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Original Research Article

Nutritional Value and Seasonal Availability of Feed Ingredients for Pigs in Uganda

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Abstract

In this study nutritional values and seasonal availability of 43 local feed ingredients for pigs in Uganda, were estimated based on nutrient analyses and literature values, information needed to develop low-cost balanced rations for pigs on smallholder farms. Parameters considered were: concentration of ash, neutral detergent fibre (NDF), crude protein (CP), calcium (Ca), phosphorous (P), ether extract (EE), total lysine (Lys), standardized ileal digestible (SID) Lys, standardized total tract digestible (STTD) P (all as % of dry matter [DM]); digestible energy (DE), (kcal kg^{-1} of DM); and DM concentration. Concentration of DE, total Lys, SID Lys, and STTD P were estimated. Ingredient seasonal availability and relative importance were identified. Ground sun-dried fish (*Rastrineobola argentea*) had highest estimated DE concentration and Napier grass (*Pennisetum purpureum*) had lowest (4209 and 535 kcal kg^{-1} of DM, respectively). Ground sun-dried fish had highest CP and estimated total Lys concentration (59.9 and 6.7% of DM, respectively) and banana peel (*Musa sapientum*), had lowest (5.21 and 0.08% of DM, respectively). Milled ingredients sampled here had higher ash than in the literature (e.g. ground sun-dried fish 58.1 vs 15.9% of DM) likely indicating sand contamination. There were 3 seasons of availability of ingredients. Banana peel, maize bran, and sweet potato vine (*Ipomoea batatas*) were ranked highest; and commercially-prepared ration, and kale/collard greens (*Brassica oleracea var. acephala*), were ranked lowest as potential feed ingredients. Ingredients with nutritional profiles suitable for pigs are available but some only in certain seasons. Estimated nutritional values may assist in ration formulation.

Keywords: subSaharan; smallholder farms; swine; local feed ingredients; seasonally available; nutritional value; proximate analysis.

INTRODUCTION

Small-scale pig production in East Africa can improve the welfare of smallholder farm families (Kristjanson et al., 2004; Ouma et al., 2014; Randolph et al., 2007). On average, these farmers raise 1 to 4 pigs to pay for medicine, school fees, food, home improvements, and to expand their farms (Dewey et al., 2011; Kagira et al., 2010; Ouma et al., 2014). However, pigs are unthrifty and grow slowly (Carter et al., 2013; Kagira et al., 2010; Katongole et al., 2012; MAAIF, 2005; Muhanguzi et al., 2012; Mutua et al., 2011; Mutua et al., 2012). Poor genetics, free-range management, parasites, and nutritional deficiencies may contribute to their slow growth (Kagira et al., 2012; Katongole et al., 2012; MAAIF, 2005; Muhanguzi, 2012; Mutua et al., 2012; Ouma et al., 2014; Thomas et al., 2013). In Uganda, smallholder pig farmers report that feeding management is an important production constraint. Feed scarcity, high cost, seasonal variations in feed quality and availability, food/feed competition between people and pigs, and lack of knowledge to formulate low-cost nutritionally balanced rations are key challenges (Katongole et al., 2012; MAAIF, 2005; Mutua et al., 2012; Ouma et al., 2014; Muhanguzi et al., 2012). Low-to-no cost opportunistic and planted forages and fruits, crop residues, and concentrates are available seasonally (Katongole et al., 2012; MAAIF, 2005; Mutua et al., 2012; Ouma et al., 2014; Muhanguzi et al., 2012). These materials could be used in the formulation of balanced rations to meet pigs' nutrient requirements, to ameliorate pig growth performance while minimizing feed costs. In Uganda, empirical studies characterizing the nutritional value and seasonal availability of local feed ingredients for pigs have not been done. This information is needed as a basis for development of seasonal low-cost balanced rations for local pigs. The objective of this study was to summarize the nutritional value, seasonal availability, and relative importance of 43 locally available feed ingredients for pigs in Central Region, Uganda as a basis for development of low-cost balanced rations. This objective was accomplished by carrying out nutrient analysis on 183 samples of 43 types of locally available feed ingredients for pigs and by estimating the DE and Lys concentration of these ingredients from nutrient profiles. Data from a comprehensive literature review complemented this information.

