietary fiber content. In this experiment, the basal diet was 30% substituted with test ingredients so the replacement of ingredients with higher fiber content resulted in increased dietary fiber. Kras *et al*. (2013) documented poor performance and lower energy retention in birds fed high fibrous diet. The lowest (P<0.05) ADFI of RB's diets might be due to its more AMEn content. Leeson and Summers (2001) and Morris (2004) reported that dietary ME value influenced broiler's feed intake and growth performance. The birds showed improved (P<0.05) FCR fed RB substituted diet might be because of lesser feed intake than that of birds fed other diets.

The samples of same feed ingredient resulted in varying AMEn values (Table 4). This AMEn variation was greater (P<0.05) among RP and WB's samples. The reason of such varying AMEn values among samples of same feed ingredient might be the differences in grains' nutrient composition cultivated in different areas. All those aspects influencing ingredient's digestibility affect its metabolizability. Like digestibility, the AMEn also depends upon ingredient's chemical composition because the plant genetics, soil conditions, agronomic practices and cultivar techniques affect both the ingredient's chemical composition and its nutritive value (Alvarenga *et al*., 2013; Ravindran *et al*., 2014). These differences were more prominent in by-products indicating variation in processing techniques and processing equipment's quality. These

Table 1: Chemical composition of corn, rice broken, rice polishings and wheat bran used in determination of AMEn (as-received basis)

	Ingredients			
Nutrient (%)	Corn	Rice broken	Rice polishing	Wheat bran
Moisture	8.67 ± 0.44	9.87 ± 0.40	6.84 ± 0.62	8.20 ± 1.28
Crude protein	8.81 ± 0.54	10.07 ± 0.21	12.38 ± 0.90	13.50 ± 0.71
Ether extract	3.61 ± 0.07	1.21 ± 0.05	10.74 ± 1.44	3.33 ± 0.47
Crude fiber	1.95 ± 0.12	0.68 ± 0.02	17.38 ± 4.06	10.21 ± 1.63
Ash	1.25 ± 0.17	1.01 ± 0.14	11.55 ± 0.63	5.09 ± 0.49
Acid insoluble ash	0.08 ± 0.06	0.17 ± 0.04	7.92 ± 0.72	1.20 ± 0.43

‡Data were average of three samples of each feed ingredient

Table 2: Ingredient and chemical composition of basal diet

Ingredient	Percentage composition
Corn	58.00
Soybean meal	35.52
Soybean oil	1.78
Di-calcium phosphate	2.17
Limestone	0.78
Sodium chloride	0.20
Sodium bicarbonate	0.23
Vitamin-mineral premix‡	0.32
Celiteᵻ	1.00
Chemical composition (%)	
Moisture	8.80
Crude protein	22.93
Ash	7.97
Crude fiber	2.40
Crude fat	4.02

ᵻCelite: Acid insoluble ash

‡ Provided per kg of diet: Retinyl acetate, 4400 IU; cholecalciferol, 118 µg; DL-α-tocopheryl acetate, 12 IU; menadione sodium bisulphite, 2.40 mg; thiamine, 2.5 mg; riboflavin, 4.8 mg; niacin, 30 mg; D-pentothenic acid, 10 mg; pyridoxine, 5 mg; biotin, 130 µg; folic acid, 2.5 mg; cyanocobalamin, 19 µg; manganese, 85 mg ($MnSO_4.H_2O$); Iron, 80 mg ($FeSO_4.H_2O$); Zinc, 75 mg (ZnO); Copper, 6 mg ($CuSO_4.5H_2O$); Iodine, 1 mg (ethylene diamine dihydroiodide); Selenium, 130 µg (Na_2SeO_3)

Table 3: Composition of experimental diets based on basal diet and test feed ingredients

Diets	Basal Diet %	Corn %			RB %			RP %			WB %		
		sample 1	sample 2	sample 3	sample 1	sample 2	sample 3	sample 1	sample 2	sample 3	sample 1	sample 2	sample 3
Corn diet 1	70	30	-	-	-	-	-	-	-	-	-	-	-
Corn diet 2	70	-	30	-	-	-	-	-	-	-	-	-	-
Corn diet 3	70	-	-	30	-	-	-	-	-	-	-	-	-
RB diet1	70	-	-	-	30	-	-	-	-	-	-	-	-
RB diet2	70	-	-	-	-	30	-	-	-	-	-	-	-
RB diet3	70	-	-	-	-	-	30	-	-	-	-	-	-
RP diet1	70	-	-	-	-	-	-	30	-	-	-	-	-
RP diet2	70	-	-	-	-	-	-	-	30	-	-	-	-
RP diet3	70	-	-	-	-	-	-	-	-	30	-	-	-
WB diet1	70	-	-	-	-	-	-	-	-	-	30	-	-
WB diet2	70	-	-	-	-	-	-	-	-	-	-	30	-
WB diet3	70	-	-	-	-	-	-	-	-	-	-	-	30

