International Journal of Agricultural Technology 2026 Vol. 22(6):2569-2588
DOI: https://doi.org/10.63369/ijat.2026.22.6.2569-2588
Available online http://www.ijat-aatsea.com
ISSN 2630-0192 (Online)

Nutrient and energy content of alternative feedstuffs and formulated diets for Swine and Poultry in the Tropics

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Escala, E. J. (2026). Nutrient and energy content of alternative feedstuffs and formulated diets for Swine and Poultry in the Tropics. International Journal of Agricultural Technology 22(6):2569-2588.

Abstract This study evaluated the nutritional composition and metabolizable energy (ME) values of locally available alternative feedstuffs—specifically cassava (*Manihot esculenta*), rice (*Oryza sativa*) bran, corn (*Zea mays*) bran, and sprouts, moringa (*Moringa oleifera*) leaves, madre de agua (*Trichantera gigantea*), water spinach (*Ipomoea aquatica*), azolla (*Azolla pinnata*), mungbean (*Vigna radiata*) and its sprouts, shrimp (*Litopenaeus vannamei*) by-product meal (SBPM) and fish silage (FS). Significant differences were observed among the feedstuffs across most parameters. Rice bran D1 had the maximum levels of crude protein (CP), crude fat (EE), and minerals such as calcium (Ca), phosphorous (P), magnesium (Mg), and potassium (K), while the lowest values were found in corn bran and cassava tuber. ME values varied, with cassava tuber exhibiting the highest ME for poultry. Among leaf meals, moringa leaf meal recorded the highest CP and EE, and lowest crude fiber (CF), while cassava leaf meal had the highest CF. *Trichantera gigantea* had the highest ash and mineral content. Cassava and moringa leaves had the highest ME for swine, while cassava leaf meal had the highest ME for poultry. SBPM had higher CP, CF, ash, Ca, and P than FS, though CP differences were not significant. FS showed higher EE, lower CF, and greater ME for both swine and poultry. Sprouting improved the nutrient profile of corn and mungbean. CP and ME increased in 9-day (9d) corn sprouts (CS), while 9d mungbean sprouts (MS) showed higher CP, ash, and minerals but reduced ME with extended sprouting. Formulated diets using these feedstuffs met nutrient and energy needs of swine, egg-type and native chickens, though fiber exceeded acceptable limits in some cases. These findings are highlighted the viability of tropical alternative feed resources as sustainable substitutes for conventional feeds.

Keywords: Feed formulation, Leaf meals, Marine by-products, Proximate analysis, Sprouts

Introduction

Animal production contributes greatly to the global supply system, serving a dual purpose in nutrition provision and economic support for rural populations. As the global appetite for meat, eggs, and related animal products continues to grow, there is increasing pressure on existing production systems to

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scale up in an environmentally and economically sustainable way. Makkar (2018) noted thatthe increase in consumption has led to increased dependence on traditional feed sources such as maize, soybean meal, and similar feed materials which have become more costly, more competitive with human food supplies and dependent on imports in many developing countries. Increased use of conventional feed ingredients not only poses threats to the viability of smallholder farming but also leads to environmental problems like land degradation, emission of greenhouse gases, and resource use related to feed crop cultivation. According to the literature review in the works of Makkar *et al*. (2014), Swain *et al*. (2014), Baruah *et al.* (2022), and Bature *et al.* (2022), increasing interest in researching alternative feed sources is seen. Alternatives to traditional feed sources are needed that can provide sufficient feed with minimum negative impacts on the environment. Unconventional feed sources that include agricultural wastes, crop residues, meals of forages, and marine wastes are being increasingly used for reducing the cost and improving the availability of feeds along with minimizing the impact of livestock production on the environment. In many developing countries, especially those in tropics, the use of alternative sources of feed has been necessitated due to many reasons. These smallholder farmers, working in resource-scarce environments, are currently making use of alternative ingredients like rice bran, cassava tubers, corn bran, fish viscera, shrimp viscera, and different leaf meals in their feed formulations (Devendra and Leng, 2011; Wanapat *et al.,* 2015). But what is preventing their efficient and extensive utilization in livestock feed formulation is the lack of information regarding their nutritional value and effectiveness of feeding. There is a variation in the composition and digestibility of these materials because of their source, processing, and even storage, which makes it necessary for their local assessment to be included in balanced diets. A more strategic evaluation of these feed resources will provide farmers and feed formulators with recent and relevant data for the preparation of an unconventional feedstuffs-based feed formulation. Previous studies by Malama *et al.* (2020), Elliott *et al*. (2022), and Ancheta *et al*. (2025) have demonstrated that innovative feed enhancement techniques, such as sprouting, can significantly improve the digestibility and nutrient density of various feedstuffs.

Despite this, the nutrient composition can vary significantly based on the specific type of material used for sprouting. Swine, egg-type chickens, and native chickens play a vital role in smallholder farming systems in tropical regions, which provides food and income for the households (McDermott *et al*., 2010; FAO, 2015). Developing cost-effective, nutritionally balanced diets using local alternative feed ingredients is essential not only to address feed cost challenges

but also to promote the long-term sustainability and resilience of these production systems.