MATERIALS AND METHODS

Seventeen local feed ingredients for pigs were identified through focus group discussions with 1400 smallholder pig farmers and 280 key informants through an in-depth value chain assessment conducted in Kamuli, Masaka, and Mukono districts of Uganda (Ouma et al., 2014). An additional 26 feed ingredients were identified by two local extension officers and 18 other local pig farmers: banana peel, brewers' waste, *Calliandra calothyrus*, celery leaf (*Apium graveolens* var. *dulce*), cottonseed meal, crushed oyster shells, glycine (*Neonotonia wightii*), guava fruit (*Psidium guajava*), jackfruit (*Artocarpus heterophyllus*), B. *oleracea var. acephala*, lead tree leaves (*Leucaena* spp.), limestone, maize bran, maize stalk and leaf, papaya leaf (*Carica papaya*), pumpkin leaf (*Cucurbita moschata*), sugar cane (*Saccharum* spp.), ground sun-dried fish, sunflower meal (*Helianthus annuus*), sweet potato tuber, wet maize bran, and crushed maize (*Zea mays*). A comprehensive literature review of the nutritional values of the 43 feed ingredients was done. A list of the ingredients is presented in Table 1 and 2.

In April 2013, a total of 185 samples of 43 different feed ingredients commonly fed to pigs (i.e. forages, tree leaves, opportunistic legumes, fruits, vegetables, home- and commercially-prepared rations, grains, and grain co-products) were collected from smallholder pig farms and purchased from feed stores in Mukono District (n = 53 and n = 8, respectively) and Masaka District (n = 109 and n =13, respectively) in Central Region, Uganda. Farms and stores were selected using convenience sampling. All samples were collected on 3 days in the same week. The aim was for each sample to weigh at least 0.2 kg. For every sample the collection date, collection location (district, village, farmer or store name), feed ingredient name and weight (grams) were recorded. For plant samples, storage details were recorded e.g. length of time between harvest and sampling and storage conditions (e.g. kept in open air, standing hay, kept in storage facility or barn, sacked, ensiled). Stage of maturity (e.g. knee high, waist high, milk stage, dough stage, flowering stage), and harvesting stage (e.g. overgrown, overripe, date and time harvested); and description of feed (e.g. moulded, yellow coloured, rotten) were also recorded. For mixed rations i.e. home-mixed or commercially prepared, storage details (e.g. sacked, heaped on floor), date and time mixed, price per kilogram in Ugandan shillings (UGX), types and amount (kg) of feed ingredients included; and name of source store were recorded. For purchased dry feed ingredients (e.g. grains, grain co-products, ground sun-dried fish, limestone, crushed oysters shells) the price (UGX kg^{-1}), and storage details (e.g. sacked, heaped on floor, sacked and on pallets) were also recorded.

For each ingredient at least one sample was collected, while for some ingredients up to 10 samples were collected based on relative importance and anticipated variability. Higher numbers of samples (8-10) were collected for feed ingredients that were ranked most important (sweet potato vine, cocoyam leaf (*Colocasia*), maize bran, cassava leaf (*Manihot esculenta*), pumpkin leaf, banana leaf, hairy beggarticks (*Bidens pilosa*), local amaranthus (*Amaranthus lividus*), and dayflower (*Commelina benghalensis*). A single sample was collected for feed ingredients ranked low in importance (A. *graveolens* var. *dulce*, N. *wightii*, *Leucaena* spp. leaves, groundsel (*Senecio discifolius*), and sugar cane). The number of samples collected was pre-determined based on (financial) resources available for nutrient analyses.

Each 0.20 kg *M. esculenta* leaf (axil, stalk, and blade), fruit tree leaf, *Colocasia* leaf (sagittate leaf and approximately 8 cm of stem), and legume and forage (leaf and stem) sample was a composite of 5-6 plants. Each avocado (*Persea americana*) (flesh and skin included, seed removed), guava, papaya, and jackfruit sample were a sub-sample of 1 entire fruit that was cut into pieces. Each banana peel sample was a composite of pieces of peels from 5-6 bananas. The two 0.2 kg brewer's waste samples were sourced from 2 batches from the same commercial brewer and each was a sub-sample of 1 larger 1000 kg sample. Each maize bran, cottonseed meal, crushed oyster shell, limestone, sunflower meal, soybean meal, wet maize bran, ground sun-dried fish, and crushed whole maize sample was a 0.1 kg composite sample taken from a single larger 1.0 kg sample of maize bran from a home (n = 1) or a feed stockist (n = 2). Sub-samples consisted of 0.2 kg grab samples taken from 5 different locations in the larger sample and mixed well. Two local crop experts identified English, and botanical names for all species of plants. Resulted obtained through nutrient analyses conducted in this study are presented in Table 2.

