MJSIR
Mountain Journal of Science and Interdisciplinary Research
PRINT ISSN: 2619-7855
ONLINE ISSN: 2651-7744
January-June 2024 • 84 (1) :16-28

Verification on Energy Digestibility in Ground Yellow Corn, Rice Bran, and Copra Expeller Fed to 10kg to 15kg Benguet Native Pigs

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ARTICLE INFO

Date Received: 10/21/2022
Date Last Revised: 05-06-2024
Date Accepted: 05-27-2024

KEYWORDS

Digestibility trial
Feeding standard
Indigenous pig
Nutrition
Feed ingredients

Abstract

Digestible and metabolizable energy contents of feed ingredients are important in swine nutrition as they directly influence feed utilization efficiency and growth performance. By accurately measuring these parameters, producers can formulate diets tailored to pigs' energy needs at various growth stages, leading to improved feed efficiency, reduced costs, and minimized environmental impacts. In this study, a digestibility trial was carried out to determine the digestible energy (DE) and metabolizable energy (ME) in ground yellow corn, rice bran, and copra expeller fed to Benguet native pigs with body weights ranging from 10kg to 15kg (102 to 127 days old) to confirm digestibility values obtained from a previous study. The total fecal collection method following the marker-to-marker approach was employed using chromic oxide as a marker to indicate the start and end of fecal collection. Ground yellow corn had 3,669 DE and 3,522 ME kcal/kg with an apparent total tract digestibility (ATTD) of 90.17%, whereas, rice bran had 4,364 DE and 4,189 ME kcal/kg with an ATTD of 84.14%. Copra expeller had 4,921 DE and 4,724 ME kcal/kg with an ATTD of 80.78%. The DE and ME values for ground yellow corn and rice bran are close to the values obtained in the previous study verified; however, values for copra expeller are different. These results are important in the establishment of feeding standards for Benguet native pigs weighing 10kg to 15kg.

Introduction

Swine production in the Philippines holds significant importance within the country's livestock sector, providing approximately 60% of the total meat production, thereby ensuring food security (Livestock Research Division, 2016). Within the domain of swine production, native pig farming contributes particular significance. These indigenous strains, including the Benguet native pigs, play a crucial role in meeting the nation's pork demand and furthering food security objectives. The Benguet native pig, developed through the "Conservation, Improvement and Profitable Utilization of the Philippine Native Pigs" research program initiated by DOST-PCAARRD in 2014, stands as a testament to efforts aimed at enhancing local pig farming practices and sustainability. Despite the substantial contribution of native pigs to the swine industry, challenges persist, particularly in optimizing their growth performance through improved nutrition and feeding practices. An essential aspect of this optimization lies in determining the digestibility profiles of feed ingredients used in their diets. According to Sauer and Ozimek (1986), digestibility is the most widely used in the evaluation of feedstuff and diet formulation for pigs at any stage.

Yellow corn, rice bran, and copra expeller are locally available feed ingredients commonly used in native pig diets. These resources are integral to formulating cost-effective diets that align with the pigs' nutritional requirements (Santiago, 2018). Rice bran, a staple feed resource in many rural areas in the country, is an alternative to yellow corn and is often combined with other local raw materials. Similarly, copra expeller, a by-product of coconut oil production, presents a viable alternative source of protein. The digestibility of these ingredients has been well-established in exotic breeds, yet remains largely unexplored in native pig populations. A recent study by Garcia (2020) reported DE and ME values of 3,345 and 3,314 kcal/kg for ground yellow corn (YC) at 93% dry matter (DM), 4,137.39 and 4,034.20 kcal/kg for rice bran (RB) at 94.46% DM, and 2,914 kcal/kg and 2,841 kcal/kg for copra expeller (CE) at 91.69% DM, respectively. However, the need for verification is imperative to ensure the applicability of these findings to the establishment of feeding standards for native pigs.

By providing baseline data on the digestibility of these key feed ingredients, our study aims to address a critical gap in the literature and contribute to the development of tailored feeding programs for native pig production. Furthermore, our research underscores the importance of optimizing feed digestibility to enhance growth performance, feed efficiency, and overall sustainability within the swine industry.

Materials and Method

All protocols in this experiment were evaluated by the Institutional Animal Care and Use Committee (IACUC) of the Benguet State University, La Trinidad, Benguet, and approved by the Bureau of Animal Industry (BAI) with reference number AR -2021-106. Benguet native pigs (Figure 1) procured from the BSU Piggery Farm were used as experimental animals.

