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Title: Nutrient Utilization in Grower Pigs fed Boiled, Ensiled or Milled Sweet Potato Roots Blended with a Wheat based Protein Concentrate

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Abstract

Sweet potato (SP) pig feeding systems are economically important to small-scale pig farmers in Southeast Asia and the Pacific region. SP roots are highly palatable and highly digestible as fresh or boiled, ensiled or dried feed. Recommended use in complex diets for pigs was 30%, with reduced growth performance at higher levels. But the use of other highly digestible protein ingredients could improve nutrient utilization. A metabolic experiment was conducted utilising a 4 × 4 Latin Square design, with four (Landrace × Large White) × Duroc grower pigs at 8 eight weeks of age. The pigs were fed four dietary treatments over four consecutive eight-day feeding periods, tested the hypothesis that there would be no difference in nutrient digestibility and utilization in pigs fed SP roots when prepared as boiled (SPBR43) or ensiled (SPER43) or milled roots (SPMR43) blended with a complementary protein concentrate, and compared against a standard Pig Grower feed (STDPG). The four tested diets contained 0.9% Lysine; however, sweet potato roots at 57% DM of diets provided 16 MJ/kg digestible energy compared to 14 MJ/kg in the wheat based Pig Grower. DM, Ash, fibre, protein and calcium digestibility of SP blended diets was similar ($p>0.05$) to STDPG. Fat (ether extract) and Phosphorus digestibility was lower ($p<0.05$) for SPBR43, but SPMR43 and SPER43 were similar ($p>0.05$) to STDPG. Carbohydrate (NFE) digestibility for SPER43 was similar ($p>0.05$) to STDPG, while SPBR43 and SPMR43 were similar to each other but much higher ($p<0.05$) than STDPG. Energy utilization of SPBR43 was higher ($p<0.05$) than STDPG, while SPER43 and SPMR43 were similar to both ($p>0.05$). N intake and N digested was lowest for SPER43, but SPBR43 and SPMR43 were higher ($p<0.05$) and similar ($p>0.05$) to STDPG. N retained (g/day) was higher for SPMR43 and SPBR43 ($p<0.05$) but SPER43 was similar to STDPG ($p>0.05$). N digestibility was higher for the SP based diets than STDPG ($p<0.05$) but SPER43 was also similar to STDPG ($p>0.05$). Sweet potato as boiled or ensiled or milled roots blended with 43% Pig Conc.1 were highly digestible and provided improved nutrient utilization, similar ($p>0.05$) growth rates and feed efficiency in pigs compared to the wheat based Pig Grower feed. SP as boiled or ensiled or milled roots blended with Pig Conc.1 can effectively constitute 57% DM of the diet of grower pigs and match the growth performance obtained from a wheat-based commercial grower pig feed.

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Keywords: Blend-feeding, grower pigs, nutrient utilization, sweet potato

Nutrient Utilization in Grower Pigs fed Boiled, Ensiled or Milled Sweet Potato Roots Blended with a Wheat based Protein Concentrate

