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Research Article

Nutrient Utilization in Local Mixed Genotype Growing Pigs Fed Wheat-Based Protein Concentrates Blended with Sweet Potato Roots Ensiled with or without Vines

MT Dom[1,3], WK Ayalew[1], PJ Kohun[1], PC Glatz[2,3], PE Hughes[2,3] and RN Kirkwood[3]*

[1]Livestock Projects, National Agricultural Research Institute, Papua New Guinea

[2]South Australia Research and Development Institute, Australia

[3]School of Animal and Veterinary Sciences, The University of Adelaide, Australia

***Corresponding Author:** RN Kirkwood, School of Animal and Veterinary Sciences, The University of Adelaide, Australia.

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Abstract

Background: Feeding sweet potato (Ipomoea batatas, L. (Lam)) roots and forage to pigs is characteristic of smallholder farming in tropical countries and particularly the use of indigenous breeds and their crossbred progeny (mixed genotype, MG) growing pigs. Presenting forage as ensiled, fermented feed, is a recent technology to smallholder pig feeding in the Pacific region, which until now was not tested for metabolic contribution to effective nutrition for MG pigs and towards reducing the feed costs of production.

Objectives: To determine the nutritional utilization of sweet potato for mixed genotype local pig breeds.

Methods: Two metabolic trials tested the total tract apparent digestibility (TTAD) of nutrients and N balance in MG growing pigs fed ensiled SP roots (ER) or roots and vines (ERV), blended with two protein concentrates at 380, 400, 430 and 500 g/kg DM into four treatment diets, ER380, ER430, ERV400 and ERV500, compared against a standard wheat-based commercial pellet diet (STD). The trials were conducted using a 4 × 4 Latin Square design with two sets of four MG pigs at 23 kg (Trial 1) and 27 kg (Trial 2) starting BW. The trial pigs were offered one of four diets interchanged during four 8 d periods, with a 5 d adaptation phase and 3 d for total collection of faeces and urine. Pigs were housed in all-steel metabolic cages (1.0 m × 1.0 m × 1.5 m) on stands 0.7 m above floor level.

Results: DMI was higher (2,290-2,739 g/d) for pigs on the SP-based diets ($p < 0.05$), ADG in Trial 1 was lower (686-718 g/d) but in Trial 2 was similar (944-1072 g/d) to pigs fed STD ($p > 0.05$), while the FCR (2.72-3.70) was higher than STD ($p < 0.05$) in both trials. DM, OM, CF, fats (EE), carbohydrates (NFE) and energy coefficients of TTAD were superior on the SP-based diets, but Ash, Ca and Total P CTTAD were reduced compared to STD ($p < 0.05$). N retained (g N/d) differed between the diets; 27.1 (ERV400), 20.8-24.8 (ER430), 27.7-29.0 (ERV500), 30.8-31.2 (STD); and did not reflect dietary CP or amino acid levels, dietary fibre content, or energy digestibility. However, N retention (NR% intake) and utilization (NR% digested) was inferior to STD for all SP-based diets except ER380 (Trial 2). Higher faecal N (g/d) ($P < 0.05$) suggested increased hind gut fermentation in pigs fed on SP-based diets, whereas higher urine N (g/d) ($p < 0.05$) indicated a lower N requirement.

Conclusion: Dietary fibre in SP vines reduced nutrient utilization for growth but MG pigs adapted over time. Reduced protein and amino acid supplementation were recommended for MG pigs.

Keywords: Blended Diets; Ensiled Sweet Potato; Growing Pigs; Nutrient Utilization

Introduction

Feeding sweet potato (*Ipomoea batatas*, L. (Lam)) roots and forage to pigs is characteristic of smallholder farming in tropical countries [1] and particularly the use of indigenous breeds and their crossbred progeny [2]. Ensiling sweet potato (SP) enables long term preservation of valuable nutrients in the perishable roots and foliage [3]. Fermented feed provides advantages to smallholder pig production but an added complexity to factors influencing pig nutrition, physiology and gut health [4-6]. Dietary fibre in forage based diets reduces energy and protein digestibility digestion in growing pigs [7], although the protein N from SP leaves is well utilized [8]. Providing effective nutrition for pigs requires blending with grain-based protein concentrates which contain a balance of essential amino acids and micronutrients to complement lower nutrients in ensiled SP feed. There is a need to further study the effect of fermented SP roots and vines in blended diets.

Additionally, there is interest in the farming of indigenous crossbred pigs fed on tropical forage diets [9]. The modern progeny of Papua New Guinean (PNG) village pigs, differentiated here from unimproved pigs as 'mixed genotype' (MG) pigs, are an important component of smallholder farming systems for household food security and income generation [10,11]. There is a paucity of research on MG pigs commonly farmed in PNG and the Pacific region, although it is recognized that these animals have survived on minimal health, nutrition and management inputs and thrive on the most basic improvements [11]. One advantage is that indigenous and crossbred pigs have greater capacity for utilizing high fibre feeds, for example, the Zimbawean Mukota pigs [12] and the Vietnamese Mong Cai crosses with Large White pigs [4,5]. PNG village pigs demonstrated high nutrient digestibility when fed raw chopped SP roots [13].