Animals, Diets, and Experimental Design

Nine Benguet native pig barrows with body weights ranging from 10kg to 15 kg (102 to 127 days old) were randomly allocated to a replicated 3x3 Latin Square Design. There were six replicates per diet with one pig per replicate. The pigs were individually penned in metabolic cages (Figure 2) with a measurement of 0.6m × 2.2m × 1.2m. The metabolic cages were installed with fecal trays to facilitate the collection of feces, a feeder, and a nipple drinker. Three experimental diets (Table 1) were formulated, one basal or reference diet and two treatment diets. On an as-fed basis, the basal diet contained 94.89% yellow corn, while the treatment diets contained 66.42% corn and 30% rice bran or copra expeller. The amount of micro-ingredients such as vitamins and minerals were included at the same rates. Ground yellow

Figure 1

Benguet Native Pig at 102 Days Old

Figure 2

Experimental Pigs Housed in Metabolic Cages

served as the reference diet, while rice bran and copra expeller were the test ingredients (Figure 3).

Feeding and Sample Collection

At the start of the study, the body weight of the pig was taken. The feed allowance per day per pig was calculated three times their estimated requirements for maintenance energy. This was equally divided into two and given at two different times of meals at 0800 and 1600h. Water access was ensured throughout the study. Feed offered was recorded, and any left-over feeds in the feeder were collected and weighed before the next feeding.

Figure 3

Samples of Ingredients Used

Table 1

Ingredient Composition of the Experimental Diets (as Fed Basis)

Ingredients, %	Diets: Yellow Corn (YC) Diet	Rice Bran (RB) Diet	Copra Expeller (CE) Diet
Ground yellow corn	94.89	66.42	66.42
Rice bran	-	30.00	-
Copra expeller	-	-	30.00
Monocalcium Phosphate (MCP)	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 composition			
DM, %	86.66	88.78	88.20
GE, kcal/kg	3,798.00	4,116.00	4,256.00

Legend: DM= Dry matter basis, GE= gross energy

There were two periods conducted with a five-day adaptation and a five-day collection in each period. Feces were collected following the marker-to-marker approach by Adeola (2001), using chromic oxide as an indigestible marker. This procedure provides more precise measurements of the duration of fecal collection compared to the index method. A five-day collection is sufficient to determine the energy values and nutrient digestibility of high-fiber diets in growing pigs using the total fecal collection method (Liu et al., 2020). The marker was included in the diet, in the morning meal of the collection period (day 6) at the rate of 4g per 100g feed. Once the feed and marker mixture were consumed, the remainder of the feed allowance for the meal was given. On day 11, the marker was given the following the same procedure as on day 6. The collection of feces started when the marker first appeared in the feces after day five. The collection stopped when the marker first appeared in the feces after day 10. Fecal collection per pig for each day was stored in the freezer at -20°C.

Sample Analysis and Data Processing

At the end of the collection period, fecal samples (Figure 4) from each pig were thawed and mixed thoroughly, from which about 20% sub-sample was taken from each sample for energy analysis. Fecal samples were oven-dried at 70ºC to a constant weight, followed by fine grinding (Figure 5) before subjecting to analysis. These procedures were adapted from the methodology of Kil et al. (2013). Reference and test ingredients, as well as diets, and feces, were analyzed for DM following the Association of Analytic Chemists International (2007; method 930.15) procedures. The energy contents of ingredients, diets, and feces were analyzed by the Animal Nutrition Analytical Science Laboratory (ANASL) at UPLB, Los Baños, Laguna using a bomb calorimeter (Model L6400, Parr Instruments Co., Moline, IL).

Figure 4

Collected Fecal Samples

Figure 5

Processed Diets and Fecal Samples

Data Gathered

Body Weight (kg). The body weight of each pig at the start of the experiment.

Feed Offered (g). The amount of feed given to the animal daily.

Feed Left-over (g). The amount of feed not consumed by each animal before a new feed is given in the morning.

Total Weight of Wet Feces (g). The total weight of feces collected during the five-day collection period.

Dry Matter of Diets (%). This was taken by oven-drying the diet samples at 105ºC to a constant weight.

Dry Matter of Feces (%). This was taken by oven-drying the fecal samples diet first at 70ºC, then at 105ºC to a constant weight.

Gross Energy (GE) of Diets and Ingredients (kcal/g). The amount of energy determined in each diet and ingredient using a bomb calorimeter.