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ABSTRACT: Sweet potato (SP) pig feeding systems are economically important to small-scale pig farmers in Southeast Asia and the Pacific region. SP roots are highly palatable and highly digestible as fresh or boiled, ensiled or dried feed. Recommended use in complex diets for pigs was 30%, with reduced growth performance at higher levels. But the use of other highly digestible protein ingredients could improve nutrient utilization. A metabolic experiment was conducted utilising a 4 × 4 Latin Square design, with four (Landrace × Large White) × Duroc grower pigs at 8 eight weeks of age. The pigs were fed four dietary treatments over four consecutive eight-day feeding periods, tested the hypothesis that there would be no difference in nutrient digestibility and utilization in pigs fed SP roots when prepared as boiled (SPBR43) or ensiled (SPER43) or milled roots (SPMR43) blended with a complementary protein concentrate, and compared against a standard Pig Grower feed (STDPG). The four tested diets contained 0.9% Lysine; however, sweet potato roots at 57% DM of diets provided 16 MJ/kg digestible energy compared to 14 MJ/kg in the wheat based Pig Grower. DM, Ash, fibre, protein and calcium digestibility of SP blended diets was similar ($p>0.05$) to STDPG. Fat (ether extract) and Phosphorus digestibility was lower ($p<0.05$) for SPBR43, but SPMR43 and SPER43 were similar ($p>0.05$) to STDPG. Carbohydrate (NFE) digestibility for SPER43 was similar ($p>0.05$) to STDPG, while SPBR43 and SPMR43 were similar to each other but much higher ($p<0.05$) than STDPG. Energy utilization of SPBR43 was higher ($p<0.05$) than STDPG, while SPER43 and SPMR43 were similar to both ($p>0.05$). N intake and N digested was lowest for SPER43, but SPBR43 and SPMR43 were higher ($p<0.05$) and similar ($p>0.05$) to STDPG. N retained (g/day) was higher for SPMR43 and SPBR43 ($p<0.05$) but SPER43 was similar to STDPG ($p>0.05$). N digestibility was higher for the SP based diets than STDPG ($p<0.05$) but SPER43 was also similar to STDPG ($p>0.05$). Sweet potato as boiled or ensiled or milled roots blended with 43% Pig Conc.1 were highly digestible and provided improved nutrient utilization, similar ($p>0.05$) growth rates and feed efficiency in pigs compared to the wheat based Pig Grower feed. SP as boiled or ensiled or milled roots blended with Pig Conc.1 can effectively constitute 57% DM of the diet of grower pigs and match the growth performance obtained from a wheat-based commercial grower pig feed.

Keywords: Blend-feeding, grower pigs, nutrient utilization, sweet potato

INTRODUCTION

Sweet potato (*Ipomoea batatas* L. (Lam)) is a common feed supplement to growing pigs in tropical countries. Sweet potato-pig feeding systems are widely practiced and economically important in Asia, Southeast Asia and the Pacific region, for example in China, Vietnam, Philippines, Tonga and Solomon Islands (Ochetim, 1993; Peters et al., 2001). In Papua New Guinea (PNG) it is a major staple crop in predominant farming systems practiced by some 360,000 rural farming households. The use of sweet potato roots and foliage as livestock feed is on the rise in Southeast Asia and developing countries in general, and may also be influenced by its seasonal availability to rural farmers, shifting food consumption patterns from roots to grains and by the need to replace costly imported feed grains such as wheat and soybean. Current research is aimed at addressing the need to establish appropriate pig and poultry nutrition for production based on local feed resources by adapting suitable technologies for small-scale farmers. A recent technology advance in PNG was the introduction of ensiled sweet potato for feeding pigs from techniques adapted and proven in Vietnam (Peters et al., 2001).

Sweet potato (SP) roots contain about 30% DM and less than 2% crude protein, but the root starch provides 17 MJ/kg of gross energy. SP varieties in PNG contain up to 30% amylose starch (Waramboi et al., 2011), which is more resistant to enzymatic acid digestion in the stomach. Resistant starch and dietary fibre are substrates for microbial growth in the small and large intestine, thereby yielding volatile fatty acids which provide an additional source of energy to pigs (Dierick et al., 1989; Choct, 2001). Blending with complementary protein concentrates balances the deficit of essential amino acids in SP roots. Nutrient digestibility and utilization of SP root diets was reported when fed fresh (Canope et al., 1977; Rose and White, 1980), boiled (Canope et al., 1977; Dom and Ayalew, 2009a) and ensiled (Tomita et al., 1980; Giang et al., 2004) or milled (Noblet et al., 1990), and with foliage inclusion (An et al., 2004; Giang et al., 2004), but none by comparing different methods of preparation with a single protein concentrate in the same experiment.