Whereas many studies have been conducted regarding individual feed components, little work has been done on the nutritional qualities of complete feeds that have been formulated through such novel materials for non-ruminants including egg-type chicken, indigenous chicken, and swine. The mentioned species are vital for supporting the livelihood of smallholder farmers living in tropical climates. Nevertheless, feed costs amount to 70% of total costs of production in such feeding systems, hence the need for formulating low cost, yet nutritious rations.

The study addressed the limited information on the nutrient content and feeding value of locally available alternative feed materials, which hinders their effective use in formulating diets for egg-type chickens, native chickens, and swine raised by smallholder farmers. Specifically, their proximate composition, mineral content, and energy values were investigated. The goal was to assess how well these materials can meet the dietary needs of egg-type chickens, native chickens, and swine.

Materials and methods

Selection and gathering of feedstuffs

The experiment was undertaken at the Livestock Project, Capiz State University-Pontevedra Campus from January to December 2024, utilizing a variety of locally sourced agronomic crops, crop by-products, leaf meals, legumes, and their sprouts, as well as marine by-products, selected based on their availability. These materials were commonly found in the Philippines and in other tropical regions where some are already utilized individually or in combination by farmers as supplement to their animal's diet. The feedstuffs chosen include cassava (*M. esculenta*) tubers and leaves (Lakan-1 variety), rice (*O. sativa*) bran (D1, D2), corn bran (*Z. mays*), moringa leaves (*M. oleifera*), madre de agua (*T. gigantea*), water spinach (*I. aquatica*), azolla (*A. pinnata*), mungbean (*V. radiata*) and its sprouts, and marine by-products such as SBPM and FS. One kilogram of each feedstuff were dried, ground (except rice bran and corn bran since they are already fine) and submitted to proximate analysis, mineral analysis and gross energy determination.

Preparation of sprouts

Nine kilograms of mungbean and yellow corn kernel were immersed in a solution of 0.1% hypochlorite, following the procedure of Morgan *et al*. (1992),

and left at room temperature for 24 hours to initiate pre-germination. Succeedingly, the seeds were washed to remove impurities and unviable seeds. Then it was divided into 3 equal portions and spread evenly on top of the sprouting rack (118.11 x 18 x 1 inches), lined with empty sacks that served as bedding material. The seeds were covered with damp cloth for a day and allowed to germinate for 3, 6, and 9 days (Gacutan *et al*., 2021). To maintain moisture, the seeds were sprayed with water three times daily until harvest. On the designated days, the sprouts were harvested and their nutritional composition was measured through proximate analysis.

Selection and preparation of shrimp meal and fish silage

Shrimp by-products such as heads (60%) and shells (40%) were obtained and cleaned to remove any contamination. These samples were dried in an oven at 70°C to fully dry out, then ground into powder using a typical kitchen grinder. Fish by-products consisting of heads (40%), viscera (30%) and bones (30%) were obtained from a local market, cleaned with clean fresh water, then soaked in 20% vinegar (pH 4). Molasses was incorporated at a rate of 300 g per kilogram of fish by-products. The mixture was then transferred into a clean, food-grade polyethylene container with a tightly sealed cap and stored in a cool, dry, and dark environment for 14 days to allow for fermentation (Arason, 1994; Rao *et al*., 2009).

Proximate analysis, mineral content and gross energy determination of samples

Nutrient profiling was carried out on representative samples from each feedstuff to assess moisture free content, protein level, fat content, and fiber. These analyses followed the standardized procedure established by the AOAC (2016). Calcium was measured using Titrimetric method, while Mg and K levels were quantified through Atomic Absorption Spectrophotometry, while P using colorimetric method. Gross energy values were determined following Atwater and Bryant (1900) while ME was estimated using a predictive equation adapted from Carpenter and Clegg (1956).

Diet formulation using the selected locally available alternative feedstuffs

Two diet formulations using the test feedstuffs were prepared and subjected to proximate analysis to determine whether their nutrient content meets the dietary requirements of swine, egg-type chickens, and native chickens. A trial-

and-error method using Microsoft Excel was employed in the formulation process, based on dry matter (DM) content. The recommended nutrient levels for different stages of swine, egg-type, and native chickens commonly raised by smallholder farmers in the tropics is shown in Table 1. These recommendations were used to guide feed formulation, and proximate analysis was done to check if the formulated diets met the required nutrient levels.

