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Ileal and total tract digestibility in growing pigs fed ensiled taro leaves as partial replacement of fish meal, maize and rice bran

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Abstract

Taro leaves (*Colcacia esculenta*) were ensiled alone or with equal parts of taro petioles or 5% molasses. After 21 days, the lactic acid concentrations (% in DM) were 1.27, 1.45 and 1.49, and pH was 4.5, 4.0 and 3.9, for leaves alone, leaves plus petioles and leaves plus molasses, respectively. Ensiling the taro leaves reduced oxalate concentrations by 30% on leaves alone and by 50% when petioles or molasses were added.

When growing pigs equipped with a T-cannula in the distal ileum were fed a control diet (8% fish meal) or the control diet with 50% of the DM replaced by ensiled taro leaves (2% fish meal) , N retention decreased from 19 to 17 g/day but the biological value of the protein was the same on both diets (86 and 87%, respectively). It is concluded that ensiled taro leaves are a protein source of high biological value for growing pigs.

Key words: *biological value, oxalate, toxicity*

Introduction

Taro (*Colocasia esculenta)* is well-adapted to the Vietnamese climate and can grow almost everywhere with minimal maintenance, under either dryland or wetland conditions. Taro is one of the few crops that can be grown under flooded conditions. Yields of 370 tonnes/ha/year of foliage (leaves and petioles) were reported by Toan and Preston (2010) with 50% of the dry matter (DM) as leaf. Taro leaves are rich in protein (21-26% of DM) while the petioles are rich in soluble carbohydrates (Hang and Kien 2012; Hang and Preston 2009; Rodríguez and Preston 2009).

Taro contains high levels of oxalates which are important anti-nutritional compounds (Oscarsson and Savage 2007) which cause irritation and burning sensation in the throat and mouth on ingestion (Akpan and Umoh 2004). According to Hang et al (2011), the total oxalate ranged from 2400 to 4420 mg/100g of the DM in petioles and 2021 to 6342 in leaves. Total oxalate can be reduced by simple processing methods such as ensiling, boiling, soaking, wilting and washing (Hang et al 2011; Hang et al 2013). Oxalates can form non-absorbable insoluble salts with Ca^{2+}, Fe^{2+}, and Mg^{2+}, rendering these minerals unavailable (Savage et al 2009).

Ensiling of the leaves with molasses (Tiep et al 2006) or by combining them with the petioles (Hang and Preston 2010) resulted in a considerable reduction in total oxalates. The benefit of ensiling petioles with the leaves appears to be due to the high content of soluble sugars in the petiole (Rodríguez and Preston 2009).

The objectives of this study were to evaluate the changes in chemical composition of taro leaves ensiled alone, with the petioles, or with molasses, and to determine the nutritive value of diets in which ensiled taro leaves provided 50% of the diet for growing pigs replacing a combination of fish meal, rice bran and maize.

Materials and methods

Experiment 1:

Taro leaves were ensiled alone (TL), with the petioles (TLP) or with molasses (TLM). Taro leaves and petioles were harvested from farmers' gardens and ensiled in plastic bags with capacity of 1.0 kg. Each treatment was replicated three times. Samples were taken at 0, 7, 14, 21 and 56 days for analysis of DM, crude protein (CP), lactic acid, pH and oxalic acid.

Experiment 2:

Ten castrated Large White male pigs (45±2.55 kg) were fed a rice bran basal diet or the basal diet replaced 50% by taro leaves ensiled with molasses (Table 1). They were fitted with simple T-cannulas (Stein et al 1998) and housed individually in metabolism cages. Chromium oxide was used as a digesta flow marker.

Table 1. Composition of experimental diets (% in DM)

Feeds	**FM**	**ETL**
Rice bran	47.0	16.6
Maize	32.0	19.5
Fish meal	8.0	2
Rice wine by-product	10.0	10.0
Ensiled taro leaves	0	50
Monocalcium phosphate	0.3	0.27
Lys	0	0.2
Meth.+Cys	0.2	0.4
Oil	0	0.5
Cr_2O_3	0.5	0.5
Proximate analysis, % in DM		
CP	17.5	18.3
Ca	0.5	0.5
P	0.4	0.4
Lys	0.7	0.7
Meth.+Cys	0.9	0.9
ADF	14.6	17.4
NDF	20.0	24.1
Oxalate	0.21	3.19

For the determination of ileal digestibility, a total of 12 digesta samples from each pig were taken during 2 days of collection. On each collection day, samples were taken every 2 hours between the morning and afternoon feeding, kept on ice and then frozen at -20^{0}C. Feces were collected four times per day and stored at -20^{0}C. Digestibility of a dietary nutrient/component at each sampling site was calculated using chromium as marker (Sauer et al 2000). Urine was collected in a bucket via a funnel below the cage. To prevent nitrogen losses the pH was kept below 4 by adding 50ml sulphuric acid 25% in the collection bucket.

