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RESEARCH ARTICLE

Effects of Differently Processed Taro Mixed With Other Ingredients on Digestibility and Nitrogen Balance in Crossbred Pigs

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Abstract: Leaves from forage crops and vegetables such as water spinach, sweet potato, cassava, and especially taro, can be incorporated into pig diets as partially replace commonly used protein sources including fish meal or/and soybean meal. However, their use remains limited among farmers and livestock producers. This study aimed to compare feed intake, determine apparent digestibility coefficients, and analyze nitrogen retention in pigs fed various forms of taro-based diets. The experiment was conducted from September 9 to October 20, 2025, at Svay Rieng University, located along National Road 1, Chambak Village, Chek Commune, Svay Rieng City, Svay Rieng Province, Cambodia. Four castrated male crossbred pigs (average body weight: 15 kg; approximately 50 days old) were used in a 4×4 Latin square design. The study included four dietary treatments: fresh taro, boiled taro, dried taro, and ensiled taro, each applied across four experimental units. The trial was conducted over four periods, with each period comprising 5 days for diet adaptation followed by 5 days for the collection of feces and urine. Findings from the study demonstrated that crossbred pigs consumed higher amount of DM intakes in T2 (748 g/day) and T4 (784 g/day), highly coefficient digestibility of DM in T1 (87.1%) or T2 (88.9%), and greatly nitrogen retention in T2 (9.27%). In conclusion, fresh or ensiled taro may be used at a 10% inclusion rate in pig diets, as long as it is thoroughly mixed with other ingredients. The crossbred pigs consumed high amount of DM intakes, exhibited highly in coefficient digestibility of DM, and indicated a greater nitrogen retention.

Keywords: Crossbred Pig, Digestibility, Ensiled Taro, Nitrogen Balance, Nitrogen Retention

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Introduction

In Cambodia, crossbreeding is a dominant practice in the pig sector, with studies indicating that approximately 33.3% of pigs raised by farmers in the Great Lake floodplain and coastal zones are crossbred [1]. Imported breeds, including Landrace, Large White, and Duroc, are commonly introduced due to their superior growth performance, high feed efficiency, and greater carcass yield. However, these breeds are generally less adapted to the tropical climate and are more susceptible to local diseases and environmental stressors [2]. In contrast, indigenous pig breeds in Cambodia are well known for their strong adaptability to harsh environmental conditions, tolerance to endemic diseases, and ability to utilize low-quality feed resources [3, 4]. Therefore, crossbreeding matters aim to combine the desirable traits of both genetic groups to enhance the growth rate and carcass quality from exotic breeds while retaining the adaptability, hardiness, and disease resistance of local breeds [3]. As a result, crossbred pigs have become the preferred choice among farmers, as they offer a balanced combination of productivity and resilience, making them more suitable for the diverse production systems found across Cambodia [3-5]. Therefore, improving feeding practices is essential to maximize the productive potential for crossbred pigs. Leaves from crops such as sweet potato, taro, and water spinach, together with foliage from shrubs like cassava and mulberry, can be utilized as alternative protein sources in pig diets, potentially reducing or substituting soybean meal and fish meal. Among these feed resources, taro (Colocasia esculenta), often referred to as old cocoyam, has demonstrated considerable promise as a protein supplement because of its high digestibility and superior biological quality [6]. In addition, taro foliage is relatively low in fiber, and more digestible than that of other protein-rich forages [7].

The taro plant (Colocasia esculenta) belongs to the family Araceae and is widely grown in Cambodia, particularly in ponds and on wasteland. Taro contains two forms of oxalates: soluble and insoluble. Research indicates that young taro leaves contain higher levels of oxalates (589 ± 36 mg/100 g fresh weight) compared with mature leaves (433 ± 15 mg/100 g fresh weight). In addition, soluble oxalates make up about 74% of the total oxalate content in taro foliage [8, 9]. A research study conducted in Cambodia by [8] reported the taro leaves were commonly boiled prior to feeding to pigs, as fresh leaves were not readily consumed. More currently, methods for preserving taro plant through ensiling have been proposed [10], and this method has been shown to significantly reduce oxalate levels [11]. Cambodian farmers have extensive experience using taro leaves and stems, most often cooking them to avoid skin irritation associated with handling or feeding the fresh plant material [12]. It is believed that oxalate compounds in the leaves and stems are responsible for this irritation by oxalate salts [13]. In addition, a combination of ensiled taro leaves and water spinach has been successfully used to fully replace soybean meal in the diets of pregnant and lactating Mong Cai gilts, without negatively impacting their reproductive performance [14]. Recent research indicates that ensiling the entire taro plant (leaves and stems) is the most effective approach for lowering oxalate concentrations and that this method has been readily adopted by farmers in Vietnam [15]. Furthermore, [10] also found that taro stems contain high levels of soluble sugars, eliminating the need for conventional silage additives such as molasses. This evidence supports the ensiling of taro leaves and stems together without additional sugar supplementation.