The relative abundance and convenient availability of sweet potato forage makes this feed resource an attractive option for smallholder farmers providing supplementary feed to growing pigs that are high in digestible energy. However, the diets tend to be limited by metabolic availability of critical digestible nutrients in protein and amino acids potentially hindered by higher dietary fibre content. The digestive capacity of modern MG pigs fed ensiled SP forage as the major feed component has not been studied to date. Two metabolic trials were conducted using eight MG growing pigs to determine nutrient utilization when fed SP roots ensiled with or without vines blended with two formulated wheat-based protein concentrates. The experiments tested the hypothesis that there would be no difference to nutrient digestibility, growth performance and N balance between growing MG pigs fed blended SP-based diets or a wheat-based commercial pellet feed. Such studies provide a basis from which nutritional evaluation of cost-effective pig diets may be formulated for smallholder farmers making maximum use of locally sourced or farm-grown forage feeds.

Methods and Materials

Location

Two 32 d metabolic trials were conducted were conducted consecutively from September to October 2015 using facilities at the PNG National Agriculture Research Institute's (NARI) Labu Station (Lat. 6° 40' 27" S Long. 146° 54' 33" E) in Morobe Province, where the climate is tropical humid. Minimum and maximum temperatures during the trials were 24 °C to 31 °C (Trial 1) and 21 °C to 33 °C (Trial 2), at 40% to 100% RH during the trials.

Metabolic experimentation for Total Tract Apparent Digestibility (TTAD) of nutrients followed closely the methods of Giang., *et al*. [4], An., *et al*. [8] and Dom., *et al*. [20] for the comparative evaluation of very contrasted diets based on wheat grain against sweet potato and cassava forage material applied in blended diets with protein concentrate meals.

Experimental pigs and metabolic crates

Two groups of six castrated male growing MG pigs at body weights (BW) 20.2 ± 1.95 kg and 24.1 ± 3.44 kg were selected from Robinson Kale Family Piggery, based at Kindeng in Jiwaka Province (Lat. 5°47'31"S Long. 144°25'18"E), transported to Labu Station, and maintained on standard commercial pellet feed for 14 d (Trial 1) and 19 d (Trial 2), after which four pigs with mean BW's of 22.9 ± 1.14 kg (Trial 1) and 27.1 ± 1.3 kg (Trial 2) were placed into metabolic crates for the experiment feeding. Metabolic crates were two twin-room, all-steel units with dimensions 1.0 m × 1.0 m × 1.5 m on stands 0.7 m above floor level placed in the centre of an open sided shed with the crates positioned face-to-face for visual contact. Eight pigs remained in the cages for the entire 32 d experimental periods. The additional four pigs were kept in pens.

Experiment diets

Two protein concentrates, Pig Conc.1 and Universal Conc., were prepared as a dry meal (Associated Mills Ltd., Lae (PNG)). Soybean, wheat and minerals and other micronutrients were imported products. All other ingredients were available from local producers. Flame Stockfeed Pig Grower (Associated Mills Ltd., Lae, PNG) pellet (~10 mm) feed was the control standard (STD). A local SP cultivar (Rachel White) was used to produce SP silages. The highlands grown SP roots, harvested at maturity in packed 90 kg bags were bought at the Lae Main Market. Fresh SP vine (four non-specific varieties) was harvested from local gardens around Labu Station. Processing and ensiling was done immediately when roots and vines were received and silage was fermented for at least 14 d before feeding to pigs. SP roots were shredded, SP vine were diced into 0.5 to 1 cm pieces, using a manually operated chopper. The material was mixed before ensiling; using table salt (NaCl) at 0.05% w/w of feed as a preservative and promptly packed and compressed into large 80 L polyethylene bins used as storage silos. Acidity in ensiled sweet potato roots was measured at pH 4.0 (data not shown).

Two silage treatments were SP roots ensiled alone (ER) and SP roots ensiled with vines (ERV) on a 1:1 kg DM basis. The SP vines provided approximately 300 and 250 g/kg DM in ERV400 and ERV500 respectively. Four treatment diets were prepared by weighing fresh components calculated to provide 2,000 g DM on each feed offered. Universal Conc. was blended at 380 g/kg DM or Pig Conc.1 at 430 g/kg DM with ensiled SP roots providing 620 and 570 g/kg DM in ER380 and ER430 diets respectively; Pig Conc.1 was blended at 400 and 500 g/kg DM with 600 and 500 g/kg DM of mixed SP root and vine silage in diets ERV400 and ERV500. Blending the daily feed was done by hand in large basins. Nutrient compositions of the component feeds and the treatments diets are shown in Tables 1 and 2 respectively.