Fecal Energy (kcal/kg). The amount of energy determined in the fecal samples collected in each animal using a bomb calorimeter.

Data Computed

Feed intake (g). The total feed consumed by each pig during the five-day collection period using the formula:

a. $\text{Total feed intake, as fed basis} = \text{Total feed offered} - \text{Total feed left-over}$

b. $\text{Total DM} = \text{Total feed intake} \times \text{DM of Feeds intake}$

Apparent total tract digestibility (ATTD) of GE (%). This was computed using the formula:

a. $$\text{ATTD of GE in the diet (\%)} = \frac{\text{Energy intake} - \text{Fecal energy output}}{\text{Energy intake}} \times 100$$

b. $$\text{ATTD of GE in the ingredient (\%)} = \frac{\text{DE (DM basis)}}{\text{GE ingredient (DM basis)}} \times 100$$

Energy Intake (kcal). This was computed by multiplying the DM intake by the energy in the diet.

Fecal Energy Output (kcal). This was computed by multiplying the total weight of dried feces (kg) by fecal energy (kcal/kg).

Total Fecal Dry Matter (%). This was computed using the formula:

$$\text{Total fecal DM (\%)} = \frac{(\text{DM at } 70^{\circ}\text{C} \times \text{DM at } 105^{\circ}\text{C})}{100}$$

Total Weight of Dried Feces (g). This was computed by multiplying the total weight of feces by the total fecal DM.

Energy Calculation. The amount of energy lost in the feces was determined and the levels of DE in each of the three diets were calculated following the procedures of Adeola (2001).

a. $$\text{DE diet (kcal/kg)} = \frac{\text{Gross energy intake} - \text{Fecal energy output}}{\text{Total feed intake, kg}}$$

The ME in each diet was estimated using the formula (Holden et al. 2010; National Research Council of the National Academies, 2012):

$$\text{ME diet (kcal/kg)} = \text{DE}_{\text{DM basis}} \times 0.96$$

The DE and ME in the ground yellow corn diet were multiplied by 66.42% to calculate the energy contribution from the corn diet to the DE and ME in diets containing rice bran and copra expeller. The DE and ME in rice bran and copra expeller were calculated by difference using the following equation according to Widmer et al. (2017).

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

b. $$ME_A = \frac{ME_D - (S_B \times ME_B)}{S_A}$$

Where: DE_A/ME_A= digestible energy/ metabolizable energy of the test ingredients (kcal/ kg), DE_D / ME_D = digestible energy/metabolizable energy of component in the diet based on the test ingredients (kcal/kg), DE_B / ME_B = digestible energy/metabolizable energy of the component in the diet based on the reference ingredients (kcal/kg), S_B = contribution level of a component from reference ingredients to the diet based on the test ingredients (%), and S_A = contribution level of the component from test ingredient to the diet based on the test ingredients (%).

Data Analysis

Data were analyzed using the MIXED procedures of SAS (SAS int. Inc. Cary, NC) with a pig as the experimental unit. The model includes diet as the fixed effect and pig and period as random effects. The least-square means were calculated for each independent variable. When the diet was a significant source of variation, least square means were separated using the PDIFF options of SAS and adjusted using the Tukey-Kramer test. The a-level that was used to determine significance was $p<0.05$.

Results and Discussion

Gross Energy (GE) Content of the Diets

The ingredient composition and analyzed GE content of the experimental diets are presented in Table 1. Among the diets, CE had the highest GE content at 4,256 kcal/kg, followed by the RB diet at 4,116 kcal/kg, and the ground YC diet with the lowest GE at 3,798 kcal/kg. The primary constituents of swine diets, such as carbohydrates, proteins, fats, and fiber, contribute differently to the gross energy content. These differences in GE values can be attributed to variations in residual oil content among the feed ingredients. Rice bran and copra expeller typically contain higher levels of residual oil compared to yellow corn (National Research Council of the National Academies [NRC], 2012). The amount of residual oil or fat present in the feed ingredients significantly contributes to the overall energy content of the diet, since fats generally have a higher energy content compared to proteins and carbohydrates. While GE provides a measure of the total energy available in a feed, it does not reflect how much is available to be utilized by the animal; thus, digestibility trials are conducted.

Energy Balance and Digestibility of the Experimental Diets

Table 2 presents the energy balance of 10kg to 15kg Benguet native pigs fed diets containing ground yellow corn, rice bran, and copra expeller.