Importantly, there is a need to establish benchmark performance for commercial and local mixed genotype pigs fed local feeds under PNG's varied production environments. Farmed herds of commercial breeds originating from Australian genotypes require 1.00 to 0.63 g standardised ileal digestible (SID) lysine/MJ DE for males and 0.86 to 0.40 g SID lysine/MJ DE for females, at 20 to 100 kg live weight (Moore et al., 2013b). This was higher than recommended Australian industry standards and the requirements of grower pigs recommended by the National Research Council (NRC, 1998). Diets based on local feed ingredients may fail to supply the pig lysine

requirement. However, the lysine requirement of semi-improved (0.71% to 0.61%) or unimproved (0.61% to 0.54%) breeds (Patience et al., 1995) may be applicable to PNG's mixed genotype pigs. The DE contribution of carbohydrates in SP roots to growing pigs in PNG should also be estimated in relation to utilisation of total available lysine. Benchmarking SP based diets using commercially bred pigs would provide better assessment of the nutritional requirements of local crossbred pigs fed similar blended diets.

A concentrate containing protein meals, synthetic amino acids, vitamins, minerals, mould inhibitors, antioxidants and essential medication was formulated to complement SP roots of an abundantly available cultivar commonly referred to as Rachel. The blended diets with SP roots either boiled or ensiled or as dried and milled roots were tested on commercial bred grower pigs for apparent total tract digestibility (ATTD) of nutrients and energy and N-balance, compared against a standard Pig Grower pellet feed. The experiment tested the hypothesis that there would be no difference in nutrient digestibility and utilization in pigs fed 57% dry matter of the diet as SP roots with 43% wheat based protein concentrate.

METHODS AND MATERIALS

Experiment location and design

This research was conducted at the PNG National Agricultural Research Institute's (NARI) Labu Livestock Research Station in Morobe Province (Lat. 6° 40' 27" S Long. 146° 54' 33" E) situated about 16 km from the CBD of Lae. The local climate was typically warm and wet with average daily temperatures averaging 30 ℃ and 84% relative humidity. The metabolic experiment was conducted using a 4 × 4 Latin Square design with four diets as interchanged treatments fed to four grower pigs over four consecutive 8-day feeding periods. Pigs were randomly allocated to four metabolic cages in an open sided shed for the entire 32 days.

Experiment animals

Six crossbred pigs (Landrace × Large White) × Duroc, at 8 weeks of age (20.9 ± 1.3 kg) were selected from Rumion Piggery Ltd, a large-scale commercial farm in Morobe Province. The pigs were kept in a 4 m × 5 m concrete pen and fed the standard Pig Grower for the first day and then adapted to the test diets by *ad libitum* group feeding on each diet (SPBR43, SPER43 and SPMR43; see below) changed every two days for six days. No negative reactions were observed during the adaption period and four pigs with similar body weight (26.5 ±

1.4 kg) were selected and randomly placed into individual metabolic cages for experimental feeding. On d 5 and d 8 of consecutive periods each pig was removed from its cage for weighing to an accuracy of 0.01 kg. Pigs were managed according to the animal welfare guidelines prescribed the University of Adelaide Animal Ethics Committee; Approval Number 0000016426.

Metabolic cages

Metabolic cages were two double-caged, steel units with dimensions 1.0 m × 1.0 m × 1.5 m on stands 0.7 m above floor level. The cages were equipped with sliding trays to collect faeces. The trays were angled to allow urine to be rapidly drained from the tray. Any solid contaminants from feed, faeces or hair were trapped by a steel coil which allowed urine to drip through a funnel directly into a 2.5 L sealed brown glass bottle through a fine metal-sieve. Each cage was placed in the centre of a concrete pig pen in an open-sided shed. Four fans were placed at the head of each cage to provide ventilation to the pigs for the duration of the experiment. During the experiment, minimum and maximum temperatures were 21 ℃ and 32 ℃, respectively. Relative humidity ranged from 77% to 90%.