Dry pellet feed and the protein concentrate meal were sampled as received from commercial producing mill. SP roots as fresh roots and in dry milled form, and SP vines delivered fresh were sampled for chemical testing on the day received for processing, while ensiled SP forage was delivered as wet silage sampled after 14 d of fermentation. Samples were stored briefly in a refrigerator before same day delivery to chemistry laboratory.

Experimental procedures

The experimental design used in both metabolic trials was a 4 × 4 Latin Square with four diets as interchanged treatments fed to growing pigs over four consecutive 8 d feeding periods, with 5 d of adaptation feeding before 3 d feeding for sampling. Test diets were interchanged according to a randomized schedule, offered *ad libitum* and refusals collected every 24 h on each morning. Feed offered and refused was weighed on a digital scale (ASDA 692/240, 5000 ± 0.1 g). Fresh piped water (local reservoir) was readily avail-

Nutrients	Feed components			
	ER	**ERV**	**Pig Conc.1[1]**	**Uni. Conc.[1]**
Chemical analysis (g/kg DM)				
DM	435	269	879	903
OM	400	248	791	782
Ash	35	21	88	121
CF	10	30	41	47
EE	2	2	44	92
CP	19	32	329	377
NFE[2]	370	185	377	266
Ca	4.6	9.3	18.0	20.7
Total P	4.3	3.8	9.7	10.6
Total N	3.0	5.1	52.6	60.3
Calculated from formulation and published data (g/kg DM)				
Leu	1.0	2.2	23.4	25.6
Lys	0.8	1.2	20.3	24.4
Met	0.1	0.3	8.2	10.7
Meth+Cyst	0.6	0.7	12.6	15.7
Thr	0.9	1.6	11.8	14.3
Try	0.1	0.2	3.5	4.2
DE (MJ/kg)[2]	15.5	15.8	15.6	14.2
Lys:DE (kg/MJ)[2]	0.05	0.08	1.30	1.72
Ca:P[2]	1.07	2.45	1.86	1.96
NDF[3]	49	73	179	184
ADF[3]	23	50	59	63
Lignin[3]	5	13	14	15
Starch[3]	301	186	146	80
Total sugars[3]	40	24	41	44

Table 1: Nutrient composition of feed components combined on DM basis as blended diets for growing MG pigs

ER = 100% ensiled sweet potato roots: ERV = ensiled sweet potato roots and vines, mixed on 1:1 DM basis: Pig Conc.1 = Pig concentrate1: Uni. Conc. = Universal concentrate.

[1]Protein concentrates Pig Conc.1 and Universal Conc. were provided by Carey Animal Nutrition Ltd, 3 Walnut Grove, Cherrybrook, NSW, Australia, 2126, prepared by Associated Mills Ltd., Lae (PNG. Ingredient composition of Pig Conc.1: Wheat grain, 120 g/kg, Meat meal 130 g/kg, Blood meal 50 g/kg, Fish meal (PNG) 100 g/kg, Tallow 40 g/kg, Soybean meal 180 g/kg, Wheat millrun (PNG) 358 g/kg, Salt 3 g/kg, Choline chloride (75%) 1 g/kg, Rhodimet-88 Liquid (Methionine) 4 g/kg, Lysine HCl 1 g/kg, Pig Premix 10 g/kg, Mycostat 1 g/kg, Sorbasafe 2 g/kg.

Pig Premix: Vitamin A 15.0 miu, Vitamin D 4.0 miu, Vitamin E 45.0 g, Vitamin K 3.0 g, Niacin 25.0 g, Pantothenic Acid 15.0 g, Folic Acid 1.0 g, Riboflavin/B2 6.0 g, Vitamin B12 30.0 mg, Biotin 100.0 mg, Vitamin B6 3.28 g, Vitamin B1 1.80 g, Cobalt 1.0 g, Iodine 1.0 g, Molybdenum 2.0 g, Selenium 0.15 g, Selplex (inorganic Se) 0.15 g, Copper 10.0 g, Iron 100.0 g, Manganese 50.0 g, Zinc 150.0 g, Ethoxyquin 125.0 g, Surmax 200 75.0 g, Mold Inhibitor 500.0 g, Rovabio Excel AP T-Flex 50.0 g.

Ingredients composition of Universal Conc.: Meat meal 140.6 g/kg, Fish meal 105.3 g/kg, Tallow 43.8 g/kg, Soybean meal 219.3 g/kg, Millrun 384 g/kg, Choline chloride 1 g/kg, Rhodimet-88 liquid (Methionine) 6.3 g/kg, Avizyme (1310) 0.7 g/kg, Mycostat 0.87 g/kg, Sorbasafe 1.75 g/kg.