Rice distillers' by-product, also known as residue from rice fermentation, is the solid material left after rice undergoes fermentation and alcohol is distilled, typically in small-scale or household production systems. In this process, cooked rice is fermented using yeast, after which the alcohol is extracted by distillation. The residual material is typically used as a wet feed ingredient for pigs. This by-product is generated in considerable quantities at the household level, especially in the Mekong Delta [9]. In rural regions of the Lao PDR, rice distillation residue locally referred to as Bay Srar is considered a valuable source of high-quality protein. It is produced as the by-product remaining after fermented rice, treated with yeast, undergoes alcohol distillation [16]. Farmers commonly use this by-product in pig feeding by mixing it with other ingredients such as rice bran and broken rice, and especially for fattening pigs [17]. As Vietnam, Bay Srar is also widely utilized as a common feed resource for raising the pigs [9]. It contains about 17–33% crude protein on a dry matter basis, with an average of around 23%, and offers a well-balanced amino acid composition [9]. Research has further indicated it may fully replace protein feed such as soybean or fish meal in diets for raising pigs without negatively affecting performance. Overall, rice distillers' by-product contains relatively high levels of good-quality protein (>20% crude protein in dry matter), particularly in terms of amino acid balance [18].

Rice bran is a nutrient-rich feed ingredient widely used in animal diets. It provides a high level of energy and fat, and is also a valuable source of essential vitamins, particularly vitamins B and E [19]. According to [20], rice bran contains approximately 91% dry matter, with a digestible energy value of 2,040 kcal/kg. Its composition includes 13.5% crude protein and essential amino acids such as 0.17% methionine, 0.10% cysteine, 0.50% lysine, 0.10% tryptophan, and 0.40% threonine. In addition, it contains 5.9% crude fat, 13.0% crude fiber, 11.0% ash, 0.10% calcium, and 1.70% phosphorus.

Corn serves as the primary energy ingredient that has potential as livestock feeds, particularly highly valued in pig nutrition due to its low fiber content and balanced nutrient composition [21]. Based on the report of [20], corn contains about 86% dry matter and provides approximately 3,373 kcal/kg of metabolizable energy. Its nutrient composition includes 7.5% crude protein, with methionine and cysteine each at 0.18% and tryptophan at 0.07%. It also contains 0.29% tannins, 3.5% crude fat, 1.9% crude fiber, 1.1% ash, and 0.01% calcium.

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This study aimed to assess feed intake, determine digestibility coefficients, and evaluate nitrogen retention in pigs fed diets containing differently processed taro, in combination with rice wine by-products, fish meal, rice bran, and red corn.

Materials and Methods

Study Location and Duration

This study was implemented from 9 September to 30 November 2025 at Svay Rieng University campus, situated along National Road 1 in Chambak Village, Chek Commune, Svay Rieng City, Svay Rieng Province, Cambodia. Throughout the experimental period, the ambient daily temperature varied between 37°C and 39°C.

Animals and Housing

The trial was performed in a regulated housing system consisting of four independent pig pens, each measuring 1.0 m × 0.8 m × 1.6 m. The pens were built with steel framing, plastic mesh, and plastic sheeting, and were installed within an open-sided shed covered by a zinc roofing system supported by a steel structure. Every pen had its own feeder and waterer, while the metabolism cages were designed and enabled the separate collection of fecal and urinary outputs. Feces were gathered using a plastic mesh installed beneath the floor, while urine was allowed to pass through the mesh and was channelled onto a polyethylene sheet, which directed it through a filter placed in a funnel leading into a plastic collection bucket. A total of four castrated male crossbred pigs were used in the experiment, with one pig allocated per pen [22]. Before the start of the trial, all pigs were dewormed and vaccinated against salmonellosis, pasteurellosis, and pest porcine diseases. The vaccines, manufactured by Vietnam, were imported into Cambodia through Green Feed Company [23]. The pigs were adapted to both the experimental diets and housing conditions for seven days prior to data collection. During the study period, the ambient temperature fluctuated between 26°C and 33°C, while relative humidity values ranging from 75% to 81%.