Treatment diets

The experimental treatments were diets formulated according to available nutritional data from NRC (1998) and a nutritional database at Carey Animal Nutrition. The protein concentrate, Pig Conc.1, was formulated to provide all essential amino acids and micronutrients to supplement imbalances in sweet potato. Soybean, wheat, and minerals and other micronutrients were imported products (Table 1). All other ingredients were available from local producers. A commercially available Pig Grower pellet feed was used as the standard for comparison with nutritionally balanced diets made from sweet potato blended with Pig Conc.1. SP test diets and standard were weighed to provide 2,000 g DM for each feed offer. Blended diets consisted of 43% SP feed and 57% Pig Conc.1 on DM basis. Sweet potato roots from identified local cultivar, Rachel, were sourced from Lae Town Main Market. Chemical analysis of the blended ingredients confirmed the nutrient content of the formulated rations (Table 2). The processing of feed components for each SP diet was as follows. The roots were divided into three groups for boiling, milling and drying into a meal, or for ensiling. SP roots stored in large hessian sacks were briefly soaked in water and the dirt washed off before being chopped into large irregular chunks (<250 g). To prepare SP boiled roots (SPBR), about 4 to 5 kg of root were then placed into clean water sufficient to cover the pieces; salt was added at ~20 g (0.5% wt/wt) to the total mass, with each boiled root preparation

reweighed to provide 2,000 g DM. To prepare the fermented feed SP roots (SPER) were milled using a modified flake mill (Project Support Services (PSS) Ltd, Lae), 0.5% w/w salt was added to the freshly milled material, which was then immediately packed and sealed in 80 L plastic bin silos lined with polyethylene Tuffa® garbage bags. Acidity in ensiled sweet potato roots was measured at pH 4.0 when silo bins were opened after at least 14 days of fermentation and maintained in good quality for the duration of testing. To prepare milled SP roots (SPMR), cleaned fresh roots were grated using a modified flake mill (PSS Ltd) then sun-dried for an initial period of about 6 hours before being placed into a large-capacity Labec® forced air-draft oven for drying overnight at 105℃. Dry SP gratings were milled using a roller mill (PSS Ltd) to provide a coarse crumble texture (~5 mm pieces). Salt (0.5% w/w) was added to SPMR43 during mixing with protein concentrate. The standard Pig Grower pellets were also roller milled to a coarse crumble texture (from ~10 mm to ~5 mm pieces). Dry and ensiled SP feed were stored in silo bins in a cool, dry shed for daily preparation. Pig Grower and Pig Conc.1 were stored as received in hessian bags and opened bags were kept in two large bins fitted with lids.

Feed offer, refusal collection and pig welfare

The four 8-day feeding periods included 5 days for adaptation to the test diets and 3 days feeding for total collection of faeces and urine. Feed components were weighed (balance limit 5000 ± 0.5 g) fresh to make blended diet weights equivalent to 2000 g DM diet per offer at the first period, 3000g DM for the second and 4000 g DM diet in the third and last periods. Feed offered was thoroughly hand-mixed and stored daily in individual large plastic dishes. To allow *ad libitum* feeding, additional feed was provided at around 1000 h, 1300 h and 1700 h, as required, each day. All remaining feed was collected and weighed as refusal. The pigs were washed down every morning and metabolic cages cleaned daily. Mist spray was provided by hand as required. Clean piped rain water was available at all times through steel-nipple drinkers placed next to the feeding trough.

Collection of feed, faeces and urine samples

Samples of each feed component were sent for chemical analysis at the beginning of the experiment. Faeces were weighed fresh, dried, and then milled to a coarse meal with a hand-grinder. Urine samples were collected in sealed brown bottles over 24 h each day. Dried faeces and urine for each period were separately pooled and duplicate samples stored at 0 ℃ before chemical analysis.

Tested parameters and chemical nutrient proxies

All chemical tests were completed at the National Analytical and Testing Services Laboratory Ltd (Lae, PNG). Moisture and proximate analysis for crude fibre, crude fats (Ether extracts), Kjeldahl-N for crude protein and N in faeces and urine, and Ca and total P followed AOAC methods (2012). Estimate for carbohydrates, Nitrogen-free extract (NFE), was calculated from tested feed proximate data. Lysine, methionine and methionine-cysteine were estimated from Pig Conc.1 assuming that it was the major source of amino acids. DE on DM basis was calculated using the formula DE (kCal) = 4,151 - (122 × %Ash) + (23 × % CP) + (38 × %EE) – (64 × %CF), where R2 = 0.89 (Noblet and Pérez, 1993), and converted by 1kCal = 4.184 MJ.