[2]Nitrogen Free Extracts (NFE), Digestible Energy (DE), Lysine: digestible energy ratio (Lys:DE), Calcium: Total Phosphorus ration (Ca:P) were calculated from chemical proximate analysis values in this table.

[3]Neutral detergent fibre (NDF), acid detergent fibre (ADF), Lignin, Starch and Total Sugars calculated for each of the Treatment components using data from Carey Animal Nutrition formulation of Pig Conc.1 and Uni. Conc. and for sweet potato roots and vines using updated data on Feedipedia (Heuze*et al*., 2015).

able from nipple drinkers, and four overhead fans (Air Monster 18" id) were directed at the cage and clear of the feeding trough and operated at full volume throughout the feeding period. Manual mist spraying was applied when temperatures reached 30 °C and was also applied during humid periods when pigs displayed discomfort (e.g. restless in cage, scratching, heavy breathing and unsettled when laying). Body weights were measured on d 1, 6 and 8 of each period using a digital platform balance (Xiangshan® T3811-JE2; 200 ± 0.02 kg). Close daily observations were made of the pigs and cage set-up during sample collection days to ensure clean separation of faeces and urine. Pigs were managed according to prescribed animal welfare guidelines approved by The University of Adelaide Animal Ethics Committee (Approval Number 0000016426). The two metabolic trials were completed without incident to the eight selected MG pigs. There were no indications of diarrhoea or other abnormality of body condition, temperature, or behaviour, and standing in crates did not negatively affect the feeding behaviour.

Total collection of faeces and urine was achieved through steel floor bars with 5 mm spacing, onto sliding steel trays, angled to allow urine to drain off while solid contaminants were trapped by a wire coil allowing urine to be funnelled through a fine metal-sieve into 2.5 L sealed brown glass bottles (Note: sulphuric acid for ammonia N fixation was not available at the time of testing). Faeces were weighed before drying in a Labec® forced air oven at 105 °C, milled and stored in a cool, dry location in Snap-lock® sealed plastic sampling bags. Urine was stored in 500 mL PET bottles in an upright Westinghouse freezer at 4°C until delivery. Sampling was done over 3 d for each 8 d period and faeces and urine samples from each test diet were pooled for the collection period. All samples were collected in 1 kg or 0.6 L duplicates at the end of each 10 d period before pooling and sub-sampling for immediate delivery to chemistry laboratory.

Sample collections

Nutrient analytical testing

Chemical proximate analyses of feed, faeces and nitrogen in urine was conducted at the National Analytical and Testing Services Laboratory Ltd (Lae, PNG) using AOAC [14] Official Methods for DM (AOAC 930.15), crude protein (AOAC 954.01), and total fat determined as ether extracts (EE) (AOAC 920.39), crude fibre (AOAC 978.10), ash (AOAC 942.06), calcium (AOAC 927.02) and total phosphorus (AOAC 964.06). Organic matter (OM) was calculated as OM % = DM %–Ash %. Digestible Energy (DE) was calculated as DE (kCal) = 4,151 – (122 × Ash %) + (23 × CP %) + (38 × EE %) – (64 × CF %), R2 = 0.89 [15] and converted to MJ/kg. Essential amino acids, leucine, lysine, Methionine cysteine, threonine and tryptophan, and dietary fibre as neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (Lignin) were calculated from combined formulation ingredients of Pig Conc.1 (Carey Animal Nutrition) and published values [16].

Statistical analysis

Suitability of the sample size and power in the 4×4 Latin Square design was determined on G*Power Version 3.1.9.2 (Franz Faul, Universitat Kiel, Germany) for statistical testing conducted at 95% significance level. Pearson correlation coefficients were calculated for Minimum and Maximum temperature influence on daily DMI. All data sets were analysed by ANOVA of the Latin Square design using GenStat 15th Edition (VSN Ltd) and the means were separated by Tukey's Honest Significant Difference (HSD) test.

Results

Treatments

Inclusion of SP vines in the ensiled feed increased the ash, CF, carbohydrates (as NFE), total P, NDF, ADF and lignin content in the blended diets ERV400 and ERV500 compared to ER380 and ER430. Total sugar was higher in the blended SP root diets ER380 and ER430. However, these nutrients were higher in STD diet (Table 2). Five essential amino acids were estimated to be higher in SPERV500 than the other four diets including STD. DE was similar in the blended SP diets and these were higher than in the STD pellet diet. Lysine: DE ratio was superior for ER38 and ERV500. Coefficients of TTAD, growth pig performance and N balance from Trial 1 and 2 are in Tables 3 and 4, respectively.