Experimental Design and Treatments

Four castrated male pigs of Large White × indigenous crossbreed, averaging 15 kg in body weight and 50 days old, were distributed to four dietary treatments following a 4 × 4 Latin square design. The trial comprised four experimental periods, each lasting 10 days, with the first 5 days designated for adaptation to the experimental diets and the subsequent 5 days allocated for total feces and urine collection. The four experimental diets were formulated in accordance with the guidelines presented in Animal Nutrition [24], and the nutrient requirements for pigs established by the National Research Council [25]. The dietary treatments included T1: Contained 10% boiled taro, 15% fermented rice, 17% fish meal, 41.5% rice bran, 17% red corn, and 0.5% premix plus salt; T2: Contained 10% ensiled taro, 15% fermented rice, 17% fish meal, 41.5% rice bran, 17% red corn, and 0.5% premix plus salt; T3: Contained 10% dried taro, 15% fermented rice, 17% fish meal, 41.5% rice bran, 17% red corn, and 0.5% premix plus salt; and T4: 10% fresh taro, 15% fermented rice, 17% fish meal, 41.5% rice bran, 17% red corn, and 0.5% premix plus salt.

Experimental Diets and Feeding

Rice bran, red corn, fish meal, and vitamin-mineral premix were procured from a local market near Svay Rieng University at the beginning of the experimental research. Fresh taro leaves and stems were collected from lakes, ponds, and canals located throughout Svay Rieng Province. Rice wine by-products were also collected from local households involved in traditional small-scale rice wine production.

Ensiling of taro plants: Taro leaves and stems were cut into pieces approximately 2-3 cm in length and packed into plastic bags. The contents were well compacted to eliminate air as much as possible and then tightly sealed in bags and placed in plastic containers for fermentation. After 20 days of ensiling, the fermented taro was opened and offered to the pigs.

Drying of taro plants: Taro leaves and stems were cut into small sections of approximately 2-3 cm, and then sun-dried until their moisture content was sufficiently reduced and the material became completely dry. The dried materials were then ground into taro meal before being mixed with other ingredients according to the feed formulation.

Use of fresh taro plants: Fresh taro leaves and stems were cut into pieces measuring approximately 2-3 cm and exposed to sunlight for two hours to partially lower their moisture content before being incorporated into the experimental diets.

Preparation of Homemade Feeds: Four different dietary groups were formulated using the same ingredient levels and the same basic formulation. Rice bran, red corn, fish meal, premix, and salt were mixed with different forms of taro plant processed by boiling, ensiling, drying, or used fresh. All feed ingredients were thoroughly mixed before being processed in a milling machine to produce pelleted concentrate feed.

Feeding System

The feeding system was designed to ensure controlled and uniform feed intake across treatments T1, T2, T3, and T4. The quantity of feed provided was determined according to the anticipated daily feed intake relative to the pigs' live body weight, as established during the adaptation phase. During this phase, pigs were gradually accustomed to their respective dietary treatments and feeding schedule to stabilize intake and minimize feed refusals.

Throughout the collection period, feed allowances were adjusted and then standardized based on the actual intake recorded during the adaptation phase, thereby ensuring that all animals received quantities consistent with their voluntary consumption capacity. This controlled feeding approach allowed for accurate measurement of intake and nutrient utilization.

The daily feed allowance was weighed manually for each pig and divided into three equal portions, which were offered at 07:00, 12:00, and 16:00 h. This feeding schedule was designed to maintain uniform feed consumption and minimize digestive disturbances. Throughout the testing, cleaning water was provided ad libitum through drinking nipples, with no observed feed residues within the sampling period, confirming that the feeding levels were appropriate and well matched to the animals' intake capacity as established during the adaptation period.

Sample Collection

Representative feed samples were first homogenized using a coffee grinder and immediately stored at −20 °C. At the end of each collection period, samples from each pig and period were thawed, re-homogenized using the same grinder, and sub-sampled for analysis.

Fecal samples were collected a minimum of twice daily and weighed immediately after collection. A representative subsample equivalent to 10% of the total fecal output was thoroughly mixed and stored at −20 °C. At the end of each collection period, stored samples from each pig were thawed and thoroughly homogenized prior to laboratory analysis.

Urine samples were collected in plastic containers containing 10 mL of concentrated sulfuric acid (H_2SO_4) to maintain the pH below 4 and prevent ammonia losses through volatilization. A 10% daily subsample was taken and stored at −20 °C until subsequent analysis.

Changes in Live Weight

At the start of each experimental period, pigs were individually weighed to record initial body weight and then to determine the feed allowances accordingly. Final body weights were measured at the end of the last experimental period to determine overall weight change over the course of the study.

Chemical Analysis

The Dry Matter (DM) content of feed ingredients, feed offered, and fecal samples was determined using the microwave drying method described. The pH of fresh feces and urine was measured using a glass electrode pH meter. Organic matter (ash), Nitrogen (N), and Crude Fiber (CF) contents in feed, feces, and urine were determined according to [26] methods. All sample analyses were performed in duplicate to ensure accuracy and reliability.

