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Digestible and Metabolizable Energy in Ground Yellow Corn, Rice Bran, and Copra Meal Fed to 10 to 15 kg Philippine Native Pigs (Benguet Strain)

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The experiment was conducted to determine the digestible energy (DE), metabolizable energy (ME), and apparent total tract digestibility (ATTD) of gross energy in ground yellow corn, rice bran, and copra meal when fed to Philippine native pigs. Nine barrows with an average initial bodyweight of 10 kg and ages ranging from 60 to 75 d old were housed individually in metabolism crates and randomly allotted to a triplicated incomplete 3 × 2 Latin square design with three diets and two periods. A corn-based diet containing 94.89% yellow corn and two diets containing 66.42% yellow corn and 30% rice bran or copra meal were fed to the native pigs for 10 d, which included a 5 d adaptation period and a 5 d collection period. The DE and ME in rice bran and copra meal were calculated using the substitution procedure with yellow corn as the basal ingredient. On a dry matter basis, ground yellow corn contained 3445 DE and 3314 ME kcal/kg, with 75.45% ATTD of gross energy (GE). Rice bran had 4137 DE and 4034 ME kcal/kg with 87.02% ATTD of GE, whereas copra meal contained 2914 DE and 2841 ME kcal/kg, with 64.72% ATTD of GE. These values are important in the establishment of feeding standards for the Philippine native pigs.

Keywords: digestibility, feeding standards, indigenous pigs

Abbreviations: ATTD—apparent total tract digestibility, DE—digestible energy, DM—dry matter, GE—gross energy, ME—metabolizable energy, NRC—National Research Council

INTRODUCTION

The Philippine native pig is a valuable genetic resource of the Philippine swine industry. Survey studies conducted by Maddul (1991), More et al. (1999), Lee et al. (2005), and Villanueva and Sulabo (2018) in different areas of the country show that poor nutrition is one of the major problems in native pig production. However, limited research on the nutrition of Philippine native pigs has been conducted and the nutrient requirements are not yet fully elucidated. In contrast to hybrid pigs which are fed commercial diets, native pigs in the Philippines are commonly fed household wastes or fruit-vegetable wastes. Although these feedstuffs are considered as low input, they do not provide sufficient and balanced nutrition for optimal growth. The initial intervention to address the poor performance of native pigs is to determine their nutrient requirements. Requirements of hybrid pigs are available in the Nutrient Requirements of Swine published by the NRC (2012), but such values may not be the optimum requirement for native pigs. Digestibility and utilization of nutrients are affected by the genotype (Ndindana et al. 2002; Len et al. 2007; Urriola and Stein 2012; Villanueva 2022) and bodyweight (Urriola and Stein 2012) of pigs; thus, specific nutrient requirements for native pigs should be determined.

The conduct of feed ingredient evaluation through nutrient digestibility studies is a requisite procedure in the establishment of nutrient requirement for native pigs. Digestibility of nutrients in feed ingredients needs to be determined because it is recognized that swine diets are most precisely formulated based on the digestible content instead of the total nutrient content (Stein 2017). Nutrient requirements of swine are generally influenced by genotype, physiological status, performance potential, and environmental conditions (NRC 1998). Likewise, not all nutrients contained in the diet are digested and absorbed; thus, it is necessary to determine the amount of each nutrient that is utilized by the animal (NRC 2012). This results in better performance of animals, higher returns, and lesser negative impact of animal excretions to the environment.

This research was carried out to determine the digestibility of energy in locally available feed ingredients when fed to native pigs. Rice bran and copra meal are locally available raw materials which can be used as alternatives to yellow corn and soybean meal, respectively. Rice bran is one of the feed resources that local pig producers traditionally use for their native pigs. Rice mills are located in the country's rural areas where rice bran can be procured at an affordable price. Copra meal is a by-product of coconut oil production. The Philippines is the second largest producer of coconut in the world (FAO 2023), and the by-products of coconut oil production generated are used as animal feed (Agriculture 2017). Native pig producers commonly feed these ingredients in combination with vegetable trimmings or rejects and other farm by-products. However, the digestibility of these ingredients in native pigs, particularly the Benguet strain, is not yet determined. To develop feeding programs utilizing these raw materials, their digestibility needs to be determined first; hence, the conduct of this research.