Statistical analysis

All data were collated on MS Excel and GenStat 15th Edition (VSN Ltd) was used for the ANOVA by Latin Square design with means separated by Least Significant Differences (LSD).

Insert Table 1.

Insert Table 2.

RESULTS AND DISCUSSIONS

Feed intake and growth

Table 3 displays all the results of feed intake and pig growth, nutrient digestibility, energy utilization and N balance. The overall mean DM feed intake of grower pigs of diets was greater than 2.5 kg/day ($p<.001$). DMI was highest for SPBR43 ($p<0.05$), and SPMR43 the second highest, while SPER43 and STDPG were similarly lower ($p>0.05$). DM intake did not correlate to maximum temperature (r values -0.03 to 0.18) but was weakly correlated (r values 0.32 to 0.42) with minimum temperatures (data not shown). This can be explained by pigs feeding in the late afternoon and evenings when shed temperatures were cooler. Average daily bodyweight gain (ADG, $p=0.826$) was higher than 1.2 kg/day and overall feed conversion ratio (FCR, $p=0.500$) was 2.11 kg/kg, but there were no statistical differences in growth rate between any of the treatment diets.

Insert Table 3.

Digestibility and N Balance

DM digestibility was similar (p=0.059) in pigs fed the SP blended diets or the commercial pellet diet (STDPG). Ash, fibre, protein and calcium digestibility were also similar (p>0.05). Fat (ether extract) digestibility was lowest (p<0.05) for the SPBR43, but SPER43 and SPMR43 were similar to STDPG (p>0.05). Phosphorus digestibility was also lower for SPBR43 (p<0.05). Carbohydrate (NFE) digestibility was as high as 90% for the all the diets and, but SPER43 was similar (p>0.05) to STDPG and both were lower than SPBR43 and SPMR43 (p<0.05). SPBR43 energy utilization was superior (p<0.05), however SPER43 and SPMR43 were not different to STDPG (p>0.05). N intake were reflective of the high DMI of pigs fed on all the diets with a statistically lower value for SPER43 (p<0.05). SPER43 also resulted in higher N losses in the faeces and less digested N (p<0.05). N urine losses from SPER43 and SPMR43 were lower than STDPG and SPBR43 (p<0.05), the shift from N loss to faeces possibly indicating increased microbial activity on the ensiled and milled SP diets. SPBR43 provided higher digested N (p<0.05) but retained N was not different from SPER43, SPMR43 or STDPG (p>0.05) due to a higher urine N loss (p<0.05). SPMR43 resulted in the highest N retained (p<0.05), while N retained on the SPER43 and SPBR43 were similar to STDPG (p>0.05). NR% of N intake and digested was greater on SPMR43 (p<0.05), whereas, although NR% of NI was lower for SPER43, the lower urine N loss allowed for similar NR% of ND (p>0.05) to SPMR43.

DISCUSSION

Apparent total tract digestibility (ATTD) of nutrients and energy in commercial breed grower pigs fed on boiled, ensiled or milled SP root diets were improved compared to the standard Pig Grower feed. ATTD of nutrients in the three tested SP diets was in agreement with the literature. For example, fresh, uncooked sweet potato was highly digestible for all nutrients except protein (57.2%) when fed to local village pigs in PNG (Rose and White, 1980). Similarly, cooked (Canope et al., 1977), ensiled (Tomita et al., 1985) and dried sweet potato chips (Noblet et al., 1990) provided very palatable and highly digestible diets for crossbred grower pigs of improved genotypes. However, protein digestibility in our test diets were improved up to 85% compared to the reported values, which were typically below 60% for SP-based diets or above 70% when cooked. The similar N-retention as percentages of N intake and digested N demonstrated an improved nutrient utilization for pig growth. With better energy availability, the SP roots blended as boiled, ensiled or dry meal form provided a highly efficient feed for commercial crossbred grower pigs. Nitrogen intake and N-retained (g/day) in this work were superior to