The chemical composition of diets and ileal and fecal samples was determined by the standard methods (AOAC 1990). NDF and ADF were determined according to Van Soest et al (1991). Cr_2O_3 in feed, feces and ileal digesta was determined by atomic absorption spectrometry after ashing (Fenton and Fenton 1979). Lactic acid was determined by the method of Ranfft (1973) and oxalate according to Savage et al 2000).

Statistical analysis

The data were analyzed by ANOVA using the General Linear Model (GLM) of Minitab Statistical Software, version 15.1 (Minitab 2000). Tukey pair-wise comparisons were used to determine differences between treatment means at $P<0.05$.

Results and discussion

Effect on silage quality

The pH of the silage fell, and of lactic acid increased, more rapidly when the leaves were supplemented with petioles or molasses, reflecting the effect of addition of soluble sugars from molasses and the petioles (Figures 1 and 2). The increase in pH and decrease in lactic acid in the 56-day samples indicate that taro leaf silages should be used not later than 21 days after ensiling.

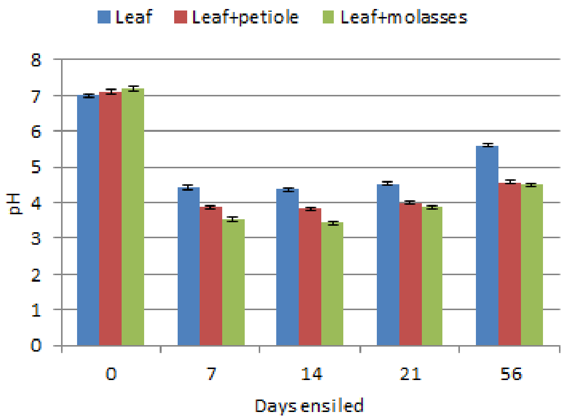

Figure 1. Changes in pH when ensiling taro leaves alone, with the petiole or with molasses

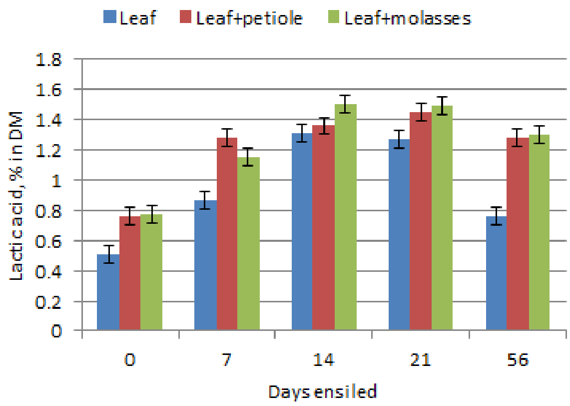

Figure 2. Changes in lactic acid when ensiling taro leaves alone, with the petiole or with molasses

After ensiling for 21 days, the concentration of oxalic acid was reduced by half (Figure 3), the effect being more pronounced when the petioles or molasses were included along with the leaves.

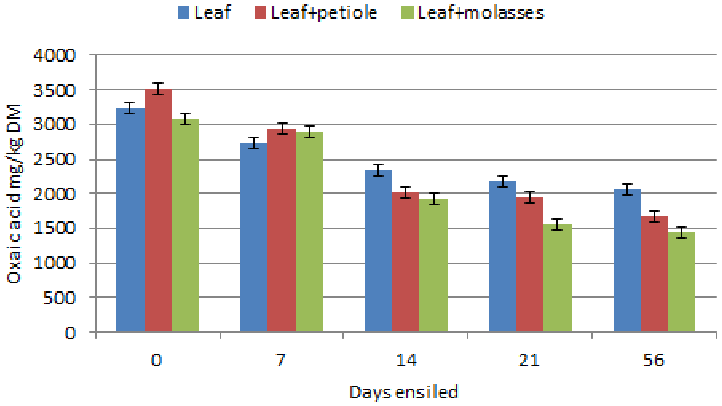

Figure 3. Changes in oxalic acid content when ensiling taro leaves alone, with the petiole or with molasses

At the optimum stage for ensiling (21 days**),** there were no differences in pH, nor in concentrations of lactic and oxalic acids between leaves ensiled with petioles and those ensiled with molasses, both being superior to ensiling of the leaves alone (Table 2).