Total Energy Intake (TEI)

The TEI observed in the study reveals significant differences ($p<0.05$) among the dietary treatments, with pigs on the RB diet exhibiting the highest TEI at 9,999 kcal, followed by those on the YC diet at 7,281 kcal, and the CE diet at 6,400 kcal. These disparities underscore the influence of diet composition on energy intake. However, it is important to note that while these differences are significant, they do not necessarily imply causation. Instead, they reflect the varying palatability and energy content of the feeds, which in turn influence feed intake.

The higher TEI observed in the RB diet group could be attributed to several factors, including the palatability and energy density of the feed. However, it is essential to acknowledge that these explanations are based on theoretical understanding rather than established causal relationships.

The methodology employed in the study, particularly the feeding protocol and adaptation period, may have influenced the observed results. The five-day adaptation period allowed the animals to acclimate to the experimental diets, stabilizing ileal outflow and potentially influencing energy intake (Kim et al. 2020). However, variations in individual animal responses to dietary changes, as well as differences in the palatability and digestibility of the feeds, could have affected the results. Incorporating feeds with higher energy density, may enhance total energy intake and support growth performance in pigs. However, careful consideration should be given to factors such as feed palatability and digestibility, as well as dietary fiber content, to prevent potential reductions in feed intake and growth performance.

Table 2

Energy Balance of 10kg to 15 Kg Benguet Native Pigs Fed Diets Containing Ground Yellow Corn, Rice Bran, and Copra Expeller

ITEM	DIET				
	Yellow corn diet	Rice bran diet	Copra expeller diet	SEM	*p* value
DM intake, g	1,959.15[a]	2,431.09[a]	1,461.84[b]	139.373	0.0008
Total enegry intake, kcal/kg	7,281.28[b]	9,999.68[a]	6,400.22[b]	559.53	0.0009
Fecal energy content of feces, kcal/kg	4,499.00[b]	4,354.17[b]	4,923.33[a]	92.8962	<.0001
Total fecel energy output, kcal	247.53[c]	898.89[a]	490.55[b]	40.784	<.0001
ATTD of GE in the diet, %	96.62[a]	91.01[b]	91.95[b]	0.3482	<.0001
DE of diet, kcal/kg AF	3,180.21[c]	3,325.63[b]	3,451.43[a]	12.5861	<.0001
ME of diet, kcal/kg AF	3,052.09[c]	3,192.61[b]	3,313.37[a]	12.0819	<.0001
DE of diet, kcal/kg DM	3,669.75[c]	3,745.92[b]	3,913.19[a]	14.2974	<.0001
ME of diet, kcal/kg DM	3,521.91[c]	3,596.09[b]	3,756.66[a]	13.7255	<.0001

The ground YC and RB diets have lower energy contents compared to the copra expeller diet, however, the pigs allotted in the former diets had a higher DM intake compared to the intake of the pigs in the latter diet. The lower intake of the pigs on copra expeller is attributed to its low palatability. Copra expeller is also known for its high fiber content and the energy value is relatively low when fed to pigs. The slow rate of passage of fiber through the digestive tract results in decreased feed intake, lower availability of organic matter, protein, and energy in the diet, and poorer growth performance of the animals (Dung et al., 2002; Noblet & Perez 1993). The dietary inclusion of copra meal should not exceed 15% for diets fed to weanling pigs, and 25% for diets intended for growing-finishing pigs (Stein et al., 2015).

Fecal Energy, Fecal Energy Output (FEO), and Apparent Total Tract Digestibility (ATTD) of GE in the Diets

The fecal energy from pigs fed with a copra expeller diet had the highest ($p<0.05$) value of 4,923 kcal/kg. On the other hand, the energy obtained from the feces of pigs fed with the yellow corn diet was 4,499 kcal/kg, while the rice bran diet had 4,354 kcal/kg, showing no statistical differences between the two diets.

The FEO reflects the amount of energy contained in the feces collected during the five-day collection period on a DM basis. Lower FEO is desirable because it indicates a lower amount of energy contained in the diet is wasted, which is an indication of better digestibility as reflected in the ATTD coefficients. The pigs fed the rice bran diet had the highest value of 898.89 kcal (91.01% ATTD), followed by pigs fed with CE diet with an average of 490.55 kcal (91.95% ATTD). Lastly, the pigs fed with the YC diet had the lowest FEO of 247.53 kcal (96.62%).