Statistical Analysis

Data on feed intake, nutrient digestibility, nitrogen balance, and Standard Errors of the Mean (SEM) were Analyzed using Analysis of Variance (ANOVA) via the General Linear Model (GLM) procedure in Minitab. Differences among treatments were considered statistically significant at $p < 0.05$, and mean comparisons were further separated using Tukey's multiple comparison test at the same probability level. In addition, correlation and regression analyses were performed to examine the relationships between feed intake or crude protein intake and nitrogen retention. The sources of variation included treatments, pig, period, and residual error. The statistical model used was as follows:

$$Yijk = \mu + Ai + Pj + Tk + eijk$$

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Where Y_{ijk}represents the dependent variable, $\mu$is the overall mean, $A_i$denotes the animal effect, $P_j$represents the period effect, $T_k$indicates the treatment effect, and $e_{ijk}$is the random error term.

Results

Chemical Characteristics of the Feed Ingredients

The feed ingredients, including dried taro, fish meal, rice bran, and red corn, had relatively high Dry Matter (DM) contents of 78.1%, 87.9%, 88.7%, and 85.7%, respectively, compared with boiled, ensiled, and fresh taro, which contained only 9.87%, 9.21%, and 10.8% DM, respectively. However, all forms of taro exhibited higher Crude Protein (CP) contents, ranging from 22.9% - 24.1% on a dry-matter basis, than rice bran (10.2%) and red corn (7.86%), which served primarily as energy sources. Fish meal was an exception, as it had a markedly higher CP content (51.5%). In addition, the rice wine by-product showed a high Organic Matter (OM) content (96.5%) but a low Crude Fiber (CF) content (2.21%) on a dry matter basis as shown in Table 1.

Table 1: Proximate composition of dietary ingredients

Ingredients	DM %	As % of dry matter		
		CP	OM	CF
Boiled taro	9.37	22.7	84.5	29.7
Ensiled taro	9.01	22.4	83.3	30.6
Dried taro	87.4	23.6	85.5	28.9
Fresh Taro	9.85	24.1	86.2	29.8
Rice wine by product	47.1	12.9	96.5	2.21
Fish meal	87.9	51.5	67.4	2.47
Rice bran	88.7	10.2	77.5	9.11
Red corn	85.7	7.86	91.5	2.42
Premix plus salt	98.3	nd	Nd	nd

nd = not determined

Feed Intake

The Dry Matter (DM) intake of pigs fed T4 (784 g/day) was the highest compared with that of pigs fed T1 (732 g/day) and T2 (739 g/day) (p< 0.01). However, DM intake did not differ significantly (p>0.05) among pigs fed the diets of T1, T2, and T3 (Table 2 and Figure 1). Crude Protein (CP) and Organic Matter (OM) intakes of pigs fed T4 (137 g/day and 755 g/day, respectively) were significantly higher than those of pigs fed T1 (121 g/day and 697 g/day), T2 (130 g/day and 713 g/day), and T3 (122 g/day and 677 g/day) (p<0.01 and Table 2). No significant differences in CP and OM intakes were observed between T1 and T3 (p>0.05 and Table 2).

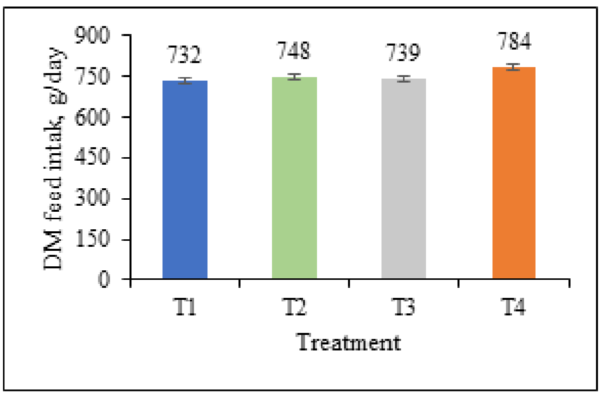

Fig. 1: Effect of dry matter feed intake in crossbred pigs fed differently processed taro mixed with other feed ingredients

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Table 2: Mean values of dry matter feed intake in crossbred pigs fed different homemade feeds

