



Effects of Substituting Taro (*Colocasia esculenta*) Wastes Silage in Diets on Growth and Nutrient Digestibility In Pigs

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Abstract | Two experiments were conducted to identify the optimal ensiling conditions of taro petiole and leaf (TPL) mixture and the effects of replacing commercial concentrate with TPL-waste silage on production parameters and nutrient digestibility in pigs. Experiment 1 was conducted with a completely randomized design consisting of five treatments and four replicates with different proportions of TPL mixture and taro peel ensiled over 60 days. Experiment 2 involved 12 castrated male Duroc x (Landrace x Yorkshire) pigs of 35 kg being allocated into a completely randomized block design with three diets: 100% concentrate (Control) and concentrate replaced by 10% (S₁₀) and 20% (S₂₀) of TPL silage. In Experiment 1, the pH of treatments declined rapidly from day 1-30 but remained stable thereafter. Dry matter (DM), crude protein (CP), and calcium oxalate (CO) contents of the silages dropped sharply up to day 30 with no significant changes thereafter - except for CO, which continued to fall to below 1% for the treatment of 50% TPL (TPL₅₀) and those with lower TPL by day 60. The TPL₅₀ for 60 days duration was selected to prepare the TPL silage for Experiment 2. No significant differences were found among the three treatments in feed intake, body weight gain, and nutrient digestibility. Similarly, there were no differences in DM, organic matter, CP digestibility, and feed conversion ratio among treatments. The ratio of TPL mixture at 50% is favorable for ensiling. Concentrate diets can be replaced with up to 20% taro-waste silage without negative impacts on pig performance and apparent digestibility.

Keywords | *Colocasia esculenta*, Performance, Petioles and Leaves, Pig, Silage

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INTRODUCTION

Pork production has increased rapidly in recent years in Vietnam, is now the largest meat industry, and plays an important role in meeting the increasing demands for meat in the country. Since feed costs make up approximately 70% of the total production cost in commercial pig farming, more and more investigations are being conducted to find ways to cut production costs and increase productivity (Caicedo et al., 2018a). Various improved formulations of feed concentrates aimed to achieve economic and sustainable growth in the pig industry are being implemented because of the increasing demand and price of traditional feed ingredients such as maize, cereals and soybeans (Caicedo et al., 2017).

Taro (*Colocasia esculenta*) is widely cultivated in Dong Thap province in the Mekong Delta region of Vietnam. The main product of taro cultivation is its tubers used as human food because it contains high contents of protein and starch (11% and 85-87%, respectively) (Temesgen and Retta, 2015). The by-products of taro cultivation are leaves, petioles, and peel (a waste discarded from taro planting by farmers and taro processing factories). The above by-products are good energy sources for livestock, and with the appropriate preservation practices, these by-products could be beneficial to the livestock farming community and relieve the pressure of competition for food between humans and animals (Mwesigwa et al., 2013).

The foliage of taro consisting of petioles and leaves (TPL) has been used as a feed ingredient, mainly for pigs, because taro leaves are rich in protein and the petioles being rich in soluble carbohydrates (Hang et al., 2017). However, calcium oxalate (CO) content in the taro petiole is high (Hang et al., 2017) which may adversely affect the digestion process. It has been reported that ensiling, cooking or drying can lower the oxalate content (Apata and Babalola, 2012). Taro waste silage, with a combination of other by-products such as banana pseudo-stem, broken rice, and soybean meal has been successfully used to produce high quality feed (Sivilai et al., 2016). The objectives of this study were (i) to evaluate the optimal proportions of TPL mixture with taro peels for silage making and (ii) to test the effect of substituting commercial concentrate with TPL silage in diets on performance and nutrient digestibility in pigs.

MATERIALS AND METHODS

This study consisted of two experiments; the first was to evaluate the optimal proportions of TPL and taro peel to produce good quality silage which was then used in the second experiment to evaluate the efficacy of substituting the traditional concentrate diet with different levels of taro by-products silage on animal performance and nutrient digestibility in pigs.

EXPERIMENT 1: PREPARATION OF MATERIALS AND SILAGE MAKING

The TPL was collected from taro growers and the peel from small taro processing factories around Dong Thap province in Vietnam. The materials were brought to Can Tho University and processed for the study. In this study, TPL consists of 95% petioles and 5% leaves (DM basis) which was used to make silage. The TPL together with the taro peels were then chopped to approximately 3 and 5 cm and later dried under sunlight until the dry matter content reached 30% before making the silage.