This research aimed to determine the digestible energy (DE), metabolizable energy (ME), and apparent total tract digestibility (ATTD) in ground yellow corn, rice bran, and copra meal fed to Philippine native pigs.

MATERIALS AND METHODS

All protocols in this experiment were approved by the Institutional Animal Care and Use Committee (IACUC) of Benguet State University, La Trinidad, Benguet, with reference number AR-2020-090. Philippine native pigs from the Benguet strain were used as experimental animals (Fig. 1). The Benguet strain is also called the Benguet native pig, which is the common group of indigenous pigs raised by backyard swine pig producers in the province of Benguet.

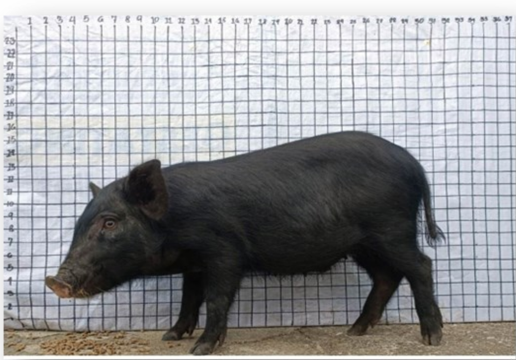

Fig. 1. Philippine native pig (Benguet Strain; 10 kg BW).

Animal, Diets, and Experimental Design

This experiment was designed to measure the concentration of DE and ME in ground yellow corn, rice bran, and copra meal fed to growing Philippine native pigs. Nine barrows with an average initial bodyweight of 10 kg were randomly distributed to a triplicated incomplete 3 × 2 Latin square design with three diets and two periods. Pigs were individually penned in metabolic cages (0.6 × 2.2 × 1.2 m) with a fully slatted floor and installed with feeders and drinkers, fecal trays, and urine buckets. Metabolism crates were designed for total but separate collection of feces and urine from each pig.

Three experimental diets (Table 1) were formulated for the digestibility trial. The basal diet contained 94.89% ground yellow corn, whereas the treatment diets contained 66.42% ground yellow corn and 30% (as-fed basis) rice bran or copra meal. The amount of micro-ingredients in the test diets, such as vitamins and minerals, were included at the same rates.

Table 1. Ingredient composition of the experimental diets (as-fed basis).[1,2,3,4]

Item	Diet		
	Yellow Corn	Rice Bran	Copra Meal
Ingredient, %			
Ground yellow corn	94.89	66.42	66.42
Rice bran	--	30.00	--
Copra meal	--	--	30.00
Monocalcium phosphate	2.29	1.60	1.60
Limestone	1.69	1.18	1.18
Vitamin premix	0.43	0.30	0.30
Mineral premix	0.14	0.10	0.10
Salt	0.57	0.40	0.40
Total	100.00	100.00	100.00
Analyzed Diet Composition			
DM, %	93.03	92.38	93.18
GE kcal/kg	4,003.00	4,280.00	3,873.00

[1]Provided the following quantities of vitamins per kg of complete diet: vitamin A, 11,128 IU; vitamin D_3, 2,204 IU; vitamin E, 66 IU; vitamin K, 1.42 mg; thiamin, 0.24 mg; riboflavin, 6.58 mg; pyridoxine, 0.24 mg; vitamin B12, 0.03 mg; D-pantothenic acid, 23.5 mg; niacin, 44 mg; folic acid, 1.58 mg; biotin, 0.44 mg.

[2]Provided the following quantities of micro minerals per kg of complete diet: Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 1.26 mg as potassium iodate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 100 mg as zinc oxide.

[3]DM = dry matter

[4]GE = gross energy

Feeding and Sample Collection

Pigs were weighed at the start of the experiment. Feed allowance per day was calculated three times their estimated requirement for maintenance energy (i.e. 106 kcal/kg $BW^{0.75}$; NRC 1998). The daily feed allowance was equally divided into two meals and was fed at 0800 and 1600 h. Clean water was provided throughout the experiment. Feed offered per day were recorded and leftovers were collected and weighed before feeding the next day.