	T1	T2	T3	T4	SE	P-Value
Total Dry Matter (DM) intake, g/day	732^{b}	748^{ab}	739^{b}	784^{a}	9.93	0.002
Total Crude Protein (CP) intake, g/day	121^{c}	130^{b}	122^{c}	137^{a}	1.69	<0.001
Total Organic Matter (OM) intake, g/day	697^{c}	713^{b}	677^{c}	755^{a}	9.8	<0.001
Total Crude Fiber (CF) intake, g/day	38.7^{b}	43.9^{b}	45.3^{b}	45.8^{a}	0.63	<0.001

abc Means in the same row with different superscripts differ significantly ($p < 0.05$)

Apparent Digestibility

The Dry Matter (DM) content of feces from pigs fed T3 (38.5%) was the highest compared with pigs fed T1 (31.2%), T2 (35.6%), and T4 (36.9%) ($p< 0.01$ and Table 3). However, on a fresh matter basis, fecal output, fecal dry matter, and fecal water content of pigs fed T4 (357 g/day, 132 g/day, and 225 g/day, respectively) were significantly higher than those of pigs fed T1 (257 g/day, 79.6 g/day, and 177 g/day), T2 (263 g/day, 93.7 g/day, and 169 g/day), and T3 (255 g/day, 97.9 g/day, and 157 g/day), respectively ($p<0.01$ and Table 3). No differences were shown in fecal fresh matter and dry matter, or water contents among pigs offered the diets of T1, T2, and T3 ($p>0.05$ and Table 3). Furthermore, the pH values of feces and urine from pigs fed T4 (7.42 and 5.27, respectively) were differently higher than those of pigs consumed the diets of T1 (6.55 and 4.25), T2 (6.96 and 4.38), and T3 (6.43 and 5.27), respectively ($p<0.01$ and Table 3). However, non-significant in fecal and urine pH were observed between pigs fed the experimental dietary of T1 and T3 ($p>0.05$ and Table 3).

Table 3: Mean values of faecal and urinary characteristics in crossbred pigs fed different homemade feeds

	T1	T2	T3	T4	SE	P-Value
Dry matter (DM), %	31.2^{d}	35.6^{c}	38.5^{a}	36.9^{b}	0.21	<0.001
Faecal excretion, g/day						
Fresh material	257^{b}	263^{b}	255^{b}	357^{a}	15.9	<0.001
Dry material	79.6^{b}	93.7^{b}	97.9^{b}	132^{a}	5.72	<0.001
Water	177^{b}	169^{b}	157^{b}	225^{a}	10.3	<0.001
pH						
Faeces	6.55^{c}	6.95^{b}	6.43^{c}	7.42^{a}	0.09	<0.001
Urine	4.25^{c}	4.38^{b}	4.73^{c}	5.27^{a}	0.06	<0.001

abcd Means in the same row with different superscripts differ significantly ($p < 0.05$)

Apparent Dry Matter (DM) digestibility was not significantly different among pigs fed T1 (88.9%), T2 (87.1%), and T3 (86.1%). Nevertheless, these treatments resulted in significantly higher DM digestibility compared with T4 (82.5%) ($p<0.01$, Table 4, and Figure 2). Similarly, pigs fed T1 and T2 showed greater Organic Matter (OM) digestibility (90.8% and 88.6%, respectively) and Crude Fiber (CF) digestibility (66.3% and 64.4%, respectively) than those fed T4 (85.4% and 51.9%, respectively) ($p<0.01$ and Table 4). However, no significant differences in OM and CF digestibility were observed between T2 and T3 or between T3 and T4 ($p>0.05$ and Table 4). Crude protein (CP) digestibility also remained unaffected by dietary treatments, with values ranging from 65.6% to 69.1%, although pigs ate the diets of T1 exhibited the highest numerical value ($p>0.05$ and Table 4).

Table 4: Mean values of apparent digestibility in crossbred pigs fed different homemade feeds

	T1	T2	T3	T4	SE	P-Value
Dry matter (DM)	88.9^{a}	87.1^{a}	86.1^{a}	82.5^{b}	0.82	<0.001
Organic matter (OM)	90.8^{a}	88.6^{ab}	87.6^{bc}	85.4^{c}	0.71	<0.001
Crude protein (CP)	69.1	68.2	65.6	67.1	2.66	0.809
Crude fiber (CF)	66.3^{a}	64.4^{ab}	57.2^{bc}	51.9^{c}	2.44	<0.001

abc Means in the same row with different superscripts differ significantly ($p < 0.05$)

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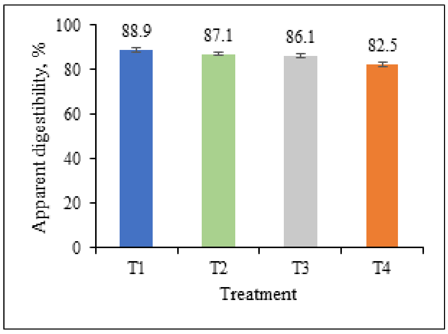