The silage experiment was conducted using a completely randomised design which consisted of five treatments with four replicates per treatment. The treatments consisted of the control which contained 96.5% TPL with no taro peel and four treatments which replaced TPL with increasing level of taro peel as follows:

Treatment 1 (TPL₉₆): 96.5% TPL + 3% rice bran + 0.5% salt (Control)

Treatment 2 (TPL₇₅): 75% TPL + 24.5% taro peel + 0.5% salt

Treatment 3 (TPL₅₀): 49.5% TPL + 50% taro peel + 0.5% salt

Treatment 4 (TPL₂₅): 24.5% TPL + 75% taro peel + 0.5% salt

Treatment 5 (TPL₀): 96.5% taro peel + 3% rice bran +

0.5% salt.

Water was added to the mixtures to achieve around 70% moisture and the materials were compacted and incubated in airtight plastic bags of approximately 60 liters in volume with a total weight of 20 kg for each. The bags were checked regularly to ensure they were properly secured and if found to be loose, the bags were opened, re-compact and re-tied.

Samples were collected from day 1, 30, and 60 after ensiling. Approximately one kg of sample was randomly collected from two bags of each replicate. The collected samples were individually assessed for their colour and aroma and stored for later analysis for dry matter (DM), crude protein (CP), lactic acid, and acetic acid using the methods of Horwitz (2005), and CO content following the methods of Savage et al. (2000).

EXPERIMENT 2: ANIMAL AND DIETARY TREATMENTS

The experiment was carried out at a pig farm in Dong Thap province, Vietnam. The animals were cared according to the guidelines of the Sub-Department of Animal Husbandry, Animal Health and Fisheries of Dong Thap province and the approval of Tra Vinh University. A total of 12 castrated male Duroc x (Landrace x Yorkshire) grower pigs (35.0±7.8 kg BW) were randomly allocated to three dietary groups in a completely randomised block design experiment with four replicates per treatment. The taro silage was ensiled following the TPL₅₀ treatment from experiment 1, and it was used to replace the commercial concentrate diets as followed:

Treatment 1 (Con): 100% concentrate,

Treatment 2 (S₁₀): 90% concentrate and 10% silage, and

Treatment 3 (S₂₀): 80% concentrate and 20% silage.

Three concentrates, namely starter, grower and finisher diets, purchased from a commercial company were used during the different periods (1-30, 31-60, and 61-90 days) of the experiment (Table 1).

Table 1: Nutritional value of concentrates used in the three feeding phases

Nutritional value	Concentrate in the experiment		
	Con_1*	Con_2*	Con_3*
Dry matter (%)	86	86	86
Crude protein (%)	18	16	14
ME (kcal/kg of feed)	3,100	3,000	3,000
Crude fibre (%)	6	8	8
Lysine (%)	1	0.9	0.8
Methionine + cysteine (%)	0.6	0.54	0.48
Calcium (%)	0.8	0.8	0.8
Phosphorus (%)	0.6	0.6	0.6

*Con_1 = day 1-30; Con_2 = day 31-60; Con_3 = day 61-90

The ratio of concentrate and taro silage was calculated based on a DM basis which was thoroughly mixed before been offered to the pigs. The pigs were fed *ad libitum* twice a day at 07:00 and 15:00 and the daily feed consumption was calculated by the difference between the amount offered and the residue before new feed was offered the next morning. The pigs were individually kept in cages (4.2x3.4 m), and clean drinking water was made available at all times throughout the 90 day experiment. The pigs were vaccinated against swine fever and porcine reproductive and respiratory syndrome prior to the start of the experiment.

The pigs were weighed on day 1, 30, 60, and 90 during the experiment to determine body weight gain (BWG). At the same time, DM intake and feed conversion ratio (FCR, kg DM/kg BWG) for each of the above periods were determined.

Apparent nutrient digestibility (AND) for the different treatments was carried out during the last 7 days of each measuring period of the experiment following the method of McDonald et al. (2002). All experimental pigs were kept in their respective individual cages with a concrete floor. Total faeces from individual pigs were collected twice a day, weighed, and mixed with 15 mL of 10% Sulphuric acid to inhibit further microbial growth and reduce the loss of ammonia, and all faecal samples were immediately stored at -20°C. At the end of 7 days, the frozen faecal samples were thawed and then pooled by animal to give 12 samples and stored at -20°C pending for analysis. Feed, feed residue, and faecal samples were analysed for DM, organic matter (OM), and CP following the method of Horwitz (2005).