Table 1. Nutrient recommendation for various stages of swine, egg-type, and native chickens

[c]Nutrients (%DM Basis)	[a]Swine			[a]Egg-type chickens		[b]Native Chicken
	Starter	Grower	Finisher	Developer (12-18 wks)	Layer (18-42 wks)	Grower (6-14 wks)
CP%	18.3	16.8	14.4	14-14.50	16.90-17.50	15.34
CF%	<5.0	<5.5	<6.0	-	-	-
Ca%	0.85	0.75	0.75	0.90-0.95	3.45-3.58	1.47%
P%	0.52	0.50	0.45	0.43-0.45	0.42-0.44	0.60%
ME (kcal.kg^{-1})	3150	3000	3000	2650-2750	2700-2800	2,993.29

[a]Nutrient recommendation values taken from PHILSAN, 2010; [b]Nutrient recommendation values taken from Lisnahan *et al.,* 2017; [c]CP (Crude Protein), CF (Crude Fiber), Ca (Calcium), P (Phosphorus), ME (Metabolizable Energy), kcal.kg^{-1} (Kilocalories per kilogram); – (unavailable values).

Experimental setup and statistical procedures

To assess each feedstuff and the formulated diets, a Completely Randomized Design (CRD) was employed, with four replicates assigned per treatment. Analysis of Variance (ANOVA) was used to determine significant differences in nutrient composition and energy content. Upon detection of significant effects, Tukey's Honest Significant Difference method was used to compare group means. Data from marine by-products were analyzed for normality (Shapiro–Wilk test) and variance homogeneity (Levene's test), with pairwise comparisons conducted using an independent samples t-test where applicable. All analyses were carried out in SPSS, with statistical significance determined at $P < 0.05$.

Results

Proximate composition, mineral content, and estimated energy values of locally available alternative feed sources

A comparison of the nutrient profile, mineral concentrations, and calculated energy values among selected locally sourced alternative energy feed ingredients is shown in Table2. Highly significant variations ($P<0.001$) were

observed in all measured parameters. Rice bran D1 exhibited the highest values for CP (13.07%), EE (8.57%), Ca (0.31%), P (2.01%), Mg (0.96%), and K (1.41%). Rice bran D2 recorded the highest CF content (19.13%) but had the lowest EE (0.66%). Corn bran showed generally lower nutrient values, while cassava tuber had the lowest CP (2.58%) and mineral contents, except for Ca, which was comparable to that of Rice bran D1 (0.31%). ME also varied notably among the feedstuffs from 1,393.72 kcal.kg^{-1} DM in corn bran to 2,465.75 kcal.kg^{-1} DM in rice bran D1 for swine, and 2,550.24 kcal.kg^{-1} DM in rice bran D2 to 3,199.01 kcal.kg^{-1} in cassava tuber for poultry.

Table 2. Comparative proximate composition, mineral content, and energy values of selected locally available alternative energy feedstuffs

[e]Nutrient components (%DM, Basis)	Feedstuffs				
	Rice bran D_1	**Rice bran D_2**	**Corn bran**	**Cassava Tuber**	**p-value**
DM, %	85.54 ± 0.04[d]	89.50 ± 0.06[a]	88.01 ± 0.02[b]	86.86 ± 0.09[c]	<0.001
CP, %	13.07 ± 0.33[a]	10.03 ± 0.62[b]	10.15 ± 0.43[b]	2.58 ± 0.21[c]	<0.001
CF, %	6.23 ± 0.08[b]	19.13 ± 0.38[a]	2.53 ± 0.01[c]	1.98 ± 0.07[c]	<0.001
EE, %	8.57 ± 0.10[a]	0.66 ± 0.07[c]	1.59 ± 0.04 [b]	0.00[d]	<0.001
Ash, %	8.19 ± 0.04[b]	10.64 ± 0.15[a]	2.89 ± 0.04[c]	1.78 ± 0.05[d]	<0.001
Ca, %	0.31 ± 0.00[a]	0.31 ± 0.00[a]	0.21 ± 0.00[b]	0.31 ± 0.00[a]	<0.001
P, %	2.01 ± 0.04[a]	0.97 ± 0.0[b]	0.59 ± 0.00[c]	0.04 ± 0.03[d]	<0.001
Mg, %	0.96 ± 0.02[a]	0.46 ± 0.03[b]	0.19 ± 0.00[c]	0.10 ± 0.00[d]	<0.001
K, %	1.41 ± 0.03[a]	0.81 ± 0.02[b]	0.64 ± 0.04[c]	0.57 ± 0.03[d]	<0.001
ME (kcal.kg^{-1})					
Swine	2,465.75	2,040.19	1,393.72	-	
Poultry	2,994.13	2,550.24	2,613.22	3,199.01	

[a-d]Values within a row bearing different superscript letters indicate statistically significant differences ($P < 0.05$); [e]DM (Dry Matter), CP (Crude Protein), CF (Crude Fiber), Ca (Calcium), P (Phosphorus), ME (Metabolizable Energy), kcal.kg^{-1} (Kilocalories per kilogram); – (unavailable values).