Digestible and Metabolizable Energy in the Diets

The digestible energy (DE) contents of the diets were computed on a fed and DM basis. From the DE values, the metabolizable energy (ME) was estimated or derived as 96% of the DE value (Holden et al., 2010). The copra expeller diet had the highest ($p<0.05$) DE and ME values of 3,913.19 DE and 3,756.66 ME kcal/kg, followed by the rice bran diet with 3,74 745.92 DE and 3,596.09 ME kcal/kg. The lowest values were computed from the yellow corn diet with 3,669.75 DE and 3,521.91 ME kcal/kg.

Energy Digestibility in the Test Ingredients

Energy digestibility in ground yellow corn, rice bran, and copra expeller in this current study was evaluated based on the concentration of digestible and metabolizable energy (kcal/kg) and the apparent total tract digestibility (ATTD) of gross energy (GE) in each ingredient.

Apparent Total Tract Digestibility of Gross Energy

The ATTD of GE reflects the amount of energy that is assumed to have been digested by the pig from the energy content of the ingredient. This parameter is used to determine the amount of energy utilized by the animals, expressed as a percent of GE intake. It only accounts for the energy lost in the feces; hence, the term is apparent.

Digestibility values obtained from the three ingredients were significantly different ($p<0.05$) from each other. Copra expeller had the highest DE value with 4,319.38 kcal/kg (as fed) and 4,921.56 kcal/kg (DM basis). This was followed by rice bran with 3,841.20 kcal/kg (as fed) and 4,364.01 kcal/kg (DM basis). Yellow corn had the lowest value with 3,251.27 kcal/kg (as fed) and 3,669.75 kcal/kg (DM basis). From the computed DE values of the ingredients, the ME values were derived by multiplying 96% of the DE (Holden et al., 2010; NRC, 2012). Based on this assumption, the estimated ME values of the ingredients are as follows: yellow corn - 3,121.30 kcal/kg (as fed) and 3,522.96 kcal/kg (DM basis); rice bran- 3,687.55 kcal/kg (as fed) and 4,189.45 kcal/kg (DM basis); and copra expeller - 4,146.60 kcal/kg (as fed) and 4,724.69 kcal/kg (DM basis). The DE and estimated ME values obtained in this current study compared to the previous study verified are presented in Figures 6 and 7. Differences in the DE and ME values of the feed ingredients as well as the difference in the values obtained from the previous study can be attributed to several factors such as nutrient composition, fiber content, processing methods, and variability in nutrient content. Each feed ingredient has a unique nutrient composition, including levels of carbohydrates, fats, proteins, and fibers, which can directly influence the energy content of the feed ingredient (NRC, 2012). Fiber content in feed ingredients can also affect their digestibility and energy content. Copra expeller and rice bran may contain varying levels of fiber, which can impact their digestibility and energy availability compared to yellow corn, which typically has lower fiber content (Noblet & Jaguelin, 2007). The processing methods used for each feed ingredient can also influence their DE values. For instance, copra expeller and rice bran may undergo different processing techniques such as drying, grinding, or heat treatment, which can affect their nutrient composition and energy content (Le Goff et al., 2002). Natural variability in nutrient content among batches of feed ingredients can also contribute to differences in DE values. Furthermore, factors such as soil quality, climate, and storage conditions can influence the nutrient composition of crops used to produce feed ingredients (Noblet et al., 2007).

Ground Yellow Corn. The GE obtained in ground yellow corn was lower at 4,044 kcal/kg compared to the values by Garcia (2020) with 4,440 kcal/kg. However, digestibility values obtained in this present study are higher with 3,669.75 DE kcal/kg and 3,522.96 ME kcal/kg with an ATTD of 90.71%, compared to the verified study by Garcia (2020) with 3,344 DE kcal/kg 3,313 ME kcal/kg with an ATTD of 75.33%.

On the other hand, the values obtained in this study are lower compared to NRC (2012) with 4,453.63 GE, 3,907 DE, and 3,844 ME kcal/kg. However, the ATTD of GE obtained in the present study is higher compared to the 87.73% ATTD by NRC (2012). Li et al. (2014) mentioned that the chemical characteristics, physical characteristics, and energy values of corn can be influenced by the location where the feedstuff was grown. Another factor that affects energy digestibility is particle size. The study of Gao (2020), concluded the mean particle size of duodenal digesta, ileal digesta, and feces was reduced with the reduction of corn particle size.