STATISTICAL ANALYSIS

All data processing was based on the General Linear Model and performed by Minitab statistical software (Release 16.1 Minitab Inc., State College, PA)(2010). Significant differences in mean values were conducted by Tukey test, with alpha < 0.05.

RESULTS

EXPERIMENT 1: EFFECTS OF PROPORTIONS OF TPL TO PEEL ON CHEMICAL COMPOSITION AND FERMENTATION CHARACTERISTICS OF SILAGE

The chemical composition of the fresh taro by-products used for this study is presented in Table 2. It shows that TPL had higher CP (13.71% vs. 9.81%) and CO (5.79% vs. 2.97%) compared to taro peel. On the third day of incubation, ensiled materials in all treatments appeared greenish in colour and were accompanied by a slight aroma and by day 30, the colour turned dark brown for all the treatments, with no further change in colour thereafter. At the

end of the experiment (day 60), no mould was observed in the silage.

Table 2: Chemical composition (%/DM) of taro by-products

Taro by-product	DM	Ash	OM	CP	CO
Petiole and leaf	9.33	16.49	83.51	13.71	5.79
Peel	10.33	9.42	90.58	9.81	2.97

DM: dry matter, OM: organic matter, CP: crude protein, and CO: calcium oxalate

Changes of DM, pH, lactic acid, acetic acid, CP, and CO in the taro silage during the 3 sampling times (day 1, 30, and 60) are presented in Figure 1. The results indicated drastic changes in the parameters measured. Dry matter content of all treatments reduced (P<0.05) over time with the TPL₉₆ having the highest DM (47.49% on day 1 and 38.45% on day 60) while TPL₀ had the lowest DM content (30.04% on day 1 and 22.87% on day 60). The pH of the silage among the treatments declined rapidly (P<0.05) from day 1 (averaged 3.99) to day 30 (averaged 3.12) and began to stabilise thereafter (averaged 2.86 on day 60). The decline in pH was reflected by a rapid increase in the lactic acid content among all the treatments initially (day 1 to 30) but later slowed down slightly. Similarly, acetic acid content also increased over time but the values were approximately half of those of the lactic acid. Calcium oxalate content of the silage can be seen to drop dramatically over time with TPL₀, TPL₂₅, and TPL₅₀ recorded being the lowest (less than 1%) among the treatments while treatments with 75% and 96% TPL remained higher than 1% (averaged 1.78%). Based on the reduction of CO content to less than 1% on day 60, and the stability of CP content from day 30 onward, TPL₅₀ which was made up by equal proportion (1:1) of TPL and peel was selected to prepare silage for the follow up feeding trial (experiment 2).

EXPERIMENT 2: EFFECTS OF SUPPLEMENTING ENSILED TARO BY-PRODUCTS ON PERFORMANCE AND FEED DIGESTIBILITY IN PIGS

The effects of replacing commercial concentrate with 10 and 20% taro-waste silage on feed intake (FI), growth, and FCR in pigs are shown in Table 3. The results showed that replacing 10% and 20% of the commercial concentrate with taro-waste silage had no effect (P>0.05) on FI, growth, and FCR in pigs within the three periods and the overall feeding. Although daily BWG of pigs in the S₁₀ and S₂₀ were lower (P<0.05) compared to the control diet during the starter period (day 1-30), this negative effect on BWG was temporary and not observed in the latter two stages (day 60, day 90) as well as the overall study. Similarly, there was a slight increase in FCR (poorer) in the S₁₀ and S₂₀ treatments as compared to the control diet but they were not significantly different during the three and overall

Table 3: Effects of substituting concentrate with 10% (S₁₀) and 20% (S₂₀) taro silage in diets on DM intake, BWG, and FCR in pigs