Parameters	Treatment means				SEM	*P*-value
	ER430	ERV400	ERV500	STD		
Coefficients of apparent total tract digestibility						
DM	0.75^{a}	0.78^{b}	0.75^{a}	0.76^{a}	0.048	0.011
OM	0.86^{b}	0.86^{b}	0.85^{b}	0.81^{a}	0.027	<.001
Ash	0.33^{a}	0.47^{b}	0.33^{a}	0.63^{c}	0.045	<.001
CF	0.57^{ab}	0.72^{c}	0.65^{bc}	0.49^{a}	0.194	<.001
EE	0.78^{a}	0.82^{a}	0.81^{a}	0.76^{a}	0.263	0.357
CP	0.76^{a}	0.83^{b}	0.82^{b}	0.84^{b}	0.087	0.003
NFE	0.93^{b}	0.91^{b}	0.90^{b}	0.83^{a}	0.074	<.001
Ca	0.13^{a}	0.23^{b}	0.22^{b}	0.57^{c}	0.082	<.001
Total P	0.13^{a}	0.51^{c}	0.21^{b}	0.54^{d}	0.044	0.001
Energy	0.97^{c}	0.95^{b}	0.97^{c}	0.85^{a}	0.007	<.001
DE (MJ/kg DM)	15.82^{d}	14.93^{b}	15.20^{c}	12.56^{a}	0.037	<.001
Growth performance						
Mean BW (kg)	41.0^{b}	39.2^{a}	39.0^{a}	41.1^{b}	0.18	<.001
DMI (g/d)	2290^{ab}	2607^{b}	2532^{ab}	2211^{a}	68.8	0.018
ADG (g/d)	915^{b}	684^{a}	718^{a}	1000^{b}	39.2	0.003
FCR	2.54^{a}	4.09^{c}	3.54^{bc}	2.20^{a}	0.20	0.005
Faeces DM (g/d)	506^{a}	489^{a}	586^{b}	585^{b}	6.83	<.001
Urine (mL/d)	2,750^{ab}	3,178^{ab}	3,199^{b}	1,072^{a}	434	0.039
N balance (g)						
N intake	55.4^{a}	62.0^{c}	74.4^{d}	59.8^{b}	0.35	<.001
Faeces N	23.7^{b}	22.5^{b}	25.2^{b}	13.4^{a}	0.98	<.001
N digested	32.4^{a}	38.2	50.3^{d}	45.7^{c}	0.83	<.001
Urine N	12.6^{b}	13.0^{b}	17.6^{c}	6.5^{a}	0.37	<.001
N retained	20.8^{a}	27.1^{b}	29.0^{c}	31.2^{d}	0.28	<.001
NR% intake[1]	36.1^{a}	46.2^{b}	45.3^{b}	65.8^{c}	1.65	<.001
NR% digested[2]	65.3^{a}	79.2^{c}	71.7^{b}	85.4^{d}	0.23	<.001

Table 2: Coefficients of total tract apparent digestibility, growth performance and N balance in growing MG pigs fed blended SP silage diets without (ER430) or with vines (ERV400 and ERV500) or a wheat-based commercial pellet (STD) diet in Trial 1.

ER430 = 570 g/kg DM ensiled SP roots (ER) blended with 430 g/kg DM Pig Conc.1: ERV400 and ERV500 = 600 and 500 g/kg DM ensiled SP roots and vine (ERV) blended with 400 and 500 g/kg DM Pig Conc.1 respectively.

[1]NR% intake is N retained as a percentage of N Intake.

[2]NR% digested is N retained as a percentage of N Digested.

Values within a row with different superscripts differ significantly at $P < 0.05$.

Parameters	Treatment means				SEM	*P*-value
	ER380*	ER430	ERV500	STD		
Total tract apparent digestibility (%)						
DM	0.83^{b}	0.81^{b}	0.74^{a}	0.73^{a}	0.090	<.001
OM	0.87^{b}	0.88^{b}	0.83^{ab}	0.78^{a}	0.121	0.005
Ash	0.80^{d}	0.44^{b}	0.37^{a}	0.53^{c}	0.095	<.001
CF	0.59^{ab}	0.65^{b}	0.64^{b}	0.42^{a}	0.411	0.026
EE	0.89^{c}	0.82^{b}	0.78^{a}	0.79^{a}	0.018	<.001
CP	0.88^{b}	0.83^{a}	0.82^{a}	0.81^{a}	0.059	0.001
NFE	0.92^{c}	0.92^{c}	0.90^{b}	0.80^{a}	0.021	<.001
Ca	0.66^{c}	0.18^{a}	0.42^{b}	0.50^{b}	0.238	<.001
Total P	0.80^{b}	0.42^{a}	0.27^{a}	0.67^{b}	0.311	<.001
Energy	0.90^{b}	0.95^{c}	0.97^{d}	0.86^{a}	0.035	<.001
DE (MJ/kg DM)	13.81^{b}	15.46^{d}	15.13^{c}	12.67^{a}	0.054	<.001
Growth performance						
Mean BW (kg)	45.8^{a}	45.1^{a}	45.0^{a}	47.2^{a}	0.88	0.328
DMI (g/d)	2717^{c}	2739^{c}	2306^{b}	2077^{a}	32.3	<.001
ADG (g/d)	994^{a}	1072^{a}	944^{a}	1067^{a}	88.0	0.704
FCR	2.71^{b}	3.70^{b}	2.72^{ab}	2.31^{a}	0.21	0.018
Faeces DM (g/d)	458^{a}	547^{b}	628^{b}	585^{b}	17.4	0.002
Urine (mL/d)	2123^{b}	2693^{c}	2881^{c}	594^{a}	74.7	<.001
N balance (g)						
N intake	67.2^{b}	66.4^{b}	67.8^{b}	55.1^{a}	0.77	<.001
Faeces N	19.3^{b}	22.1^{c}	25.7^{d}	11.7^{a}	0.14	<.001
N digested	49.7^{b}	41.8^{a}	42.5^{a}	43.9^{a}	1.15	0.010
Urine N	8.74^{a}	24.8^{c}	22.8^{c}	17.2^{b}	1.08	<.001
N retained	33.9^{c}	25.8^{a}	27.7^{ab}	30.8^{bc}	0.84	0.002
NR% intake[1]	60.2^{b}	57.0^{b}	40.8^{a}	63.7^{b}	2.07	<.001
NR% digested[2]	88.1^{d}	75.3^{b}	63.1^{a}	83.4^{c}	0.51	<.001