The proximate analysis, mineral content, and estimated energy values of leafmeals and marine by-products as alternative protein feedstuffs. Significant differences ($P < 0.001$) were noted among the evaluated leaf meals (Table 3). Among the leaf meals, moringa exhibited the highest CP content at 27.11%, followed by cassava leaf meal at 24.18%, while water spinach had the lowest CP content at 13.18%. CF was highest in cassava leaf meal (14.16%), followed by water spinach (13.07%), while moringa leaf meal recorded the lowest CF value at 8.97%. EE content was highest in moringa leaf meal (4.21%) and cassava leaf meal (4.19%), and lowest in madre de agua (1.79%). In terms of ash and mineral content, madre de agua showed notably high values with ash (20.65%), Ca (5.75%), P (2.01%), Mg (0.57%), and K (2.05%). Among the leafmeals, cassava

leaf and moringa recorded the highest ME values for swine, with 3,351.10 and 3,177.26 kcal.kg^{-1}, respectively. For poultry, cassava leaf meal showed the highest ME (3,004.15 kcal.kg^{-1}).

Table 3. Proximate analysis, mineral content, and estimated energy values of leafmeals as alternative protein sources

[f]Nutrient components (DM Basis)	[e]Leafmeals					
	Cassava leaf meal	Moringa leaf meal	Madre de agua	Water spinach	Azolla	p-value
DM, %	89.40 ± 1.04[b]	89.12 ± 0.12[b]	88.58 ± 0.09[b]	92.44 ± 0.79[a]	88.89 ± 0.46[b]	<0.00
CP, %	24.18 ± 0.65[b]	27.11 ± 0.48[a]	16.51 ± 0.22[c]	13.18 ± 0.37[d]	17.69 ± 1.58[c]	<0.00
CF, %	14.16 ± 0.22[a]	8.97 ± 0.59[c]	12.69 ± 0.98[b]	13.07 ± 0.34[b]	12.81± 0.47[b]	<0.00
EE, %	4.19 ± 0.31[a]	4.21 ± 0.51[a]	1.79 ± 0.13[d]	3.52 ± 0.34[b]	2.61 ± 0.65[c]	<0.00
Ash, %	6.80 ± 0.03[d]	12.92 ± 4.99[c]	20.65 ± 0.18[ab]	21.26 ± 2.97[a]	16.92 ± 0.95[b]	<0.00
Ca, %	1.02 ± 0.04[c]	1.99 ± 0.08[b]	5.75 ± 0.04[a]	0.10 ± 0.01[d]	1.00 ± 1.22[c]	<0.00
P, %	0.30 ± 0.00[c]	0.37 ± 0.00[b]	2.01 ± 0.03[a]	0.02 ± 0.00[d]	0.02 ± 0.00[d]	<0.00
Mg, %	0.49 ± 0.01[c]	0.54 ± 0.00[b]	0.57 ± 0.02[a]	0.03 ± 0.02[d]	0.04 ± 0.01[d]	<0.00
K, %	1.41 ± 0.00[c]	1.44 ± 0.02[b]	2.05 ± 0.03[a]	0.08 ± 0.00[d]	0.05 ± 0.02[d]	<0.00
ME (kcal.kg^{-1})						
Poultry	3,004.15	2,854.72	2,385.69	-	-	
Swine	3,351.10	3,177.26	2,665.87	-	-	

[a-d]Values within a row bearing different superscript letters indicate statistically significant differences (P < 0.05); [e]Leafmeals: Cassava (*Manihut esculenta*); Moringa (*Moringa oleifera*), Madre de agua (*Trichantera gigantea*);Water spinach (*Ipomoea aquatica*); Azolla (*Azolla pinnata*); [f]DM (Dry Matter), CP (Crude Protein), CF (Crude Fiber), EE (Ether Extract), Ca (Calcium), P (Phosphorous), Mg (Magnesium), K (Potassium), ME (Metabolizable Energy), kcal.kg^{-1} (Kilocalorie per kilogram), – (unavailable values)

Significant variations were found in all measured parameters of the marine by-products except CP (Table 4). Although SBPM had a higher CP content (31.49%) compared to FS (28.75%), there was no significant effect detected (P=0.48). SBPM contained higher CF (20.19%), ash (39.10%), Ca (13.06%), and P (1.90%) compared to FS. Conversely, FS had higher EE (2.27%), lower CF (14.23%), and higher estimated ME values for poultry (2,780.43 kcal.kg^{-1}) and swine (3,090.50 kcal.kg^{-1}).