Parameter	Treatment			SEM	P
	Control	S ₁₀	S ₂₀		
DM intake (kg/pig)					
Day 1-30 (kg)	1.223	1.122	1.133	0.034	0.185
Day 31-60 (kg)	1.730	1.704	1.657	0.042	0.645
Day 61-90 (kg)	1.827	1.967	1.902	0.056	0.665
Day 1-90 (kg)	1.593	1.598	1.564	0.044	0.711
Initial BW (kg)	34.25	35.13	35.73	1.68	0.83
Final BW (kg)	91.23	88.38	86.28	2.94	0.53
Daily BW gain					
Day 1-30 (kg)	0.46 ^a	0.398 ^b	0.374 ^b	0.015	0.019
Day 31-60 (kg)	0.715	0.658	0.635	0.036	0.27
Day 61-90 (kg)	0.725	0.718	0.677	0.042	0.69
Day 1-90 (kg)	0.669	0.626	0.594	0.023	0.15
FCR (kg DM/kg BWG)					
Day 1-30	2.66	2.82	3.03	0.135	0.29
Day 31-60	2.42	2.59	2.61	0.16	0.595
Day 61-90	2.52	2.74	2.81	0.10	0.175
Day 1-90	2.53	27.2	2.82	0.131	0.353

^{a,b}: means with different letters in the same row are significantly different (P<0.05)

Table 4: Effects of replacing of taro silage on apparent nutrient digestibility of pigs

Parameter	Treatment			SEM	P
	Control	S ₁₀	S ₂₀		
Daily DM intake (kg)	1.450	1.713	1.736	0.109	0.21
Daily OM intake (kg)	1.399	1.659	1.685	0.094	0.27
Daily CP intake (kg)	0.303	0.353	0.351	0.022	0.29
DM digestibility (%)	82.10	82.53	81.85	0.99	0.89
OM digestibility (%)	82.55	82.78	82.05	1.02	0.88
CP digestibility (%)	69.10	70.07	67.81	2.37	0.80

DM: dry matter, OM: organic matter, CP: crude protein

periods.

It was also indicated that replacing commercial diets with 10 and 20% taro-waste silage did not negatively affect (P>0.05) DM and nutrient digestibility and as a result digestible DM and nutrient intake in pigs (Table 4).

DISCUSSION

EXPERIMENT 1: CHEMICAL COMPOSITION AND FERMENTATION CHARACTERISTICS OF SILAGE

Taro by-product is a nutritious vegetative feed resource with high mineral (16.49% in taro leaf stem mixture), and CP content (13.71%), but it also contains high levels of CO (5.79%). The latter has shown to cause a negative impact on calcium absorption (Blaney et al., 1982) and also

can induce burning and irritation to the digestive tract of animals (Franceschi and Horner, 1980). Albiñan and Savage (2001) reported that the absorbed soluble oxalate into the body must be eliminated because it has no metabolic use, while insoluble oxalate is excreted in faeces. Taro peel contains high mineral content (9.42% vs. 16.49%), but lower CO (2.97% vs. 5.79%) contents as compared to the TPL. Thus using a mixture of TPL and taro peel enhanced the mineral content and reduced the oxalate content of the silage mixture. In addition, the CO content could be further reduced when ensiled, which provided a good silage that allowed for better nutrient absorption via improved digestibility (Sivilai et al., 2016).

In the present study, a significant reduction in DM content over time especially during the initial phase of ensiling

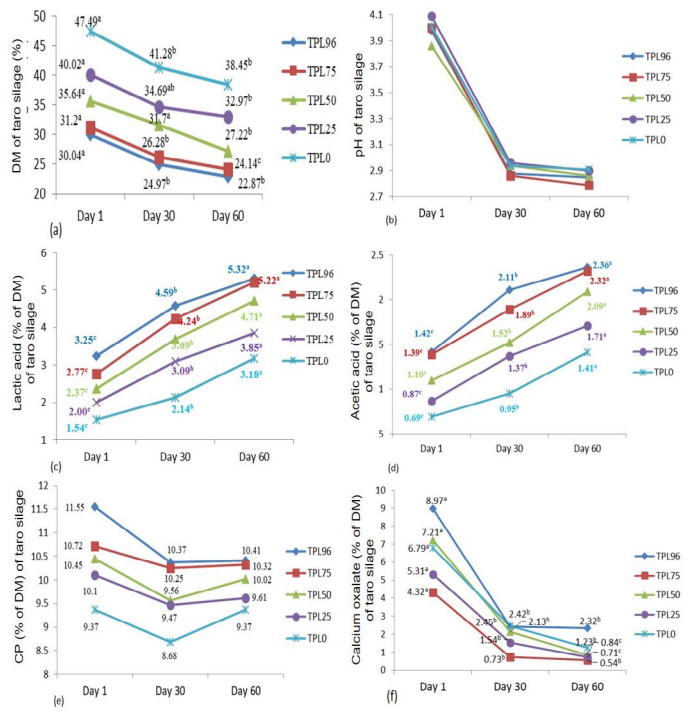


Figure 1: Changes of DM (a), pH (b), lactic acid (c), acetic acid (d), crude protein (e), and calcium oxalate (f) of taro silage of different treatments during ensiling
a, b, c: means with different letters in different collecting days are significantly different (P < 0.05)