Each period lasted 10 d, with a five-day adaptation period and 5 d collection period following the marker-to-marker approach by Kong and Adeola (2014). Chromic oxide was used as an indigestible marker to signal the start and end of collection of feces and urine. On day 6, the marker, at a rate of 4 g per 100 g of feeds, was fed to each pig. Once the mixture of feed and marker was consumed, the remainder of the feed allowance for that meal was provided. Feces and urine were collected when the marker first appeared in the feces after the administration of the start marker. The feces containing the marker had a visibly dark green color. On day 11, the stop marker was given following the same procedure in day 6. Collection ended when the marker first appeared in the feces after the administration of the stop marker. Feces were collected from the trays twice daily and stored at -20°C until the end of the collection period. Urine was collected twice daily using urine buckets with 50 ml 6 N HCl (Kim et al. 2023) as a preservative and were placed under the metabolism cages. A 20% subsample of each sample was stored at -20°C for analysis.

Processing and Analysis of Samples

At the end of the collection period, fecal and urine samples were thawed and pooled within pig, and sub-samples were collected for analysis. Fecal samples were oven-dried at 70°C to a constant weight and were finely ground before analysis. The dry matter (DM) and gross energy (GE) of ingredients, diets, urine, and feces were determined following the AOAC (2007) procedures and through bomb calorimetry (Model L6400, Parr Instruments Co., Moline, IL), respectively. The procedures of Kim et al. (2009) in the preparation and analysis of urine samples were followed.

Determination of DE and ME

Fecal and urine energy were determined and *DE* and *ME* of the diets were calculated according to Kong and Adeola (2014), as follows:

$$DE_{diet} = (GE_{intake} - \text{Fecal Energy}_{output})/\text{Feed Intake}$$

$$ME_{diet} = (GE_{intake} - (\text{Fecal Energy}_{output} + \text{Urine Energy}_{output}))/\text{Feed Intake}$$

The *DE* and *ME* in the corn-diet were multiplied by 66.42% to calculate the contribution from the corn-diet to the *DE* and *ME* in diets containing rice bran and copra meal. The *DE* and *ME* in copra meal and rice bran were calculated by difference (Widmer et al. 2007) as follows:

$$DE_A = \frac{DE_D - (S_B \times DE_B)}{S_A}$$

where DE_A = digestible energy of the test ingredient (kcal/kg), DE_D = digestible energy of component in the diet based on the test ingredient (kcal/kg), DE_B = digestible energy of the component in the diet based on the reference ingredient (kcal/kg), S_B = contribution level of component from reference ingredient to the diet based on the test ingredient (%), and S_A = contribution level of component from test ingredient to the diet based on the test ingredient (%).

Statistical Analysis

Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC), with pig as the experimental unit. The model included diet as the fixed effect and pig and period as random effects. Least square means were calculated for each independent variable. Least square means were separated using the PDIFF option of SAS and adjusted using the Tukey-Kramer test when diet was a significant source of variation. Statistical differences between means were determined at an α-level of 0.05.

RESULTS

The analyzed DM and GE of the test diets were presented in Table 1, whereas the pigs' energy balance values were shown in Table 2. The DM intake of the pigs across treatments did not differ; however, there was a difference in their energy intake. Pigs fed rice bran diet had greater (p < 0.05) energy intake compared to the pigs fed the copra meal diet, whereas the energy intake of pigs fed the yellow corn diet did not differ from the other two diets. The fecal and urine output as well as the amount of energy analyzed from the urine and fecal samples were not different. The rice bran diet had greater (p < 0.001) DE and ME compared to the yellow corn diet and copra meal diet, with DE and ME values that were not different.

Table 3 presents the digestibility values of the ingredients evaluated. The DE and ME values in rice bran were greater (p < 0.05) than in copra meal. The values calculated for yellow corn were not different from those obtained for rice bran or copra meal.

Table 2. Energy balance (DM basis) of Philippine native pigs fed with diets containing yellow corn, rice bran, or copra meal.[1,2,3,4]