Table 4. Proximate analysis, mineral content, and estimated energy values of marine by-products as alternative protein sources

[b]Nutrient components (%) (% DM Basis)	[a]Marine by-products		
	SBPM	FS	p-value
DM	92.30 ± 0.10	86.08 ± 0.07	<0.00
CP	31.49 ± 7.30	28.75 ± 0.45	0.48
CF	20.19 ± 0.40	14.23 ± 0.42	<0.00
EE	0.61 ± 0.22	2.27 ± 0.15	<0.00
Ash	39.10 ± 0.02	7.14 ± 0.02	<0.00
Ca	13.06 ± 0.05	1.71 ± 0.05	<0.00
P	1.90 ± 0.01	1.12 ± 0.01	<0.00
Mg	0.59 ± 0.01	0.13 ± 0.01	<0.00
K	0.40 ± 0.01	0.64 ± 0.03	<0.00
ME ($kcal.kg^{-1}$)			
Poultry	1,839.74	2,780.43	
Swine	2,023.35	3,090.50	

[a]Mean ± SD of marine by-products indicate show statistically significant differences at the 5% level ($P < 0.05$); [b]DM (Dry Matter), CP (Crude Protein), CF (Crude Fiber), EE (Ether Extract), Ca (Calcium), P (Phosphorous), Mg (Magnesium), K (Potassium), ME (Metabolizable Energy), $kcal.kg^{-1}$ (Kilocalorie per kilogram), – (unavailable values)

The nutrient components of corn and mungbean sprouts as alternative feedstuffs displayed in Table 5 revealed notable variations ($P< 0.05$) across sprouting durations—three, six, and nine days. Corn sprouts exhibited higher DM content (98.79%) compared to unsprouted corn (94.91%), with the highest value at 9d. CP increased from 8.29% in unsprouted corn to 9.46% in 9d CS, while CF peaked at 3.28% in 9d CS. EE and ash contents were highest in 3-day CS at 4.27% and 1.60%, respectively. Ca levels in unsprouted and sprouted corn remained comparable across germination days. In contrast, P, Mg and K contents were highest in both unsprouted and 3-day (3d) CS. Estimated ME values for poultry and swine were highest in 9d CS at 3, 466.50 and 3,898.52 $kcal.kg^{-1}$, respectively. For MS, a significant increased ($P<0.001$) in CP was observed from 23.41% in unsprouted to 36.16% in 9d MS. However, CF also markedly increased, nearly tripling from 4.09% (unsprouted) to 13.65% in 9d MS. Ash, Ca, P, Mg, and K contents significantly increased with sprouting durations ($P<0.001$), with highest values observed in 9d MS. Conversely, ME values of MS showed a noticeable decline as sprouting duration increased.

Nutrient profile, mineral content, and energy values of formulated diets using locally available alternative feed sources for swine and poultry

The two diets formulated from locally sourced alternative feedstuffs, while presenting their proximate composition (Table 6). Diet A contained 14.84% CP, 6.48% CF, 5.06% EE, and 10.31% ash. It also provided Ca at 2.33%, P at 0.93%, and estimated ME of 2,699.67 $kcal.kg^{-1}$ for swine. Diet B contained a slightly higher CP level of 15.36% and CF at 8.67%, but lower EE (3.56%) and ash (9.92%) with Ca and P levels at 2.00% and 0.67%, respectively, associated with

ME value of 2,501.61 kcal.kg^{-1} for poultry. When compared to the nutrient recommendation for the different types and stages of poultry and swine in Table 1, both diets met the crude protein requirement for swine finishers (14.4%), egg Developer (14-14.50%), and native chicken growers (15.34%). However, the crude fiber content in both diets exceeded the recommended limit for swine (≤6.0%). Diet A met the energy requirement for egg-type chickens in the developer phase (2,650–2,750 kcal.kg^{-1}), while the ME value of Diet B was below the standard requirements for all evaluated classes—swine, egg-type chickens, and native chickens.

Table 5. Nutrient composition of corn and mungbean sprouts as alternative feedstuffs