241 similarly blended cassava root diets (Dom et al., 2014). The better nutrient performance for these grower pigs
242 may have been advantaged by conditioning on the test diets while pen fed prior to adaptation feeding inside the
243 metabolic cages during the trial.
244
245 It is very likely that feed ingredient and pig genotype factors influenced the measured digestibility and growth
246 performance. For example, cooking SP roots improved the digestibility of N (Canope et al., 1977) and although
247 trypsin inhibitors may have reduced protein digestibility in ensiled SP roots (Lin et al., 1988) the higher DE
248 improved feed efficiency, albeit at reduced feed intake (Tomita et al., 1985). Nutrient digestibility and N-
249 retained in pigs fed mixed SP root and vine diets were lower for Vietnamese Mongcai × Yorkshire crossbred
250 pigs (Giang et al., 2004) than for PNG's commercially bred (Landrace × Large White) × Duroc grower pigs
251 (Dom and Ayalew, 2009). Sweet potato foliage fed at above 10% DM of feed may reduce nutrient digestibility in
252 pigs due to increased dietary fibre (Dominguéz, 1992) but performance was improved with CP above 14.5%
253 (Gonzâlez et al., 2003). SP vines were not used in this work although this may provide additional protein for pigs
254 (An et al., 2004). Our protein concentrate provided a sufficient source of nutrients to complement SP roots
255 prepared by either boiling or ensiling, or as a dried meal. Moreover, N retained on the blended SP root diets in
256 the current work compared favourably with grain-based feeds fed with different dietary fibre sources (Hansen et
257 al., 2006) and in either mashed or pellet form (Le Gall., 2009). s
258
259 The SP root based diets were formulated to provide about 0.9% total lysine resulting in the test diets having 0.52
260 g and 0.55 g total lysine/MJ DE, whereas Pig Grower contained 0.58 g total lysine/MJ DE and lower methionine
261 and DE (Table 2). Our growth rates and feed efficiencies were high even though the lysine:DE ratios were lower
262 than the 0.74 g SID lysine/MJ DE which resulted in high level performance in ADG and FCR for similar
263 crossbred genotypes (Moore et al., 2013b). This supports the finding that it is possible to reduce the level of
264 protein concentrate blended with SP while maintaining feed efficiency (Dominguéz and Ly, 1997) and pig
265 growth (Kerr et al., 2003), provided that lysine is not limiting (Kyriazakis and Emmans, 1995). However, protein
266 deposition and lysine utilization may also depend on the genotype of pigs (Patience et al., 1995). For example,
267 growth performance of Vietnamese Mongcai × Large White crossbred pigs was reduced when diets contained 40%
268 and 60% SP, with total lysine contents of 0.54% and 0.52%, respectively (Giang et al., 2004). Even when fed a
269 maize-soybean diet with 16%CP and 0.72% lysine Mongcai × Large White grower pigs (Giang et al., 2004)
270 performed below the crossbred pigs used in the current work. The nutrient utilization and growth performance of

commercial breed grower pigs improved against the standard wheat based feed when fed the SP root diets blended to 57% of DM. It is concluded that improved crossbred pig performance on SP-based diets was supported by higher DE at similar high lysine content to the wheat based Pig Grower diet.