Item	Diet			SEM	*P*-value
	Yellow Corn	Rice Bran	Copra Meal		
DM intake, g	1,987.49	1,981.60	1,728.28	181.46	0.213
GE intake, kcal/kg	7,955.93 [ab]	8,481.27 [a]	6,693.72 [b]	722.47	0.037
Fecal output, g	1,365.38	1,316.67	1,317.03	110.18	0.898
Fecal GE output, kcal/kg	4,550.17 [a]	4,216.83 [b]	4,480.00 [a]	65.10	0.001
Urine output, g	2,620.83	2,976.83	3,489.17	497.70	0.294
Urine GE output, kcal/kg	85.30	111.34	89.80	15.29	0.021
ATTD of GE, %	81.72	84.35	79.33	3.09	0.100
DE of diet, kcal/kg AF	3,043.06 [b]	3,334.97 [a]	2,862.88 [b]	115.95	< 0.001
ME of diet, kcal/kg AF	3,003.34 [b]	3,283.25 [a]	2,812.41 [b]	114.70	< 0.001
DE of diet, kcal/kg DM	3,271.07 [b]	3,610.14 [a]	3,072.26 [b]	293.24	< 0.001
ME of diet, kcal/kg DM	3,228.37 [b]	3,554.15 [a]	3,018.10 [b]	123.46	< 0.001

[1]Data are least square means of 6 observations for all treatments.
[2]Means without a common superscript letter differ ($p < 0.05$)
[3]Intake and output values are based on the data gathered for the 5-day collection period
[4] ATTD = apparent total tract digestibility, AF = as fed, DM = dry matter, GE = gross energy, DE = digestible energy, ME = metabolizable energy.

DISCUSSION

Comparisons of digestibility values obtained in this study versus other studies were based on DM values because there were variations in the DM contents of ingredients used in this study.

The GE (4438.35 kcal/kg) analyzed from the ground yellow corn used was close to the values by NRC (2012) at 4453.28 kcal/kg. The DE and ME obtained were 3344.90 kcal/kg and 3313.85 kcal/kg, respectively. These values are lower than the values by NRC (2012), which are 3907.83 and 3844.41 kcal/kg, respectively. Consequently, the yellow corn had an ATTD of GE of only 75.45%, which is notably lower than the ATTD of GE of 87.74% by NRC (2012). The yellow corn used in this study had a particle size of about 1.5 mm, which is the common size in local markets. During the conduct of this study, remarkable amounts of undigested corn particles were observed in the pigs' feces, which could have contributed to the low DE in corn. Particle size is one of the factors that affects energy digestibility. As reported by Rojas and Stein (2015), ME linearly increased when particle size was decreased. Another possible factor is the amount of ether extract in the yellow corn used. According to Lyu et al. (2019), there is a wide variation of EE in yellow dent corn, which has a direct correlation with the DE and ME values. The amount of energy provided by EE is 2.25 times greater than the energy from carbohydrates per kg of feed (NRC 2012); however, EE was not determined in this current study.

Rice Bran. The GE (4754.28 kcal/kg) value obtained in rice bran is lower than the values reported by NRC (2012) (5209.61 kcal/kg), but the DE and ME values (4137.39

Table 3. Digestible and metabolizable energy in yellow corn, rice bran, or copra meal fed to Philippine native pigs.[1,2,3]

Item	Ingredient			SEM	*P*-value
	Yellow Corn	Rice Bran	Copra Meal		
DM Content, %	93.03	94.46	91.61	--	--
AF basis					
GE, kcal/kg	4,129.00	4,392.00	4,196.00	--	--
DE, kcal/kg	3,110.33 [ab]	3,908.24 [a]	2,671.33 [b]	270.93	0.013
ME, kcal/kg	3,081.37 [ab]	3,811.35 [a]	2,604.21 [b]	277.94	0.012
DM basis					
GE, kcal/kg	4,438.35	4,754.28	4,503.11	--	--
DE, kcal/kg	3,344.90 [ab]	4,137.39 [a]	2,914.31 [b]	293.24	0.021
ME, kcal/kg	3,313.85 [ab]	4,034.20 [a]	2,841.04 [b]	301.52	0.03
ATTD of GE, %	75.45	87.02	64.72	--	--

[1]Data are least square means of 6 observations for all treatments
[2]Means without a common superscript letter differ ($p < 0.05$)
[3]ATTD = apparent total tract digestibility, AF = as fed, DM = dry matter, GE = gross energy, DE = digestible energy, ME = metabolizable energy.