[c]Nutrient components (% DM Basis)	[a-d]Corn				
	Unsprouted Corn	**CS (3d)**	**CS (6d)**	**CS (9d)**	**p-value**
DM	94.91^{c} ± 0.42	97.77^{b} ± 0.45	97.92^{b} ± 0.78	98.79^{a} ± 0.17	<0.00
CP	8.29^{b} ± 0.66	9.08^{a} ± 0.37	8.93^{ab} ± 0.19	9.46^{a} ± 0.01	<0.01
CF	2.53^{c} ± 0.20	2.24^{d} ± 0.12	2.78^{b} ± 0.04	3.28^{a} ± 0.13	<0.00
EE	3.62^{b} ± 0.10	4.27^{a} ± 0.06	3.06^{c} ± 0.08	3.60^{b} ± 0.15	<0.00
Ash	1.37^{c} ± 0.05	1.60^{a} ± 0.02	1.28^{d} ± 0.02	1.42^{b} ± 0.01	<0.00
Ca	0.33 ± 0.05	0.29 ± 0.05	0.28 ± 0.05	0.34 ± 0.05	0.31
P	0.24^{ab} ± 0.01	0.25^{a} ± 0.01	0.19^{c} ± 0.01	0.22^{b} ± 0.01	<0.00
Mg	0.05^{a} ± 0.00	0.05^{a} ± 0.00	0.04^{b} ± 0.01	0.04^{b} ± 0.00	<0.00
K	0.41^{a} ± 0.02	0.41^{a} ± 0.02	0.31^{c} ± 0.02	0.36^{b} ± 0.02	<0.00
ME (kcal.kg^{-1})					
Poultry	3,334.21	3,458.73	3,402.55	3,466.50	
Swine	3,751.35	3,890.62	3,827.44	3,898.52	
[c]Nutrient components (% DM Basis)	**[a-d]Mungbean**				
	Unsprouted Mungbean	**MS (3d)**	**MS (6d)**	**MS (9d)**	**p-value**
DM	95.59 ± 0.27^{a}	92.66 ± 0.12^{c}	94.37 ± 0.16^{b}	91.72 ± 0.04^{d}	<0.001
CP	23.41 ± 0.31^{d}	30.39 ± 0.33^{c}	33.27 ± 0.45^{b}	36.16 ± 0.26^{a}	<0.001
CF	4.09 ± 0.01^{d}	7.47 ± 0.16^{c}	8.47 ± 0.13^{b}	13.65 ± 0.21^{a}	<0.001
EE	0.93 ± 0.09^{b}	1.32 ± 0.14^{ab}	1.30 ± 0.35^{ab}	1.67 ± 0.42^{a}	<0.001
Ash	3.65 ± 0.05^{d}	4.53 ± 0.05^{c}	5.40 ± 0.14^{b}	6.29 ± 0.10^{a}	<0.001
Ca	0.11 ± 0.07^{c}	0.29 ± 0.05^{b}	0.44 ± 0.04^{a}	0.42 ± 0.00^{a}	<0.001
P	0.29 ± 0.05^{d}	0.48 ± 0.00^{c}	0.54 ± 0.01^{b}	0.64 ± 0.01^{a}	<0.001
Mg	0.13 ± 0.00^{d}	0.17 ± 0.00^{c}	0.19 ± 0.00^{b}	0.24 ± 0.00^{a}	<0.001
K	0.29 ± 0.05^{d}	0.48 ± 0.00^{c}	0.54 ± 0.01^{b}	0.64 ± 0.01^{a}	<0.001
ME (kcal.kg^{-1})					
Poultry	3,163.36	3,052.09	3,087.45	2,981.29	
Swine	3,532.24	3,394.50	3,429.45	3,304.55	

[a-d]Values within a row bearing different superscript letters indicate statistically significant differences (P < 0.05); CS (Corn Sprout), MS (Mungbean Sprout); [c]DM (Dry Matter), CP (Crude Protein), CF (Crude Fiber), EE (Ether Extract), Ca (Calcium), P (Phosphorous), Mg (Magnesium), K (Potassium), ME (Metabolizable Energy), kcal.kg^{-1} (Kilocalorie per kilogram), – (unavailable values)

Table 6. Composition of diets for egg-type chickens, native chickens, and swine finisher using locally alternative nutrient sources

Feedstuffs	[a]Diet A (%DM, Basis)								
	%DM	%CP	%CF	%EE	%Ash	%Ca	%P	ME (kcal.kg^{-1})	
								Poultry	Swine
Rice bran D1	85.54	13.07	6.23	8.57	8.19	0.31	2.01	2,994.13	2,465.75
Corn bran	88.01	10.15	2.53	1.59	2.89	0.21	0.59	2,613.22	1,393.72
Cassava tuber	86.86	2.58	1.98	-	1.78	0.31	0.04	3,199.00	
Cassava leaf meal	89.40	24.18	14.16	4.19	6.80	1.02	0.30	3,004.15	3,351.10
Madre de agua	88.58	16.51	12.69	1.79	20.65	5.75	2.01	2,385.69	2,665.87
Shrimp by-product meal	92.30	31.49	20.19	0.61	39.10	13.06	1.90	1,839.74	2,023.35
[c]Molasses	75.00	2.90	-	-	-	-	-	1,960	2,330
[c]Palm oil	99.00	-	-	99.00	-	-	-	8,000	7,800
Feedstuffs	**[b]Diet B (%DM, Basis)**								
	%DM	%CP	%CF	%EE	%Ash	%Ca	%P	ME (kcal.kg^{-1})	
								Poultry	Swine
Rice bran D2	89.50	10.03	19.13	0.66	10.64	0.31	0.97	2,550.24	2,040.19
Corn bran	88.01	10.15	2.53	1.59	2.89	0.21	0.59	2,613.22	1,393.72
Cassava tuber	86.86	2.58	1.98	--	1.78	0.31	0.04	3,199.00	--
Fish silage	86.08	28.75	14.23	2.27	7.14	1.71	1.12	2,780.43	3,090.50
Shrimp by product	92.30	31.49	20.19	0.61	39.10	13.06	1.90	1,839.74	2,023.35
Moringa leaf meal	89.12	27.11	8.97	4.21	12.92	1.99	0.37	2,854.72	3,177.26
Oyster	-	0.42	0.11	-	80.95	-	-	-	-
[c]Coconut oil	99.00	-	-	99.00	-	-	-	8,600	-