Fig. 2: Apparent digestibility in dry matter of crossbred pigs fed differently processed taro mixed with other ingredients

Nitrogen Balance

A significant dietary effect was found that on nitrogen metabolism in pigs. Animals receiving T4 exhibited the greatest nitrogen intake and urinary nitrogen excretion, averaging 21.9 g/day and 7.75 g/day, respectively. These values were significantly higher than those recorded for pigs fed T1 (19.4 g/day and 4.16 g/day), T2 (20.8 g/day and 4.81 g/day), and T3 (19.6 g/day and 5.39 g/day) ($p<0.01$, Table 5, and Figure 3). In contrast, no significant differences in urinary nitrogen excretion were detected among pigs assigned to T1, T2, and T3 ($p>0.05$, Table 5, and Figure 3). Pigs receiving T1 and T2 showed significantly higher in nitrogen retention, with mean values of 8.91 and 9.27 g/day, respectively, compared with pigs fed T4, which retained only 6.16 g/day ($p<0.01$, Table 5, and Figure 4). However, N retention did not differ significantly among pigs fed T1 (8.91 g/day), T2 (9.27 g/day), and T3 (7.19 g/day) ($p>0.05$, Table 5, and Figures 3 and 4). Regarding N retention expressed as a percentage of intake or digested N, pigs fed T1 (46.6% and 66.3%) and T2 (44.3% and 63.7%) showed significantly higher values comparing pigs fed T4 (28.7% and 41.5%), respectively ($p<0.01$ and Table 5). In contrast, nitrogen (N) retention as a percentage of intake or digested N did not differ significantly between pigs fed T3 (36.7% and 52.1%, respectively) and T4 (28.7% and 41.5%, respectively) ($p>0.05$ and Table 5).

Table 5: Nitrogen balance mean values in crossbred pigs fed various homemade feeds

	T1	T2	T3	T4	SE	P-Value
Nitrogen (N) balance, g/day						
Intake	19.4^{c}	20.8^{b}	19.6^{c}	21.9^{a}	0.27	<0.001
Faeces	6.31	6.75	6.99	8.06	0.57	0.341
Urine	4.16^{c}	4.81^{bc}	5.39^{bc}	7.75^{a}	0.30	<0.001
Retention	8.91^{a}	9.27^{a}	7.19^{ab}	6.16^{b}	0.65	0.003
Retention as % of						
Intake	46.5^{a}	44.3^{a}	36.7^{ab}	28.7^{b}	3.12	0.001
Digested	66.3^{a}	63.7^{ab}	$52.1b^{c}$	41.5^{c}	3.35	<0.001

abc Means in the same row with different superscripts differ significantly ($p < 0.05$)

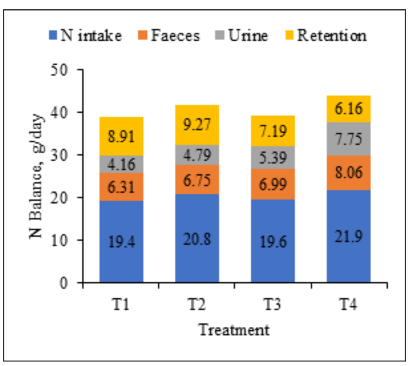

Fig. 3: Nitrogen balance in crossbred pigs fed differently processed taro mixed with other ingredients

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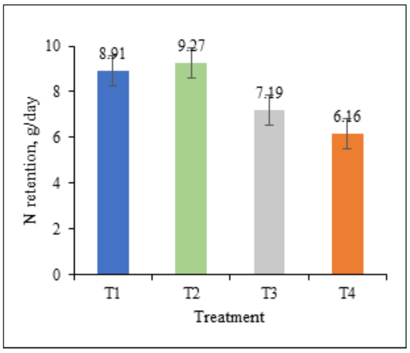

Fig. 4: Nitrogen retention in crossbred pigs fed differently processed taro mixed with other ingredients

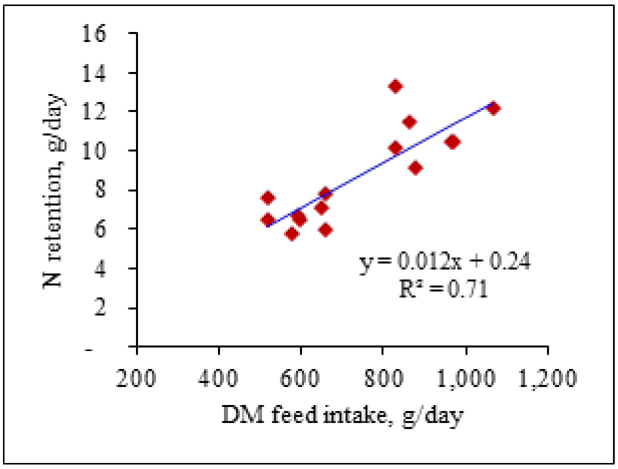

Fig. 5: Relationship between the feed intake in dry matter and nitrogen retention in crossbred pigs fed differently processed taro mixed with other ingredients