Ground yellow corn available in the local market comes in different sizes and forms as cracked, grit, and ground. The particle size of yellow corn used in this study was about 1mm or 1000 μm, while the yellow corn used by Garcia (2020) was approximately twice larger which could have resulted in lower digestibility. An ear of corn with a particle size of 1000μm is generally considered finely ground corn and is usually used in the swine diet rather than cattle diets (Loy & Lundy, 2019). Based on the study of Rojas and

Stein (2015), reducing particle size to around 400–500μm may improve energy digestibility. Corn must be milled with an average particle size of 640–650 microns (Stein, 2015; Kim et al., 2002; Wondra et al., 1995). With this, it is assumed that when a smaller particle size of yellow corn was used, the energy digestibility could have been better. Particle size is a critical consideration in using corn as raw material in feed formulation.

Rice Bran. The gross energy of rice bran obtained in this study which is 5,186 kcal/kg is higher than the reported value by Garcia (2020) with 4,650 kcal/kg. The DE and estimated ME values obtained in this study which are 4,364 DE kcal/kg and 4,189 ME kcal/kg are close to the values obtained in the verified study with 4,214 DE kcal/kg and 4,035 ME kcal/kg. However, the ATTD in the present study which is 84.14% is lower compared to the verified study with 90.62%.

On the other hand, the values obtained in the present study are notably higher than the values by NRC (2012) with 3,384 DE kcal/kg and 3,271 ME kcal/kg with an ATTD of 64.95% only from a GE of 5,209.61 kcal/kg. The ATTD of rice bran obtained in this study is also higher than the values obtained by Casas and Stein (2017) and Li et al. (2018) with 81.34% and 80.70%, respectively.

The difference in the ATTD coefficients can be attributed to the type of rice bran used, Rice bran D1 consists primarily of pericarp or bran layer and germ of rice with minimal quantity of hulls; thus, it has a lower crude fiber content (<6%) and higher crude protein (>11%). On the other hand, rice bran D2 is primarily of pericarp or bran layer and germ of rice, but has higher fiber content because it contains a higher number of hulls. It has a lower crude protein content of <9%. The aforementioned nutrient composition of rice bran is taken from Philippine Society of Animal Nutritionists (2010). It is known that the fiber content of feed ingredients lowers energy digestibility.

Higher ATTD of GE obtained in rice bran in the current and verified study is attributed to the better ability of native pigs to digest high-fiber diets. The findings of the study agree with the studies on indigenous pigs such as Black Tiaong, Kalinga native (Bondoc et al., 2017; Villanueva, 2021), and Mon Cai pigs from Vietnam (Borin et al., 2005) where they have shown better digestibility in high-fiber feedstuff compared to the hybrid pigs. Borin et al. (2005) and Len et al. (2009) stated that indigenous pig breeds may have a higher capacity to digest fiber than exotic pig breeds. Indigenous pigs were believed to have a better digestive capacity in the gastrointestinal tract and higher microbial activity in the hindgut than modified pigs, which can degrade fiber (Jorgensen et al., 1996). In the study of Cheng et al. (2018) using two different breeds of pigs, Duroc and Chinese native Lantang, they found that 53 low-abundance genera were distinct between the two pig breeds, with 11 genera being higher in the fecal microbiome of Duroc pigs, while the remaining 42 genera were higher in the Lantang fecal microbiome. It was concluded that high-fiber utilization efficiency in Lantang pigs is due to their inherent microbiological adaptation to high-fiber diets, which include the structural differences of the fecal microbial community with several genera associated with fiber utilization. The potential of putative functional genes and the number of genes encoding debranching enzymes, oligosaccharide-degrading enzymes, and lignocellulose bonding modules, contribute to extracellular fiber degradation.

Copra Expeller. The gross energy of the copra expeller used in this study is 6,062 kcal/kg, which is remarkably higher compared to the value obtained by Garcia (2020) with 4,576 kcal/kg. The DE and ME values obtained from this study were also higher with 4,921.56 DE and 4,724.69 ME kcal/kg with an ATTD of 80.78% when compared to the values determined by Garcia (2020) with 2,913 DE and 2,840 ME kcal/kg, with an ATTD of 63.66% only. With these differences in digestibility coefficients, a conclusion on the ATTD of GE in copra expeller cannot be established. The differences can be attributed to the source of the feed ingredients and the processing employed.

Moreover, the values obtained in this study are also higher than the value of 3,693 kcal/kg reported by Garcia (2019), 3,440 kcal/kg by Stein et al. (2015), and 3,430 kcal/kg by Sulabo et al. (2013). Values by NRCNA (2012) are remarkably lower with 4,082 DE kcal/kg and 3,931 ME kcal/kg but with a higher ATTD of 87.18%.