Fresh samples were immediately placed in clear zip-type plastic bags, sealed, and put in an insulated box with ice. In Masaka samples were stored in a refrigerator overnight and delivered to the laboratory the next day. In Mukono, samples were delivered to the laboratory on the day of sample collection. All drying and nutrient analysis was done at Agricultural Production Laboratory, Makerere University, Kampala, Uganda. The entire samples were weighed and frozen for several days. Samples were thawed and dried at 60 °C to constant weight in a LEEC oven model FCKI (LEEC Limited, Private Road No. 7, Colwick Industrial Estate, Nottingham, UK) and then ground to pass through a 1 mm sieve using a Foss Tector Cyclotec 1093 grinder (Fisher Scientific, Bishop Meadow Road, Loughborough, Leicestershire, UK) and immediately placed in clear zip-type plastic bags and sealed. Samples were analyzed for dry matter (ISO, 1999; 6496), ash (ISO, 2002; 5984), crude protein (IS0, 2005; 5983-2), ether extract (AOAC, 1990; 920.39), neutral detergent fibre (Van Soest and Roberson, 1985), total phosphorus (ISO, 1998; 6491), and total calcium (simple flame photometric determination using Bibby Scientific Jenway Flame Photometer PFP7 and using protocol P05-011A provided with the equipment). The DM concentration of each fresh sample was determined by calculating moisture lost cumulatively during the 2 drying procedures.

Nutritional values for leafy materials, sunflower meal, cottonseed meal, maize bran, banana peel, and *Colocasia* root were taken from the online animal feed resources information system (Feedipedia 2014) and from sources characterizing ingredients sampled in tropical areas because they were deemed to best reflect East African conditions.

Data Management

Data were managed using MS Excel (Microsoft Corporation, Microsoft Way, Redmond, WA, USA). The following parameters were included: CP, NDF, EE, Ca, P, estimated STTD P, estimated SID Lys concentration (all as % of DM), actual DM, and estimated DE (kcal kg^{-1} of DM) for later use in ration formulation. Mean, standard deviation, and coefficient of variation of each parameter for each feed ingredient was determined, based on analyses results for each sample and from the literature. Digestible energy (kcal kg^{-1} of DM), was estimated as: [4168 - (9.1 × Ash % x 10) + (1.9 × CP % x 10) + (3.9 × EE % × 10) – (3.6 × NDF % × 10)] (NRC, 2012) when not found in the literature and only for samples with ash concentration less than 25 % of DM; these extreme ash contents are considerably outside the range of values used to generate the prediction equation (Noblet et al., 1994). Total Lys concentration when not found in the literature (brewer's waste, gallant soldiers (*Galinsoga* spp.), spurge (*Euphorbia* spp.), maize stalk and leaf, *S. discifolius*, and papaya leaf) was estimated from analyzed CP concentration and literature values for Lys concentration within CP in related feed ingredients. For brewer's waste Lys concentration within CP was taken from sorghum (NRC, 2012). Lys concentration within CP in avocado, *C. calothyrus*, *Colocasia* leaf and root, cottonseed meal, *N. wightii*, guava fruit, jackfruit, *B. oleracea* var. *acephala*, lablab (*Lablab purpureus*), *P. purpureum*, papaya fruit, pumpkin leaf, sunflower meal, *Commelina benghalensis*, and sweet potato tuber was estimated from literature values, for these ingredients.

The SID (%) of Lys in all fruits was estimated using the SID (%) of Lys in citrus pulp (40%; CVB, 2003). SID of Lys in all leafy materials was estimated using the SID of Lys in alfalfa meal (56%; NRC, 2012). The SID of Lys in fishmeal (86%; NRC 2012), dehydrated *M. esculenta* (55%; CVB, 2003), cottonseed meal (63%; NRC, 2012), sunflower meal, solvent extracted (76%; NRC, 2012), sorghum (74%; NRC, 2012), corn bran (74%; NRC, 2012), were used as the nearest approximation for SID of Lys of ground sun-dried fish, sweet potato tuber, cottonseed meal, sunflower meal, brewer's waste, and maize bran respectively.

The STTD (%) of P in all fruits was estimated from the STTD (%) of P in citrus pulp (55%; NRC, 2012). The estimate for all leafy materials was based on grass meal and alfalfa STTD of P (40%; CVB, 2013). Brewer's waste STTD of P was estimated from sorghum P STTD (20 %; NRC, 2012). Corn bran STTD of P (27%; NRC, 2012) was the nearest approximation for maize bran. Calculated nutrient contents (DE, SID lysine, STTD phosphorous) are our best available estimates, and attempts should be undertaken to evaluate estimates for key feedstuffs based on more detailed nutrient analyses and digestibility studies.