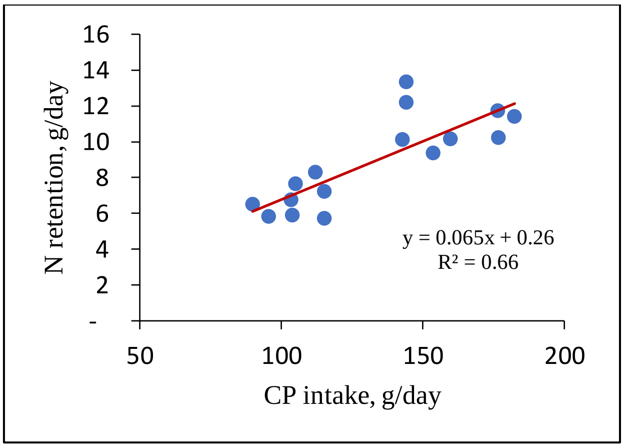

Fig. 6: Effects of the relationship between crude protein intake and nitrogen retention in crossbred pigs consumed differently processed taro mixed with other ingredients

The results indicated a positive linear relationship between dry matter intake and nitrogen retention, as represented by the regression equation $Y = 0.012x + 0.24$. With a coefficient of determination exceeding $R^2 > 0.70$, the model suggests that variations in dry matter intake accounted for a considerable proportion of the observed differences in nitrogen retention. The results suggest that as pigs consumed greater amounts of dietary DM, N retention increased gradually, reflecting improved utilization of dietary nitrogen (Figure 5). This trend implies that higher feed intake may enhance nutrient availability and metabolic efficiency, thereby supporting greater nitrogen retention in the body. Similarly, Crude Protein (CP) intake was

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positively and moderately associated with nitrogen retention, as described by the regression equation Y = 0.065x + 0.26, with a coefficient of determination R^2 >0.60. These findings demonstrate that increases in CP intake were also associated with a corresponding, although modest, increase in N retention (Figure 6). The positive relationship suggests that higher dietary protein supply contributes to improved nitrogen balance, likely through enhanced protein synthesis and reduced nitrogen losses. Overall, these relationships highlight the importance of both total feed intake and dietary protein level in influencing nitrogen retention and protein utilization in pigs.

Discussion

As presented in Table 1, fresh, boiled, and ensiled taro showed considerable differences in Dry Matter (DM), Crude Protein (CP), Organic Matter (OM), and Crude Fiber (CF) contents. These findings are generally consistent with those reported by [22] found that ensiled taro used into diets for growing pigs contained 8.92% dry matter, 22.3% crude protein, 81.2% organic matter, and 30.2% crude fiber. In comparison, the dry matter and organic matter contents recorded in the present trial were somewhat lower comparing with the findings of [7], who reported corresponding values of 11.8% and 86.1% for taro silage supplemented with rice bran. Such discrepancies are likely related to differences in taro cultivar, soil fertility, and production environment across regions of Cambodia. Furthermore, the nutrient composition of dried taro in current trial was not identical to the report of [7], who observed higher Dry Matter (DM), Crude Protein (CP), and Organic Matter (DM) contents, but lower Crude Fiber (CF) levels. These variations underscore the important roles of processing techniques, varietal differences, and local environmental conditions on the nutritional composition of taro when used as a feed ingredient.

The dry matter intake recorded for pigs fed boiled, ensiled, and dried taro in this study differed from values previously reported in the literature. [12] observed considerably lower dry matter intakes, ranging from 480 g/day to 581 g/day, in pigs offered taro silage supplemented with fish meal and sugar palm syrup. In contrast, higher intakes were reported by [27] and Chhay [7], were recorded average daily dry matter consumptions of 1,736 g and 1,131 g, respectively, when boiled or dried taro was combined with concentrate feed. Nevertheless, the dry matter intake observed in the present experiment exceeded that reported by [6], where pigs consumed only 501 g/day to 594 g/day of diets containing taro silage and rice bran. Several factors may account for these discrepancies, which may be attributed to differences in pig age and initial live weight, as well as the type and proportion of supplementary ingredients used with the various forms of taro. Moreover, the dry matter intake of pigs fed fresh taro in the current trial was lower as compared to the report of [28], who found an intake of 1,520 g/day when fresh taro was included at 5% of the diet together with other feed ingredients. Crude protein intake in the current research was comparable to the values resulted by [22] for pigs fed ensiled taro-based diets containing rice bran or rice wine by-products. However, crude fiber intake was lower than that documented in earlier studies, where daily crude fiber consumption reached approximately 130 g/day.