RB, RP and WB are the abbreviations of rice broken, rice polishings and wheat bran, respectively

results elaborate the usefulness of determining available nutritive values of native feed resources rather than to use literature values in practical feed formulation.

In cereals, the RB had higher (P>0.05) AMEn than that of corn's AMEn (Table 5). The AMEn of corn in this experiment was higher than that reported by Longo *et al*. (2004), Sauvant *et al*. (2004) and Nadeem *et al*. (2005) and less than energy value documented by Palmer-Jones and Halliday (1971), NRC (1994) and Rostagno *et al*. (2005). The reason of varying calorific values might be attributed to varying grain's nutrient composition. Palmer-Jones and Halliday (1971) reported that 3391 kcal/kg corn's energy with 3% fiber was reduced to 2532 kcal/kg when fiber content increased to 11%. Vieira *et al.* (2007) reported that corn hybrid's AMEn ranged from 3405 to 4013 kcal/kg and was related it to its varying lipid content. The ingredient's oil content influences its AMEn value (Zhou *et al*., 2010). Wang and Parsons (1998) reported that positive relationship existed in corn's energy level and its ether extract content. Meloche *et al*. (2013) documented decreased AMEn value of distillers dried grains with solubles exhibiting lower oil content than those of more oil percentage. The lipid content reduced the gastric emptying by increasing the cholecystokinin secretion in duodenum. This hormone enhanced the digestive enzymes secretions from pancreas and improved the protein and carbohydrate digestion thus increased the energy value (Alvarenga *et al*., 2013). The contrasting results regarding corn's AMEn in this study and Longo *et al*. (2004) might be attributed to varying bird's age. Longo *et al*. (2004) used 1 week old broiler chicks in their study and digestibility and metabolizability is generally less in early aged birds than that of growing age.

The RB's AMEn in this study was contrasting to that reported by Sauvant *et al*. (2004), Nadeem *et al*. (2005) and Rostagno *et al*. (2005). Although, Nadeem *et al*. (2005) used native RB to determine energy value but higher energy value in this study might be because of varying rice variety and experimental birds. The authors used 3-weeks old broilers in contrast to mature cockerels used by Nadeem *et al*. (2005). Bourdillon *et al*. (1990) documented greater energy values in broilers than cockerels and might be because of different metabolic rate of adult cockerels and growing broilers.

Table 4: Broilers' performance fed experimental diet based on different samples of feed ingredients from day 14 to 21 days of age

Parameters‡	Diet 1	Diet 2	Diet 3	SEM	*P-value*
Corn					
ADG (g)	56.81	56.45	54.83	0.64	0.424
ADFI (g)	113.31	112.83	113.10	0.14	0.420
FCR	1.99	2.0	2.07	0.02	0.423
AMEn (kcal/kg)	3303	3355	3286	26.89	0.574
Rice broken					
ADG (g)	49.51	50.66	49.97	0.40	0.521
ADFI (g)	96.37	97.65	98.06	0.49	0.367
FCR	1.95	1.94	1.96	0.01	0.779
AMEn (kcal/kg)	3343	3401	3376	23.18	0.680
Rice polishings					
ADG (g)	43.05	43.79	44.0	0.64	0.835
ADFI (g)	107.25	109.82	108.48	0.66	0.303
FCR	2.49	2.53	2.46	0.04	0.784
AMEn (kcal/kg)	2083^{a}	1752^{b}	1975^{a}	41.22	<0.001
Wheat bran					
ADG (g)	45.89	46.84	44.87	0.51	0.301
ADFI (g)	106.93	108.56	104.83	0.91	0.255
FCR	2.33	2.32	2.34	0.03	0.960
AMEn (kcal/kg)	1732^{ab}	1872^{a}	1678^{b}	29.35	0.010