Despite the knowledge that bulky feeds such as SP reduce feed intake (Bindelle et al., 2007) the improved nutrient utilization in pigs fed on ensiled SP roots in the current work may be related to a lower energy requirement for digesting fermented carbohydrates (starch and non-starch polysaccharides) (Choct, 2001), the prebiotic effect from lowered gut pH (Lindberg, 2014) and a greater availability of energy from VFAs providing an energy increment for growth (Dierick et al., 1989). The Pig Grower feed, based on 91.2% wheat, afforded dissimilar fibre content (5.6% CF) than SP roots (0.9%-1.6% CF). The influence of different dietary fibre fractions on nutrient digestibility and utilization is an element worth further investigation. Moreover, the digestibility of these blended SP root diets fed to the mixed local genotype pigs farmed in PNG may vary and growth is likely to be reduced in different environments. Earlier work with PNG village pigs, which were admixtures of native and introduced genotypes, revealed a natural ability to perform reasonably well on lower nutrient diets of SP forage (Rose and White, 1980). Recent evidence indicates that an overall admixture of pig genotypes (Spencer et al., 2006; Ayalew et al., 2011) had occurred over 400 years of uncontrolled breeding (Hide, 2001) and has resulted in varied performances for pigs produced on small-scale piggeries. However, the production of these modern mixed genotype pigs may be improved by breeding for enhanced capacity for digesting dietary fibre (Noblet et al., 2013; Lindberg, 2014). SP blended rations should be investigated for gilts/sows and weaner piglets to provide reduced cost feeding options for small-scale producers. While the growth rate of pigs in penned conditions may be lowered from our current caged estimated ADG, blend-feeding has proved economical compared to single feed and phase feeding options (Moore et al., 2013a) and this seems likely given the very high feed efficiency achieved by the commercial grower pigs. Economic assessment should be made to determine the incremental benefit-cost of SP blended feed rations which replaced a major portion of the imported wheat grain used in small-scale pig production. There is scope for investigating improved nutrition of local mixed genotype pigs fed on similar diets containing local forage ingredients blended with complementary concentrate feeds. Further SP blended rations should be investigated for gilts/sows and weaner piglets to provide reduced cost feeding options for small-scale producers.

CONCLUSION

Sweet potato blended as boiled, ensiled or milled roots at 57% of the diet with 43% Pig Conc.1 were highly digestible and provided improved nutrient utilization, similar growth rates and feed efficiency compared to a wheat based grower feed. It was therefore concluded that sweet potato blended with balancing pig concentrate as boiled or ensiled or milled roots can effectively constitute on DM basis as much as 57% of the diet of grower pigs and can more than match the growth performance obtained from a wheat-based commercial pig grower feed.

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CONFLICT OF INTEREST

All authors report no conflict of interest in regard to this study

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389 **Table 1.** Composition of Pig Conc.1 protein concentrate and the standard commercial Pig Grower diet

Ingredients (%)	Pig Conc.1	Pig Grower
Wheat 11.5 ENZ (FW)	12	31.2
Meat meal 50	13	5.25
Blood meal 85	5	-
Fish meal 56 (FR.PNG)	10	2
Tallow	4	-
Soybean meal	18	-
Millrun 15 PNG	35.8	60
Limestone fine	0	0.5
Salt	0.3	0.15
Choline chloride 75%	0.1	0.05
Rhodimet-88 Liquid (Methionine)	0.4	-
Lysine HCL	0.1	0.2
Lae Feeds Pig Premix	1	0.5
Mycostat	0.1	0.05
Sorbasafe	0.2	0.1
Total	100	100

390 Ingredients formulations provided by Carey Animal Nutrition.

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Table 2. Nutrient composition in the SP roots either boiled (SPBR) or ensiled (SPER) or milled (SPMR) and complementary protein concentrate (Pig Conc.1), SP treatment diets and commercial standard grower pig feed (STDPG)

Nutrients	Components				Treatment diets			
	SPBR	SPER	SPMR	Pig Conc.1	SPBR43	SPER43	SPMR43	STDPG
DM	37.7	31.6	83.5	87.9	49.7	43.9	85.4	92.7
Ash	0.87	1.20	1.80	8.80	4.21	4.53	4.85	6.39
Fibre	0.90	0.90	1.60	4.10	2.25	2.30	2.69	5.64
Fat	0.49	0.37	0.68	4.40	2.14	2.13	2.30	3.78
Protein	1.00	0.97	2.40	32.9	14.5	15.0	15.7	16.5
NFE†	34.4	28.2	77.0	37.7	35.8	32.3	59.9	60.4
Calcium	0.09	0.09	0.09	1.80	0.81	0.84	0.83	0.92
Total P	0.11	0.09	0.16	0.97	0.47	0.48	0.51	0.97
Total N	0.16	0.16	0.38	5.26	2.31	2.39	2.51	2.64
Lysine*	-	-	-	2.03	0.85	0.89	0.88	0.86
Methionine*	-	-	-	0.82	0.35	0.36	0.36	0.24
Meth+Cyst*	-	-	-	1.26	0.53	0.55	0.55	0.53
DE (MJ/kg)**	16.9	16.7	16.4	15.6	16.3	16.2	16.0	14.8
Lys:DE (g/MJ)***	-	-	-	-	0.52	0.55	0.55	0.58
Ca:P***	-	-	-	-	1.72	1.76	1.63	0.94