Table 3: Coefficients of total tract apparent digestibility, growth performance and N balance in growing MG pigs fed three blended SP silage diets without (ER380 and ER430) or with vines (ERV500) or a wheat-based commercial pellet (STD) diet in Trial 2

ER380* = 620 g/kg DM ensiled SP roots (ER) blended with 380 g/kg DM Uni. Conc.*: ERV400 and ERV500 = 600 and 500 g/kg DM ensiled SP roots and vine (ERV) blended with 400 and 500 g/kg DM Pig Conc.1 respectively.

[1]NR% intake is N retained as a percentage of N Intake.

[2]NR% digested is N retained as a percentage of N Digested.

Values within a row with different superscripts differ significantly at $P < 0.05$.

Trial 1: MG pigs starting at 23 kg BW

Nutrient digestibility to MG pigs in Trial 1

CTTAD for DM was higher ($P < 0.05$) in MG pigs fed ERV400 than ERV500, ER430 or STD (Table 3). OM, CF, fats (EE), carbohydrate (NFE) and energy CTTAD were superior in pigs fed the SP-based diets. Protein CTTAD was higher for pigs fed STD, ERV400 and ERV500 diets and the lowest for pigs fed ER430. Ash, Ca and phosphorus CTTAD were lower on the SP-based diets than the wheat-based STD.

Growth performance of MG pigs in Trial 1

The mean BW of MG pigs over the 32 d metabolic trial was lower on ERV400 and ERV500 ($p < 0.05$). DMI was higher on ERV400 and ERV500 than ER430 and STD (Table 3). There was no correlation between minimum daily temperatures ($p = 0.456$) and DMI. There was correlation (17% of DMI data) to maximum daily temperature ($p < 0.001$) observed as lower DMI during hotter days (data not shown). MG pig performance on STD was better than ERV400 and ERV500 but similar to ER430. Daily faecal DM output was higher from pigs fed STD and ERV500. Daily urine output (mL) was higher for the three SP-based diets.

N balance in MG pigs in Trial 1

N intake (g/d) to the growing pigs (Table 3) was different between the diets ($p < 0.05$). Faecal N output (g/d) was higher in pigs fed the SP-based diets than wheat-based STD. Digested N was highest on ERV500. Urine N losses (g/d) were almost twice as high on the SP-based diets as STD. N retained (g/d) by MG pigs was better on STD than on SP-based diets. N retention (NR% intake) was better on STD, while ERV400 and ERV500 were similar and ER430 the least. N utilization (NR% digested) was highest on the STD diet.

Trial 2: MG pigs starting at 27 kg BW

Nutrient digestibility to MG pigs in Trial 2

CTTAD of DM and OM were higher in pigs fed ER380 and ER430 ($p < 0.05$) (Table 4). Ash CTTAD were very different to pigs on each of the diets and higher for ER380 compared to the other three diets. CF CTTAD was improved in pigs fed SP-the based diets compared to the wheat-based STD. Fat and CP CTTAD was high for all four diets. Carbohydrate (NFE) CTTAD was much higher in pigs fed on SP-based diets, than pigs fed on wheat-based STD. Ca and Total P CTTAD were much higher to pigs fed ER380 and STD than ER430 or ERV500. SP-based diets provided over higher CTTAD energy to growing pigs compared to the wheat-based STD.