Table 2. Mean values of pH, lactic acid, oxalic acid and acetic acid (all as g/100g DM) in taro leaves after 21 days ensiled: alone, with equal amounts of petiole or with molasses

	pH	**Lactic acid**	**Oxalic acid**	**Acetic acid**
Leaf	4.53[a]	1.27[b]	2.19[b]	0.910
Leaf+petiole	4.00[b]	1.45[a]	1.95[a]	0.920
Leaf+molasses	3.87[b]	1.49[a]	1.56[a]	1.08
SEM	0.043	0.0805	0.0406	0.0464
P	<0.001	0.02	<0.001	0.079

[ab] *Means in the same column without common superscript differ at p<0.005*

Nutritive value of ensiled taro leaves for pigs

The values for apparent NDF digestibility at the ileum and rectum were lower, when ensiled taro leaves replaced 50% of the control diet (Table 3). There were similar, slight,ly negative, effects for apparent digestibility of crude protein for the ETL diet compared with the control.

Table 3. Mean values for apparent digestibility coefficients in pigs fed a control diet or the control diet replaced 50% by taro leaves ensiled with molasses

	Control	**ETL**	**SEM**	***p***
Ileum				
CP	0.74	0.71	0.048	<0.001
NDF	0.33	0.22	0.013	0.004
CF	0.15	0.11	0.092	<0.001
OM	0.69	0.72	0.0069	0.12
Rectum				
CP	0.77	0.75	0.038	0.013
NDF	0.62	0.56	0.076	<0.001
CF	0.51	0.41	0.079	<0.01
ADF	0.47	0.44	0.056	0.04
OM	0.81	0.79	0.0023	0.001

Table 4. Mean values for N balance in growing pigs fed a control diet or the control diet replaced 50% by taro leaves ensiled with molasses

	Control	**ETL**	**SEM**	***p***
DM intake, g/d	1060	1054	19.1	0.84
N balance, g/d				
Intake	28.4	28.5	0.51	0.88
Feces	6.34	9	0.49	<0.001
Urine	3.2	2.6	0.32	0.26
Retention	19	17	0.39	<0.001
N retained, % digested	86.0	87.0	2.41	0.66

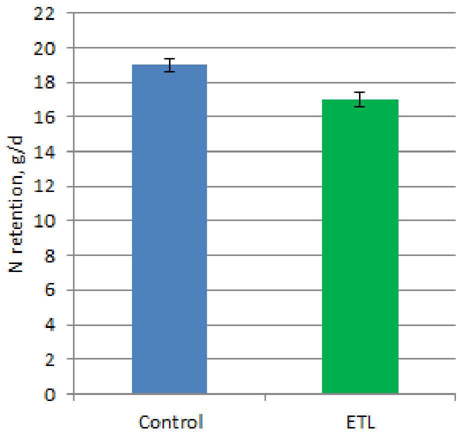

Figure 4. N retention for the control and ensiled taro leaf (ETL) diets

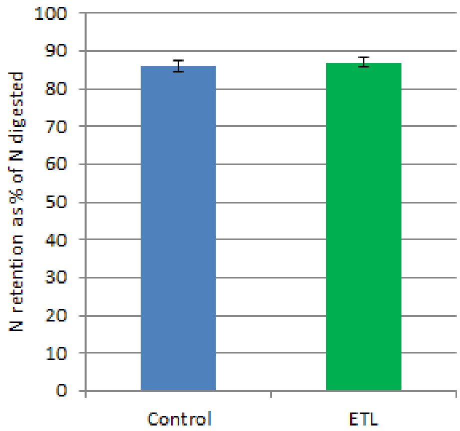

Figure 5. N retention as % of N digested for the control and ensiled taro leaf (ETL) diets

The similar values for N retained as percent of N digested in pigs fed the ETL and control diets indicates that the protein in the diet with 50% ensiled taro leaves has a high biological value (Table 4; Figure 5). There were marked decreases in oxalate concentration from ileal to rectal locations (Table 5). This can be explained by the soluble oxalates combining with Na^+, K^+ or NH_4^+ (Noonan and Savage 1999) and the absorption of the soluble oxalate salts in the small intestine via active transport and passive absorption (Hatch and Freel 2005). Oxalate solubility within the small intestine appears to be a critical factor, as evidenced by the propensity of concomitant calcium ingestion to reduce oxalate absorption in the small intestine (Liebman and Chai 1997; Liebman and Costa 2000), presumably by chelating with oxalic acid. A 30% reduction of insoluble oxalate in the rectum may be related to the action of microorganisms in the large intestine.

Table 5. Mean values (± SEM) for concentration of oxalate (mg/100g DM) in digesta at the ileum and in feces for the diet with 50% ensiled taro leaves

	Ileum	Rectum	% reduction
Total oxalate	2996 ± 302	1362 ± 346	55
Soluble oxalate	1236 ± 39	131 ± 21	89
Insoluble oxalate	1760 ± 289	1231 ± 326	30

Conclusions

- Taro leaves can be successfully ensiled by themselves or in combination with petioles or supplementation with 5% molasses.
- The ensiling process improves the product markedly by reducing oxalate concentration by up to 50% of the original values.

Acknowledgments

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