[a]Nutrient composition of Diet A; [b]Nutrient composition of Diet B; [c]Values taken from PHILSAN 2010, -DM (Dry Matter), CP (Crude Protein), CF (Crude Fiber), EE (Ether Extract), Ca (Calcium), P (Phosphorous), Mg (Magnesium), K (Potassium), ME (Metabolizable Energy), kcal.kg^{-1} (Kilocalorie per kilogram), – (unavailable values)

Table 7. Proximate analysis of formulated diets composed of locally available alternative feedstuffs for egg-type and native chickens and swine diets

Diets	Nutrient Composition of Diets (% DM, Basis)								
	%DM	%CP	%CF	%EE	%Ash	%Ca	%P	ME (kcal.kg^{-1})	
								Poultry	Swine
A	92.79	14.84	6.48	5.06	10.31	2.33	0.93	-	2,699.67
B	89.95	15.36	8.67	3.56	9.92	2.0	0.67	2,501.61	-

Note: DM (Dry Matter), CP (Crude Protein), CF (Crude Fiber), EE (Ether Extract), Ca (Calcium), P (Phosphorous), Mg (Magnesium), K (Potassium), ME (Metabolizable Energy), kcal.kg^{-1} (Kilocalorie per kilogram), – (unavailable values)



Figure 1. Pelleted feeds composed of the locally available alternative feedstuffs for native chicken grower (A) and swine finisher (B)

Discussion

Proximate composition, mineral content, and estimated energy values of locally available alternative feed sources

Feedstuffs—particularly Rice bran D1 and cassava tuber—show potential as alternative energy sources in swine and poultry diets. ME levels in cassava tubers used in this study exceeded the commonly reported range 3,000-3,200 kcal.kg^{-1}, as documented by Egena (2006), Buitrago *et al*. (2007), Khajarern and Khajajern (2007). This elevated ME value supports the suitability of cassava tubers for use as a valuable energy source for poultry feed formulations. Cassava provides the highest carbohydrate content in food plants and can potentially replace corn in supplying energy components in chicken diets (Morgan and

Choct, 2016). Nevertheless, due to their low CP and mineral content, there would be need for supplementation with proteins and minerals or inclusion of other supplementary feedstuffs to have a balanced ration. On the other hand, feed ingredients like corn bran and Rice bran D2, having lower energy content but moderate to high fiber and CP levels, may be more appropriate as partial ingredients in diets for grower or finisher stages where animals are tolerant to higher fiber. The appropriateness of the feedstuffs is further dependent on the physiological status of the animal. This means that the starter pigs would need more energy and protein than the test feedstuffs alone provide. However, these ingredients can serve as cost-effective alternatives in grower or finisher diets when combined with higher-energy supplements. According to findings by Anaeto and Adighibe (2011), as well as subsequent research by Ghomsi *et al*. (2017) and Kim *et al.* (2021), partially replacing conventional energy sources such as maize with cassava or rice bran in swine and poultry diets had no detrimental effect on animal performance, provided that nutritional balance was maintained. Likewise, rice bran is commonly utilized as part of the diets of food animals (Chae *et al*., 2002; Schramm *et al*., 2007) given its rich energy content along with favorable bioactive compounds, including essential key nutrients including vitamins, plant sterols, fibers, and vital minerals (Gul *et al.,* 2015; Heredia-Olea *et al*., 2020).

The levels of EE, CP, and CF observed for moringa in the present analysis were consistent with those reported by Gidamis *et al*. (2003), Sarwatt *et al*. (2004), Olugbemi *et al*. (2010), and Sultana (2020). Increased CP levels in *M. oleifera* and *M. esculenta* leaf meals confirm their value as plant-derived source of protein for swine (Zhang *et al*., 2019) and poultry animals (Tesfaye *et al*., 2013). But the high amount of fiber should be considered in the inclusion rate of these feedstuffs specially for poultry and swine diets. Studies in swine have shown that diets high in fiber can influence the morphology of the intestinal lining, as demonstrated by Jin *et al*. (1994). Different approaches have been explored to increase the dietary benefits of fibrous materials as feed for pigs, as noted by Agyekum *et al*. (2017). Native or indigenous chickens are known to exhibit greater tolerance to dietary CF than commercial breeds (Mabelebele *et al*., 2014). Although they are typically resilient and adaptable, questions remain about how effectively they can break down CF. The DM, CF, ash, and Ca content of madre de agua are consistent with the observations by Jaya *et al*. (2008). Madre de agua, when fed to layer chickens, has been found to increase yolk color, suggesting it is a good source of protein and beneficial for the egg's natural pigment (Balba *et al*., 2026). According to Attia *et al.* (2023), it has been observed that *T. gigantea* leaves have a good composition of amino acids that is equal to that of soybean meal, which is a common feed for animal’s diet. Also, it

has been observed that *T. gigantea* contains rich amounts of important minerals such as Ca, P, and K.