Growth performance of MG pigs in Trial 2

Mean BW's of the pigs on the four treatment diets were similar ($p > 0.05$) throughout Trial 2 (Table 4). DMI were 400-700 g higher for the ER380 and ER430 than ERV500 and STD. There was no correlation of DMI with minimum ($p = 0.130$) or maximum ($p = 0.278$) daily temperatures (data not shown). ADG were statistically similar on the four diets however FCR were very different between ER430 and STD ($p < 0.05$), with ER430 the least efficient. Pigs fed ERV400 and ERV500 had statistically similar FCR to STD and ER430. Faeces DM output (g/d) was the lowest from pigs fed ER380 while urine output (mL/d) was over three to five times higher for pigs fed the SP-based diets than STD diet.

N balance in MG pigs in Trial 2

N intake (g/d) was similar ($p > 0.05$) to pigs fed the SP-based diets despite differences in dietary CP (Table 1) or DMI (Table 4). There were statistical differences in the pigs daily faecal N output from each of the diets ($p < 0.05$), but SP-based diets were higher than STD. Digested N (g/d) to pigs was higher for ER380, but similar for ER430, ERV500 and STD. Urine N (g/d) losses were much lower on ER380 followed by STD. Urine N losses from pigs fed ER430 and ERV500 were similar. N retained (g/d) was highest in pigs fed ER380 and lowest in ER430, where the only major difference between the two diets was the methionine and Methionine cysteine levels. N retention (NR % intake) was similar in MG pigs fed ER380, ER430 and STD and lowest for pigs fed on ERV500. N utilization (NR% digested) was different in MG pigs the four diets and was the highest for pigs fed on ER380.

Discussion

Nutrient utilization in MG growing pigs

This work demonstrated improvement in the nutrient utilization by growing pigs for blended SP-based diets which were comparable to their performance on a wheat-based commercial pellet diet. OM, CF and energy CTTAD in growing pigs fed the mixed ensiled SP root and vine diets was better than the wheat-based STD. Energy digestibility was particularly high in ERV400 and ERV500 diets. Considering that these SP-based diets provided less starch than STD diet the additional DE gained must have been from the higher digestibility of blended SP-wheat starch and dietary fibre. Reduced energy digestibility for the STD diet was probably related to the higher dietary fibre (NDF) and faster passage rate through the gut [17], although the latter effect was not measured. CTTAD in the PNG MG pigs was similar to that of the PNG indigenous village pigs fed raw SP roots where digestibility was high despite the lower nutrition provided [13]. The nutrient profile of SP-based diets tested in this work was similar to specifications of Australian standards for growing pigs [18]. In addition, CTTAD in these MG pigs was superior to Mong Cai × Large White crossbred growing pigs fed similar SP-based diets in Vietnam [4,8]. Mong Cai crossbred pigs have physiological and morphological adaptations for digesting high fibre feeds [5,9]. Similar adaptations to improved digestion of fibre may be proposed for the MG pigs farmed in PNG, although the current population are believed to have genetic admixture with wild, feral and village populations in PNG [11,19].

Interestingly, nutrient utilization in the MG pigs was also comparable to commercial crossbred genotype pigs fed very similar ensiled SP root diets with the same diet formulations however their growth rates were higher [20]. This is expected considering the continual admixture of the indigenous pigs with introduced exotic breeds over several generations [10,19]. In fact, the CTTAD and growth performance appeared to improve in the heavier growing pigs (23 kg vs. 27 kg) fed SP-based diets but not for the wheat-based commercial diets. It was therefore surmised that a longer exposure to SP feed while under smallholder farmer management and the subsequent trial adaptation period (14 d vs. 19 d) modified the MG pig capacity for digesting dietary fibres in blended SP diets, as found to occur with observations on other crossbred pigs [5,21]. This is an important finding considering that the MG pigs are an expanding subset of commercially farmed growing pigs in PNG where SP is a major feed resource. It is likely that consistent feeding on the same diets rather than changeover feeding as in these experiments may present distinct differences in performance of growing pig. Also, the MG pigs in tropical production environments may be economically competitive to imported commercial exotic genotypes when using feeds such as sweet potato or cassava [22,23]. Local pigs are more adapted to the warm climates and to available fibrous feeds [9,24].

The findings support the theory that MG pigs may have improved capacity to digest the fibre SP vine and foliage. However, other factors, such as variation in feed ingredients as well as their micronutrient levels, and even small differences in nutrient composition may also have influenced the outcome of nutrient digestion and absorption. Nevertheless, superior CTTAD in the SP-based diets resulted in much higher energy digestibility. The higher OM and CF CTTAD for SP-based diets indicates increased fermentation in the hindgut and it is probable that increased fibre digestibility added microbial N and volatile fatty acids added to the total energy supply [25,26]. In wheat-based STD the higher dietary fibre (NDF, ADF and lignin) probably lowered the energy digestibility. Insoluble fibre does not affect ileal digestion whereas soluble fibre reduces nutrient absorption but not starch absorption [27]. SP roots and vines provide a mixture of dietary fibre. Although not directly studied in this work, a slower rate of digesta passage through the gut and fermentation of soluble fibre in the large intestine affects nutrient absorption and digestible energy balance [5]. The higher DE supplied by SP roots and vines may have significantly contributed to growth and maintenance in MG pigs.