Variations in the nutrient composition of copra meal and copra expellers are mainly a function of the differences in residual oil concentration (Stein et al., 2015). Another factor that could affect the utilization of energy is the nutritional profile of the feedstuff and the treatment or processing employed, either by mechanical extraction or solvent extraction. Copra expellers are the residue from processing by the continuous screw process, mechanical extraction with an oil content of between 1.5-7%, but sometimes more if old machinery is used. In solvent extraction, copra meal is the product, which contains 0.5-1.5% depending on the efficiency of solvent extraction (Copra Expeller Cargo Handbook, n.d). In the market, copra meal and copra expeller are not distinctly labeled; thus, they are identified based on the energy content. Copra expellers have relatively higher amounts of energy compared to copra meal. Copra meal contains the following: GE value is 4,199 kcal/kg (90% DM) and crude fat is 3% (NRC, 2012), whereas CE contains 4,308 kcal/kg of GE (NRC, 2012), 14% crude fat (PHILSAN, 2010).

The amount of residual oil is a significant determinant of the nutrient density of co-products like rice bran and copra expeller; however, it was not assessed in this study. Hence, this can be explored in future related research.

Table 3

Energy Digestibility in Ground Yellow Corn, Rice Bran, and Copra Expeller Fed to 10 to 15 Kg Benguet Native Pigs

ITEM	INGREDIENTS				
	Yellow Corn	Rice Bran	Copra expeller	SEM	*p* value
DM, %	88.60	88.02	87.76	-	-
As-fed basis					
GE, kcal,kg	3,583[c]	4,565[b]	5,347[a]	-	-
DE, kcal/kg	3,251.27[c]	3,841.20[b]	4,319.38[a]	37.5546	<.0001
ME, kcal,kg	3,121.30[c]	3,687.55[b]	4,146.60[a]	36.0491	<.0001
DM basis					
GE, kcal/kg	4,044[c]	5,186[b]	6,092[a]	-	-
DE, kcal/kg	3,669.75[c]	4,364.01[b]	4,921.56[a]	42.7337	<.0001
ME, kcal/kg	3,522.96[c]	4,189.45[b]	4,724.69[a]	41.0237	<.0001
ATTD of GE, %	90.71	84.14	80.78	-	-

Note: Means with different superscripts are significantly different at P < 0.05 level; data are least-square means of 6 observations for all treatments.

Figure 6

Comparison of the DE Values of Ingredients on DM Basis (kcal/kg)

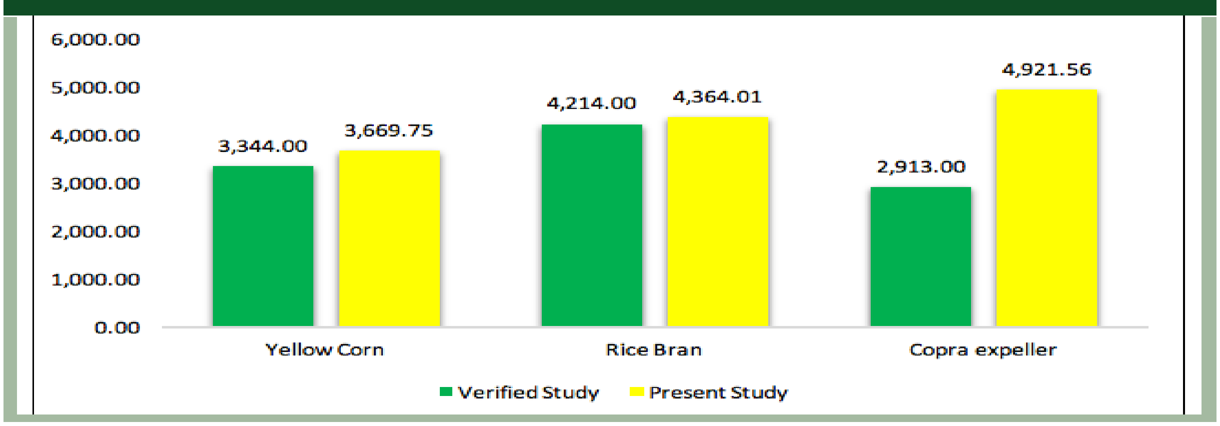
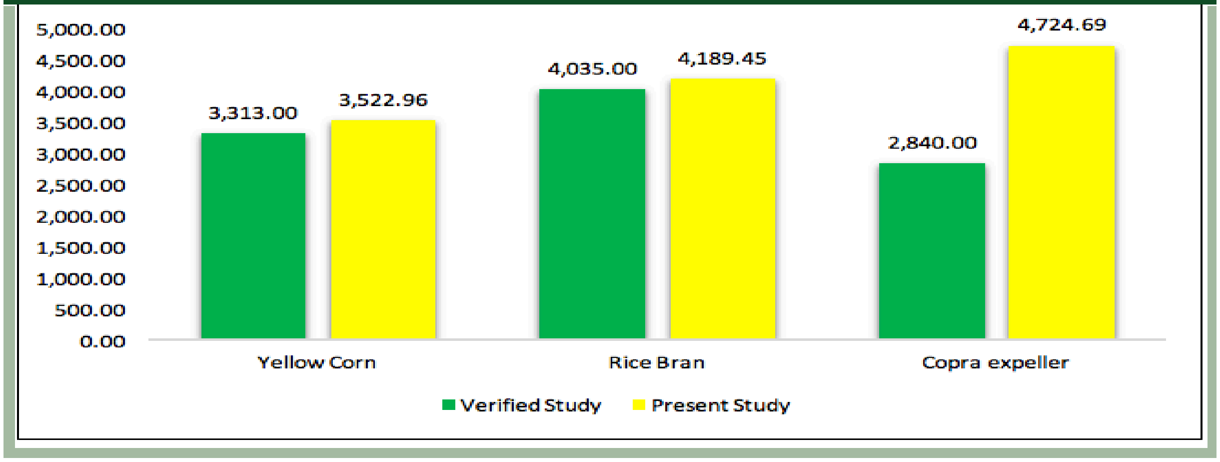