process was noted as a result of the rapid growth of microorganisms and the respiration of the plant materials that consumed large amounts of oxygen, breaking carbohydrates into carbon dioxide and water. The above process resulted in an anaerobic environment in the system. In the next phase of the ensiling process, lactic bacteria (which only acted under the anaerobic environment provided) converted soluble carbohydrates into organic acids, carbon dioxide, water, and hydrogen sulphide, resulting in a gradual reduction of DM. The reduction in DM observed in this study agreed with the above process which was also reported previously (Malavanh et al., 2008) that DM of taro leaves declined when ensiled with sugar cane molasses and (An and Lindberg, 2004) that there was a decrease in DM when ensiling sweet potato leaves (SPL) with cassava root meal, SPL with sweet potato root meal, and SPL with sugar cane molasses. According to Muck (2010), a successful fermentation will see the number of lactic acid producing bacteria dominate under the anaerobic conditions in agreement with the increased lactic acid over time in all the treatments in the present study. The increased lactic acid content over time had led to a decreased pH. This, in addition to the activity of lactic bacteria, may also involve other microorganisms such as probiotics and fungi that activated changes in soluble carbohydrates to lactic acid, acetic acid, and other organic acids capable of inhibiting harmful bacteria and enzymes (Russell and Diez-Gonzalez, 1997).

Production of glycolate oxidase enzymes was inhibited by the anaerobic ensiled environment due to the loss of oxygen (Roos and Hatfield, 2003) which resulted in the synthesis of CO being inhibited and the decomposition of CO. The concentration of CO also affected the availability of dietary calcium because of the need to excrete soluble oxalate salts (Hang et al., 2011). The reduction of CO content in the taro-waste silage is clearly shown in this study indicating that the ensiled taro waste silage is a safer feed than if it is used fresh. Although the concentration of CO in the TPL₉₆ treatment declined about 4-fold (from 8.97% to 2.42% on day 30 and 2.32% on day 60) the CO content after 60 ds ensiling still remained the highest among the treatments. This could be due to the higher CO content in the initial TPL materials. On the other hand, the concentration of CO of TPL₅₀ treatment declined about 9-fold from 7.21 to 0.84% over the 60 day fermentation to lower than 1%, making it a safer feed for animals such as pigs. The reduction of CO in ensiled TPL was reported to be due to the increased organic acid content (Hang and Preston, 2010). A reduction of oxalate in ensiled taro leaves was also reported previously (Malavanh et al., 2008; Hang et al., 2016; Hang and Savage, 2018). Hang et al. (2016) suggested that the stage of ensiling was optimal when the oxalate content no longer changed. Following this criteria treatment TPL₅₀ ensiled for 60 day was selected to produce taro waste silage for experiment 2.

EXPERIMENT 2: ANIMAL PERFORMANCE AND DIGESTIBILITY

BWG and FCR are the most important parameters when evaluating the effect of feeding in livestock, including pig production because they determine profitability. Results of this study showed that daily FI, BWG (except for day 1-30), and FCR were not different among treatments during the starter (day 1-30), growth (day 31-60), finisher (day 61-90) and overall (day 1-90) periods. The above results thus indicate that commercial concentrate can be replaced with up to 20% TPL silage without any negative effects on growth and overall performance in pigs during production. This result has three important inferences: firstly, by replacing commercial concentrate with agricultural wastes, there is a potential to cut feeding cost which made up of 70% total production cost in most livestock production systems; secondly, it opens up the opportunity to utilise agricultural waste, which otherwise will be left unused leading to environmental pollution; and third and most importantly, the use of agricultural waste for livestock feeding can reduce the competition for food between human and livestock production.

The overall BWG recorded for this study ranged from 670 g (Control) to 590 g (S₂₀), and as previously mentioned, they were not statistically different, and was similar to the

daily BWG of pigs (Large White x Mong Cai) reported by Ly et al. (2010) that were fed diets with protein from fish meal being replaced by ensiled cassava leaves, dry cassava leaves, dry sweet potato vines, and ensiled sweet potato vines. However, the overall BWG of pigs in the study was higher than that of the report of Ly et al. (2010) with a reported BWG from 394 to 470 g/pig/day. The results were similar to the 590 g BWG reported by Hang and Preston (2010) for crossbred pigs (Mong Cai female x Large White male) at 65 days of age fed on a supplemental diet which contained 30% ensiled taro leaves. The results from the latter seems to suggest the possibility of replacing the commercial concentrate with higher than the 20% TPL silage used in the present study in pigs. This hypothesis merits further investigation in the future.