kcal/kg and 4034.20 kcal/kg, respectively) were remarkably higher than the values reported by NRC (2012) (3384.28 kcal/kg and 3271.83 kcal/kg, respectively). On as fed basis, the values determined by Robles and Ewan (1982) — 3880 DE kcal/kg and 3710 ME kcal/kg — were close to the results of this study. The ATTD of GE (87.02%) obtained in this study is higher than the values reported by NRC (2012), Casas and Stein (2017), Lee et al. (2022), and Kim et al. (2022) with 64.96%, 81.34%, 81.70%, and 72.80%, respectively, using exotic breeds (Duroc, Landrace, and Large White). Better digestibility of rice bran in this study can be attributed to the genotype of the pigs used (Lindberg 2014). Results of this study confirm the ability of indigenous breeds of pigs such as Meishan pigs (Kemp et al. 1991; Urriola and Stein 2012), Zimbabwean Mukota pigs (Kanengoni et al. 2002; Ndindana et al. 2002), Vietnamese Mon Cai pigs (Borin et al. 2005; Len et al. 2007), and Philippine Black Tiaong pigs (Villanueva 2022) to utilize fiber more efficiently compared to hybrid pigs. These native pigs were not subjected to intensive breeding and selection programs which could have enabled them to retain the digestive physiology of their wild ancestor pigs which survived on diets with high fiber contents. In the metagenomics study of Cheng et al. (2018), results showed that Lantang pigs — native pigs from China — have inherent microbiological adaptations to high-fiber diets, which enable them to utilize fiber better compared to Duroc pigs from the United States. About 42 genera of fecal microbiome were identified in Lantang pigs, which were associated with fiber utilization. Moreover, the number of genes responsible for encoding debranching and degrading non-starch polysaccharides were higher in Lantang pigs than in Duroc pigs.

Copra Meal. The GE (4503.11 kcal/kg) value of the copra meal is almost the same as the reported value by NRC (2012) (4564.13 kcal/kg). However, the DE and ME values in this current study is lower (2914.31 and 2841.04 kcal/kg, respectively) than the values reported by NRC (2012) (3271.74 and 3109.78 kcal/kg, respectively); Sulabo et al. (2013) (3430 and 3248 kcal/kg, respectively); and Son et al. (2012) (3440 and 3340 kcal/kg, respectively). The ATTD of 64.72% is also lower compared to the value of 71.68% by NRC (2012). Conversely, the ATTD of GE obtained by Son et al. (2017) is lower at 54% (2413 DE and 2306 ME kcal/kg). Variations in the energy content of copra meal and copra expellers are mainly due to the differences in residual oil concentration (Stein et al. 2015). The GE in copra meal is greater than that in yellow corn; however, the DE and ME values are lower due to the high fiber content (Stein et al. 2015) with a total dietary fiber of about 46.9% (Jaworski et al. 2014). Increased concentration of dietary fiber reduces energy digestibility (Yin et al. 2000; Noblet and Le Goff 2001).

Rice bran and copra meal are both considered high-fiber ingredients; however, results of this study indicate that rice bran has a better ATTD of GE compared to copra meal. This can be attributed to the solubility of their fiber contents. Soluble fiber has a relatively higher digestibility compared to insoluble fibers (Noblet and Le Goff 2001; Gutierrez et al. 2016). Rice bran contains about 20% to 24% total dietary fiber (USDA 2018; Singh et al. 2020), with a lesser amount of insoluble fiber ranging from 6.10 to 6.44 % (Singh et al. 2020). On the other hand, copra meal contains about 41.4% insoluble fiber (Jaworski et al. 2014), which is remarkably higher than that in rice bran.

CONCLUSION

To determine the digestible energy (DE), metabolizable energy (ME), and apparent total tract digestibility (ATTD) of gross energy (GE) in particular feed ingredients when fed to Philippine native pigs (Benguet strain), nine 10 – 15 kg barrows were fed ground yellow corn, rice bran, and copra meal. The digestibility values (on dry matter basis) of the feed ingredients used in this study are as follows: ground yellow corn with 344.90 DE and 3313.85 ME kcal/kg with 75.45% ATTD of gross energy GE; rice bran with 4137.39 DE and 4034.20 ME kcal/kg with 87.02% ATTD of GE; and copra meal with 2914.31 DE and 2841.04 ME kcal/kg with 64.72% ATTD of GE. These digestibility values can be used in the formulation of rations for 10 – 15 kg Philippine native pigs in the conduct of feeding trials for the establishment feeding standards specific for Philippine native pigs.

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