In this study, FS proved to have a more beneficial nutrient content than SBPM in this study. Despite both feedstuffs being rich in CP content, FS proved to have more digestibility indicators due to its low CF and ash content, high EE levels and higher ME value for poultry and swine. The results of Santana *et al.* (2023) and Putri *et al.* (2024) confirmed the presence of FS variability in nutritional content influenced by different sources and processing. Similar results were obtained by Brito *et al*. (2020) and Eggink *et al.* (2025) regarding the SBPM feedstuff. The reasons for such variability are related to different origins, species, age, feeding, processing techniques, and ratios of viscera including head and shell in shrimp as stated by Okoye *et al.* (2005). Despite having lower digestibility indicators, SBPM is considered to be useful in the diets of laying hens because of the large amount of Ca and P – minerals important for eggshells formation. On the contrary, addition of FS to broiler diet has been shown to be linked with good growth performance, which may be due to increased activity of digestive enzymes, improved nutrient absorption, and alteration in gut microbial population like increase in beneficial microbes and enhanced short-chain fatty acids production (Shabani *et al.,* 2019). Similarly, SBPM has also proved to be effective in improving performance of animals (Linh *et al.,* 2003; Septinova *et al.,* 2011). Particularly, its superior mineral composition, especially with respect to higher calcium content than FS, makes it an attractive protein meal option for mineral supplementation in poultry feeding. Therefore, both FS and SBPM qualify to be used in diet.

Sprouting plays an important role in increasing the nutritional value of corn and mungbean and thus makes them possible alternatives to be used for energy and protein in animal feed. Differences in the nutritive value of germinated corn have been reported in the studies conducted by Gacutan *et al.* (2021) and Puttaswamy *et al*. (2022), whereas the differences in the nutritive value of germinated mungbean have been recorded in the experiments carried out by Elobuike *et al*. (2021) and the findings of Kemal *et* al. (2025). Such variations have been caused due to differences in variety, period of germination, age of seed, and methods of pretreatment. The process of germination decreases the presence of antinutrients, breaks down the indigestible protein and improves the quantity and quality of proteins in legume seeds according to the observations of Ohanenye *et al.* (2020). It is necessary to consider the increases in fiber contents and variations in metabolizable energy during prolonged germination when including such feedstuffs in the diet.

Nutrient composition, mineral content, and energy values of formulated diets using locally available alternative feed sources for swine and poultry

The diets developed using locally available alternative nutrient sources like rice bran, corn bran, cassava tuber, cassava leaf meal, madre de agua, moringa leaf meal, SBPM, and FS hold great promise to cater to the nutritional needs of swine finishers, native chicken growers, and egg-type chickens. The agronomic crops and by-products such as cassava tuber and corn bran are a great source of energy as they contain a high amount of carbohydrates, and cassava leaves, moringa, and *T. gigantea* leaves are a rich source of protein, vitamins, and inorganic nutrients such as minerals. SBPM and FS are further used for increasing the protein content in the diet as they supply essential amino acids which are deficient in plants (Vidoiti *et al*., 2007). Furthermore, using moringa and *T. gigantea* leaves may be advantageous because of the presence of bioactive compounds with antioxidant effects (Mahfuz and Piao, 2019; Corpuz, 2024). In comparison to the conventional feed formulas based on the import of soybean meal and maize, using these locally available alternatives might lower feed costs. Apart from making the diets economically feasible to small-scale farmers, this was instrumental in providing sustainable feed production systems on a local level. Though both the diets had higher fiber content than the recommended level for swine, the provision of dietary fiber through leaf meals and bran would have been beneficial for the gut physiology of poultry, especially in broiler and layer chicks, which are better able to tolerate high-fiber diets (Walugembe *et al.,* 2014). However, the minerals content, especially Ca and P, was above the requirement level.

The formulation of the pelleted feeds made up of the locally available alternative feedstuffs for swine finisher and native chicken grower is an example of the practical use of the nutrient-rich formulation. The physical form of the pelleted feeds implies that they have the good physical quality of promoting efficient feed utilization with minimal losses while providing the nutritional needs of target livestock.

It was found in this study that the following alternative feedstuffs: rice bran, cassava tuber, cassava and moringa leaf meals, madre de agua, FS, and SBPM; have promising nutritional compositions, making them ideal for use in feed formulations for swine and poultry. The studied alternative feedstuffs had variable nutritional compositions including the variability in proximate composition, mineral composition, and metabolizable energy contents. Some of the studied feedstuffs like cassava tuber and rice bran D1 have high energy contribution, while the M. oleifera and M. esculenta leaf meals provide proteins. The formulated rations slightly exceeded the recommendations for dietary fiber

content for swine but supplied adequate protein and had enough energy and mineral contents for target livestock categories.

Acknowledgements

Sincere appreciation is extended to Capiz State University through the Research Development, and Extension Office for its invaluable support and contributions to the effective execution and achievement of the study objectives.

Conflicts of interest

No competing interests have been identified in connection with this work.

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(Received: 6 February 2026, Revised: 15 September 2026, Accepted: 16 September 2026)