Figure 7

Comparison of the Estimated ME Values of Ingredients on DM Basis (kcal/kg)



Conclusions

The energy concentrations of the evaluated ingredients provide valuable data on their feeding values in native pigs. On a dry matter basis, ground yellow corn exhibited 3,669.75 DE kcal/kg (with an ATTD of 90.71%) and 3,522.96 ME kcal/kg. Meanwhile, rice bran had 4,364.01 DE kcal/kg (with an ATTD of 84.14%) and 4,189.45 ME kcal/kg. Lastly, the copra expeller had 4,921.56 DE kcal/kg (with an ATTD of 80.78%) and 4,724.69 ME kcal/kg. These findings underscore the importance of considering digestibility when formulating pig diets.

The digestibility values obtained for rice bran suggest its superior utilization in native pig breeds compared to exotic breeds. This highlights the potential for leveraging locally available feed resources to optimize performance in specific pig populations, contributing to more sustainable and cost-effective production systems. Discrepancies in digestibility values for yellow corn and copra expeller compared to previous studies may be attributed to variations in particle size and nutrient composition of the raw materials. These findings emphasize the need for careful selection and characterization of feed ingredients to ensure accurate formulation and predictable performance outcomes in pig diets.

The study's findings hold significant implications for native pig nutrition and feed management practices. By identifying the most digestible and energy-dense feed ingredients, producers can enhance feed efficiency, reduce production costs, and minimize environmental impact. Moreover, leveraging locally available resources, such as rice bran, not only improves economic viability but also supports sustainable agricultural practices and strengthens food security in pig farming communities.

Recommendations

As per findings of this study, the recommendations are as follows: (1) Considering the digestible energy and metabolizable energy values obtained from yellow corn and rice bran, they are well-suited for formulating rations tailored to the nutritional requirements of 10kg to 15kg Benguet native pigs; (2) It is recommended to conduct a growth trial that explores different levels of rice bran inclusion in the diet of Benguet native pigs to maximize growth performance, feed efficiency, and economic returns; (3) When formulating diets for Benguet native pigs, it is recommended to use yellow corn with a particle size not exceeding 1mm. This finer particle size enhances digestibility, ensuring that the pigs can efficiently utilize the energy and nutrients present in the feed, ultimately leading to improved growth and performance; and (4) Before feed formulation, raw materials intended for research purposes should undergo thorough energy and proximate analysis. This analysis ensures the accuracy of nutrient composition data, enabling researchers to formulate diets with precision and confidence. Moreover, it allows for adjustments to be made based on variations in ingredient quality or availability, thereby optimizing feed formulations for consistent and reliable results in research trials.

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