Values sharing different superscripts (a-b) within rows differed significantly (*P<0.05*)
‡ADG = average daily gain/bird, ADFI = average daily feed intake/bird, FCR = Feed conversion ratio
AMEn = Apparent metabolizable energy corrected for nitrogen
SEM = Standard error of mean

In this study, the RP possessed more (P<0.05) AMEn than WB in cereal by-products. The RP's AMEn was less than that stated by Sauvant *et al*. (2004), Leeson and Summers (2001) and NRC (1994). The reason for such contrasting results might be due to varying processing conditions (Rao and Reddy, 1986). The RP is the by-product of rice processing industry thus processing affects the chemical composition. The polishing and pressure during processing affects grain's quality (Ambreen *et al*., 2006). Even varying temperature during processing can

Table 5: Broilers' performance fed experimental diet based on different feed ingredients from day 14 to 21 days of age

	Diets based on feed ingredients				SEM	*P- value*
Parameters‡	Corn	Rice broken	Rice polishings	Wheat bran		
ADG (g)	56.03[a]	50.04[b]	43.61[d]	45.87[c]	0.62	< 0.001
ADFI (g)	113.08[a]	97.35[c]	108.52[b]	106.77[b]	0.74	<0.001
FCR	2.02[b]	1.94[a]	2.50[d]	2.33c	0.03	<0.001
AMEn (kcal/kg)	3315.00[a]	3372.00[a]	1936.00[b]	1760.00[c]	90.31	<0.001

Values sharing different superscripts (a-d) within rows differed significantly (*P<0.05*)
‡ADG = average daily gain/bird, ADFI = average daily feed intake/bird, FCR = Feed conversion ratio
AMEn = Apparent metabolizable energy corrected for nitrogen
SEM = Standard error of mean

impact the energy level. The increasing drying temperature from 80 to 120°C resulted in decreased AMEn of corn without changing grain's gross energy and nutrient composition (Carvalho *et al*., 2004). In addition, RP adulterated with rice husk (high in fiber) may be another aspect affecting its nutritional value (Ambreen *et al*., 2006). It might also be due to inconsistent chemical composition of rice varieties (Rao and Reddy, 1986). That's why the AMEn of RP (1936 kcal/kg) was close to 1953 kcal/kg documented by Pasha *et al*. (2008) as they also used native RP samples in their experiment.

The determined WB's AMEn content was in-between the values stated by other workers (Kuzmicky *et al*., 1978; Sauvant *et al*., 2004; Nadeem *et al*., 2005; Rostagno *et al*., 2005). This difference in energy value might be attributed to variance in wheat type and soil or agronomic conditions. However, the AMEn of one WB sample (Table 4) was concordant with that reported by Nadeem *et al*. (2005). Cozannet *et al*. (2010) reported that from proximate fractions, the only fiber content accounted for considerable AMEn variation in wheat by-products. Ravindran *et al*. (2014) reported that fiber was negatively correlated (r = -0.64), while fat was positively correlated (r = 0.38) to AME. Although an ample data regarding feed ingredient's energy value have been published. But several terminologies and methods had been used to determine these values. These methods included total collection or partial collection method with help of some appropriate marker. Different terms used included the apparent metabolizable energy (AME), apparent metabolizable energy corrected for nitrogen (AMEn), true metabolizable energy (TME) and true metabolizable energy corrected for nitrogen (TMEn). Furthermore, different animal species and strains of varying ages and sex were used, therefore, direct comparison of energy values determined in this trial and reported literature seems little valid.

In this trial, the higher AMEn value of RB from cereals and cereal by-products could be attributed to its more starch content. The cereals and their by-products being the rich sources of starches share equitable calories in poultry diet. The starch is the major energy source in grains (Moran, 1982; NRC, 1994) and its content may vary between ingredients. There is less correlation between feed ingredient's energy value and starch content but there is very strong correlation between ingredient's calorific value and the digestible starch. The starch digestibility may vary not only between ingredients but also between samples of same ingredient. Rostagno *et al*. (2005) reported higher starch content in RB (74.45%) compared to corn (62.48%), WB (54.93%) and RP (27.40%) (Sauvant *et al*., 2004).

Conclusion

The varying nutrient composition of native feed ingredients and their by-products resulted in variations in broiler's growth performance and AMEn values. The RB had higher AMEn value amid cereals. Form cereal by-products, the RP exhibited more AMEn than WB. Formulating broiler diets using AMEn values determined from locally available feed ingredients may help in efficient broiler production.

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