Growth performance of growing MG pigs

DMI for pigs fed ERV400 and ERV500 diets was not affected by the bulky ensiled SP vine and foliage, contrary to some predictions [28]. The amounts of SP-vine inclusion in the diet were higher than the recommended 100 g/kg DM for growing pigs [29]. SP-vine in ERV500 (250 g/kg DM) was not detrimental to performance, however when fed ERV400 (300 g/kg DM) growth performance was reduced. It appears that the high DMI in MG pigs when fed ERV400 and ERV500 was not an advantage to growth performance in lower body weight pigs. Feed conversion ratio for SP-based diets improved in heavier BW pigs (Trial 2) and also reflected the better N retained (g/d). The wheat-based STD produced the best growth performances at lower DMI. Pelleting feed improves the feed efficiency and energy digestibility [30], and this was an advantage to pigs fed the wheat-based diet commercial control diet.

N utilization in growing MG pigs

Crude protein digestibility in pigs fed SP-based diets was comparable to those fed the wheat-based STD. N retention on SP-based diets was lower than the STD. However, compensatory improvement in N utilization occurs in growing pigs when soluble fibre (pectin) is included in the diet [31] and this was observed on the SP-based diets. Utilization if digested N for retention improved by 18-33% for SP-based diets compared to 20% for STD diet. SP leaves provide adequate ileal and total tract digestibility for OM (82-88%), CP (74-75%) and CF (61%) although lower in DM [8]. Higher amounts of SP foliage reduce N retention and growth and this is mainly due to the increase in dietary fibre particularly when offered in dry form [4,7]. The level and type of dietary fibre may influence ileal N [5,32], although amino acid digestibility is not affected [32]. SP vines in this work did not increase dietary fibre in ERV400 or ERV500 compared to the wheat-based STD. Fresh SP-vines offered at lower levels improve protein digestibility and nitrogen retention due to a relatively rich amino acid profile in SP leaves [8]. The same may be expected for the ensiled SP vines which included the foliage.

It is apparent that the amino acid supplementation in the concentrate feeds vastly improved the N absorption. This was evident in the increased faecal and urine N output for pigs fed SP-based diets despite mostly similar faecal DM output to STD. High DM intake leads to sloughing of epithelial cells in the gut which adds to faecal N. A shift in N losses from urine to faeces was found in the SP-based diets and this is an indication of microbial fermentation in the pig gut [26]. However, it is more likely that the SP-based diets provided in excess of MG pig requirement for protein and amino acids because the urine N loss was statistically very high. On SP-based diets the improved N utilization was supported by higher digestible energy and was regardless of levels of crude protein and amino acid or the effects of dietary fibre. By comparison the wheat-based diet (STD) provided less digestible energy but greater N retention and utilization to growing MG pigs. The better performance on STD pellet diet was related to better amino acid absorption. It is surmised that more energy was required for protein digestion and maintenance needs in the growing pigs fed the SP-based diets and that this occurred at the expense of growth [34,35]. Importantly the N retained by growing pigs fed SP-based diets (20.8-29.0 g N/d) reached the level for the wheat-based pellet feed (30.8-31.2 g N/d). Further reduction of the protein levels in blended SP diets with amino acid supplementation is possible for growing MG pigs and may be unlikely to affect their growth performance [36]. At lower dietary protein adequate amino acid supplementation will provides similar performance to pigs fed 16% protein [37].

Conclusion

Nutrient and energy utilization in growing pigs fed blended diets of SP-roots ensiled with or without vines was similar to that in the wheat-based commercial pellet feed however growth performance was reduced. MG pigs demonstrated high capacity for digesting ensiled SP vines at 25% and 30% DM however these diets may be better suited to finisher pigs and sows. The higher OM and CF digestibility and high DE gained from SP-based diets indicated that fermentation in the hindgut contributed to the growing pigs energy balance. Although dietary fibre in SP vines reduced growth performance, and occurred when pigs were fed inconsistently on mixed diets, the heavier pigs had adapted over time. Protein digestibility was high but poorer N retention reflected excess N losses, and possibly contributions from endogenous sources during digestion and from microbial activity. Nevertheless, N utilization was improved and indicates that lower protein or amino acid supplementation may be recommended for MG pigs.

Recommendations

Reducing the level of sweet potato vines for local MG pigs grown by smallholder piggeries may be appropriate for maximizing growth of younger animals. Improved N utilization should be further investigated for determining more precise protein and amino acid requirements for MG growing pigs. The overall implication that sweet potato may provide a nutritious and potentially economically viable feed resource for local farmers should be investigated in more extensive feeding trials.

Conflicts of Interest

The authors declare no conflicts of interest.

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