†NFE is Nitrogen Free Extracts, which includes carbohydrates, sugars, starches, and some hemicelluloses.

*Calculated on DM basis supply of total lysine, methionine and Meth+Cyst from Pig Conc.1 as the major source of all essential amino acids.

**Calculated on DM basis using proximate data and the formula of Noblet and Pérez (1993).

***Ratios calculated on DM basis using the respective nutrient and energy values in this table.

412 **Table 3.** DM intake (g/day), average daily gain (g/day) and feed conversion ratio (kg/kg), total tract apparent
413 digestibility of nutrients and energy (%) and N balance (g/day) for blended SP diets fed to (Large White ×
414 Landrace) × Duroc grower pigs (26.5 ± 1.4 kg) in metabolic trial

Parameters	Grand mean	Treatment means				SED	LSD	*F* pr.
		SPBR43	SPER43	SPMR43	STDPG			
DMI	2548	3192[a]	2061[c]	2690[b]	2251[c]	124.1	303.8	<.001
ADG	1211	1255[a]	1239[a]	1158[a]	1193[a]	113.7	278.2	0.826
FCR	2.11	2.26[a]	1.76[a]	2.29[a]	2.12[a]	0.363	0.887	0.5
DM	88.3	91.3[a]	88.7[a]	90.1[a]	83.2[b]	2.41	5.91	0.059
Ash	74.1	70.6[a]	74.0[a]	78.4[a]	73.6[a]	5.14	12.58	0.542
Fat	75.8	69.9[a]	76.8[b]	79.3[b]	77.0[b]	1.506	3.69	0.004
Fibre	60.3	59.9[a]	52.9[a]	69.0[a]	59.2[a]	10.28	25.16	0.523
Protein	85.4	87.4[a]	82.1[a]	84.6[a]	87.7[a]	2.61	6.39	0.209
NFE*	90.9	94.4[a]	87.8[b]	93.8[a]	87.6[b]	1.254	3.068	0.002
Calcium	75.9	72.9[a]	77.3[a]	80.1[a]	73.5[a]	5.41	13.23	0.544
Total P	75.3	68.2[a]	79.7[b]	76.8[b]	76.4[b]	2.52	6.47	0.025
Energy	91.3	94.3[a]	91.1[a,b]	91.9[a,b]	88.0[b]	1.62	3.97	0.045
N intake	64	71.3[a]	51.7[b]	67.9[a]	65.2[a]	4.49	10.98	0.02
N faeces	8.4	7.2[a]	10.1[c]	8.8[b]	7.6[a]	0.24	0.58	<.001
N digested	55.9	64.0[a]	42.7[b]	59.2[a]	57.6[a]	5.28	12.93	0.031
N urine	7.1	7.3[a]	6.1[a,b]	5.0[a,b]	9.9[a]	1.38	3.37	0.049
N retained	44	44.8[a,b]	35.4[a]	54.5[b]	41.5[a]	4.47	10.94	0.027
NR% of NI†	70.4	70.0[a]	67.2[a]	76.1[a]	68.4[a]	5.31	12.99	0.417
NR% of ND‡	84.3	85.8[a]	83.9[a,b]	89.6[a]	77.9[b]	3.17	7.76	0.05

415 Means with different superscripts are significantly different at p<0.05.

416 *NFE is Nitrogen Free Extracts, which includes carbohydrates, sugars, starches, and some hemicelluloses.

417 †NR% of NI is N retention as a percentage of N intake.

418 ‡NR% of ND is N retention as a percentage of N digested.

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