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In this experiment, the coefficients of apparent digestibility for dry matter, organic matter, and crude protein were within the range of 82.5% to 88.9%, 85.4% to 90.8%, and 65.6% to 69.1%, respectively. These findings are comparable to those reported by [11], who found dry matter digestibility values ranging from 84.3% to 85.0%, organic matter digestibility from 86.7% to 87.2%, and crude protein digestibility from 69.7% to 76.2% in pigs fed diets containing fresh or ensiled taro supplemented with cassava root meal and rice bran. Comparable results were also documented by [22], who reported dry matter and organic matter digestibility coefficients of 85.4% and 87.3%, respectively, in pigs receiving ensiled taro diets containing rice wine by-products, fish meal, and rice bran.

The crude fiber digestibility obtained in this experiment was higher than the range previously reported, which generally varied from 48.2% to 57.9%. Moreover, the digestibility coefficients for dry matter and organic matter in the present research were higher if compare with report of [29], who observed lower digestibility values in pigs fed ensiled taro combined with rice bran, irrespective of enzyme supplementation. Likewise, [30] reported considerably lower dry matter digestibility (65.5% to 68.1%) in pigs fed cooked taro and cassava leaves supplemented with protein concentrate, rice powder, and red palm oil. These variations in nutrient digestibility are likely associated with differences in taro processing techniques, dietary inclusion rates, and the composition of the supplementary ingredients used across studies.

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Nitrogen retention, expressed either as absolute daily retention or as a proportion of nitrogen intake and digested nitrogen, was the highest on pigs ate the diets having ensiled or boiled taro supplemented mixed with other feed ingredients (Table 5). These findings are similar to those reported by [22], also found enhanced nitrogen utilization in pigs receiving ensiled taro-based diets containing rice wine by-products, fish meal, and rice bran. Nevertheless, the percentages of nitrogen retained relative to nitrogen intake (32.6%) and digested nitrogen (43.9%) in the present study were somewhat lower than values resulted elsewhere. In contrast, [31] documented substantially higher in nitrogen retention of pigs ate the ensiled taro mixed with a more nutritionally complex ration containing maize, mineral supplements, and synthetic amino acids. The comparatively lower retention observed in this experiment may be attributable to differences in diet formulation, particularly with respect to nutrient balance, palatability, and amino acid adequacy. The nitrogen retention values obtained here were slightly lower if compared to the report of [32, 33], both of whom recorded higher daily nitrogen retention (10.8 g/day to 16.9 g/day) of pigs offered the ensiled taro supplemented with rice bran, rice wine by-products, or exogenous enzymes. In contrast, the present values exceeded those observed by [12], where considerably lower nitrogen retention (2.89 g/day to 5.42 g/day) was reported in pigs fed taro silage with fish meal and sugar palm syrup. Overall, the variation in nitrogen retention among studies is likely associated with differences in taro processing methods, dietary inclusion rates, nutrient composition, and the types of supplementary ingredients incorporated into the diets.

Conclusion

According to the findings in the present study, the fresh taro or ensiled taro can be used at 10% and mixed with other feed ingredients, including rice wine by product, fish meal, rice bran and red corn. The crossbred pigs consumed high amount of DM intake contents ranging from 748-784g/day, exhibited highly in coefficient digestibility of DM ranging 87.1-88.9%, and indicated a greater nitrogen retention of 8.91-9.27g/day. It is really necessary to be further studying the effects of those finding diets to examine on the growth performance for both local and crossbred fattening pigs.

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Author's Contributions

Phiny Chiv: Conceptualization, study design, methodology development, data analysis, and writing of the initial manuscript draft.
Saravuth Tum and Putheasath Sin: Critical feedback, manuscript review, and language improvement.
Sotheany Prom, Pheara RoekPronh, Vanchey Ros, Siphol Von, Sak Sao, Sinath Oung and Mey Sao: Experimental work and data collection.
Sophany Morm: Data analysis and preparation of the initial manuscript draft.

Ethics

The experimental work was carried out at the Faculty of Agriculture, Svay Rieng University, Cambodia. All animals were handled according to the Animal Welfare Guidelines of the Animal Health and Production Office of Svay Rieng Province. The study received ethical approval from Svay Rieng University, confirmed by an official letter dated March 11, 2025.

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