The BWG obtained in this study was higher than the 443 to 541 g reported by Toan and Preston (2010) when using processed TPL as feed in the diets of crossbred pigs (Yorkshire x Mong Cai), but lower than that (840–850 g) (Caicedo et al., 2018b) when fattening castrated pigs (Pietrain x Duroc x Landrace) with a diet containing 65% taro tuber silage. The higher BWG reported by the latter (Caicedo et al., 2018b) is no doubt due to the higher energy content of the taro tuber as only obtained between 115 to 152 g BWG when using feed ensiled with taro foliage and banana stem for indigenous Moo Lat pigs (Manivanh and Preston, 2015). Results of this study are in agreement with the findings of Caicedo et al. (2018a) and Lezcano et al. (2017) that partial replacement of feed ingredients provides the potential to reduce costs in pig production.

It is also worth noting that DM, OM and CP digestibility of the two taro-waste silage diets was not different from those of the control diet with an overall 83% for DM and OM digestibility and 69% for CP digestibility, indicating that replacing commercial concentrate with up to 20% taro-waste silage did not adversely affect feed digestibility in pigs. The digestibility of CP (69%) was in agreement with the report from An and Lindberg (2004) when feeding castrated male pigs (Large White x Mong Cai) with diets containing SPL ensiled with cassava root meal, SPL ensiled with sweet potato root meal, and SPL with sugar cane molasses resulting in CP digestibility of 69.8%, 68.7%, and 71.5% respectively. Higher apparent rectal digestibility of DM (88.7%), OM (91.8%) and CP (91.9%) were reported in castrated male fattening pigs (Large white x Duroc x Pietrain) fed diet with 20% taro tubers meal as a replacement for yellow corn (Caicedo et al., 2018b), or when supplementing with 20% ensiled taro DM (91.2%), OM (93.33%), and CP (85.05%) (Caicedo et al., 2017). The discrepancy between the results of the above studies and those in the present study is not surprising because the former used taro tuber meal while ours used TPL waste.

There was a marginal increase in the FCR values of the two taro silage supplemented diets as compared to the control during the different feeding periods, but no major differences were detected ($P > 0.05$). This was similar to what was reported by Ly et al. (2011) where the FCR of pigs (Large White x Mong Cai) showed no substantial difference in results when fed diets containing 0–20% ensiled cassava KM94 leaves. The overall FCR (kg DM feed/kg BWG) was 2.53 for the control, 2.72 for S_{10} , and 2.82 for S_{20} . The FCR obtained in this study was better than those (3.07 to 3.43) for crossbred pigs (Yorkshire x Mong Cai) at two months of age fed TPL processed with different methods (Toan and Preston, 2010). Interestingly, the overall FCR obtained in this study was marginally lower than that reported by Caicedo et al. (2018a) (2.89) who fed castrated pigs in the fattening stage with a diet containing 65% taro tubers silage, and that reported by Ly et al. (2010) (3.1–3.4) when pigs (Large White x Mong Cai) were fed diets having fish meal replaced with ensiled cassava leaves, dry sweet potato vines, and ensiled sweet potato vines.

CONCLUSIONS

It was shown that good silage can be made from various proportions of TPL and taro peel. Based on the overall ensiling parameters, particularly the reduction of CO content by approximately 9-fold, we suggest that the treatment TPL₅₀ incubated for 60 days is the optimal method of preparing TPL-taro peel silage. The feeding trial indicated that commercial concentrates can be replaced with up to 20% of the TPL₅₀ taro-waste silage without having any negative impacts on animal performance, thus providing a potential means to use agricultural waste to reduce environmental pollution and to reduce competition for food between human and for animal production.

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CONFLICT OF INTEREST

There are no conflict of interest.

AUTHORS CONTRIBUTION

LTTL, NT and NTN contributed to the design of the study. NT, LTH and NTAT conducted the data collection and analysis. LTTL and HTL prepared the first draft. JBL and NTN criticized and revised the manuscript. All authors have read and approved the final manuscript.

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