Seasonal Availability and Relative Importance

Mukono and Masaka districts are located in Central Region, in the Lake Victoria Crescent agro-ecological zone (www.fao.org). This zone is characterized by hilly and flat areas with soils that are good to moderate, altitude ranges from 1,000-1,800 m, and average rainfall of 1,200-1,450 mm (www.fao.org). On the day of sampling in each of the districts, seasonal availability and relative importance of each feed ingredient were estimated by one local crop and veterinary extension officer and one pig farmer (Table 3). On a pre-developed form, all ingredients were listed vertically and the months of the year were listed horizontally so as to form a grid. Officers and farmers, each on a unique form, indicated the months in which each ingredient was available by writing an X in the appropriate cells. On the same form, beside each ingredient, they wrote the relative importance of each feed ingredient with 10 being the most important and 1 the least important. The mean relative importance was determined for each ingredient (Table 3).

RESULTS

Estimated values, mean and standard deviation for nutrient profiles of the 43 ingredients are presented from the literature (Table 1) and as determined through nutrient analysis in this study (Table 2). Across ingredients estimated DE concentration ranged from (535 to 4209 kcal kg^{-1} of DM) and EE concentration ranged from 0.19 to 20.1% of DM. Ground sun-dried fish had the highest estimated DE concentration. *P. purpureum, S. discifolius*, *Amaranthus cruentus* or *dubius* and commercially mixed ration had low estimated DE concentration. Individual samples of ground sun-dried fish (n = 3), commercial feed (n = 1), cottonseed meal (n = 1), and *Commelina benghalensis* (n = 3) had ash concentration greater than 25% (69.0, 46.7, 58.8, 30.7, 27.3, 32.5, 33.7, 25.5% of DM, respectively). For those samples with extremely high ash contents DE contents could not be estimated reliably (Noblet et al., 1994). Avocado fruit with peel had the highest EE concentration. *Amaranthus cruentus* or *dubius* and sweet potato tuber had low EE concentration. Across ingredients ash

Table 1. Dry matter (DM) concentration, estimated digestible energy concentration (DE) (kcal kg^{-1} of DM) and nutrient composition (% of DM) of locally available feed ingredients for pigs in Central Region, Uganda estimated from a review of the literature

Item	N	Source[a]	DM[b], % as fed	DE[c], kcalkg^{-1} of DM	Ash, % of DM	CP[d], % of DM	NDF[e], % of DM	EE[f], % of DM	Calcium, % of DM	Phosphorus, % of DM	Estimated STTD[g] Phosphorus, % of DM	Estimated Total Lys[h], % of DM	Estimated % of DM SIDLys[i], % of DM
Dietary requirement (25-50kg growing pig)	1	NRC (2012) model: ADG 415 g/d Feed intake 1.48 kg DM / day[12]	90.0	2970	-	9.16	-	-	0.30	0.33	0.14	0.65	0.56
Amaranth leaves, raw	1	[1]	8.31	n/a	n/a	29.6	n/a	n/a	n/a	n/a	n/a	1.53	0.86
Avocado fruit raw, all commercial varieties (*Persea americana*)	1	[2]	26.8	n/a	n/a	7.5	n/a	n/a	n/a	n/a	n/a	0.49	0.20[v]
Banana leaf (*Musa sapientum*)	2	[2]	58.0 ± 51.4	1603 ± 463.4	9.9 ± 1.3	12.8 ± 2.6	58.5 ± 4.0	5.0 ± 3.8	0.8	0.2	0.13[j]	n/a	n/a
Banana peel- sun-dried (*Musa sapientum*)	5	[2]	55.5 ± 56.8	2974 ± 511.9	11.8 ± 2.0	6.9 ± 1.1	29.4 ± 1.8	10.5 ± 3.4	0.4	0.2	0.06 ± 0.05[j]	0.11	0.06[u]
Calliandra calothyrus	21	[3-9]	90.4 ± 1.46	2924†	5.81 ± 1.28	20.5 ± 3.3	35.6 ± 10.5	4.70	0.80 ± 0.47	0.23 ± 0.08	0.08 ± 0.05[j]	1.48 ± 0.21	0.83 ± 0.12[u]
Cassava leaf (*Manihot esculenta*)[o]	2	[2]	57.8 ± 49.9	2777 ± 261.7	8.3 ± 1.2	23.7 ± 1.6	42.3	6.4 ± 0.6	1.4 ± 0.3	0.4 ± 0.1	0.23 ± 0.04[j]	1.3	0.75[u]
Celery leaf (*Apium graveolens var. dulce*)	1	4.66	n/a	16.09	14.81	n/a	3.65	0.86	0.52	0.21[j]	0.58	0.32[u]	
Cocoyam leaf (*Colocasia*)	3	[1, 10, 11]	36.1 ± 43.1	2363†	13.6±1.56	23.9 ±9.64	37.6*	8.43 ± 4.62	0.75*	0.42*	0.17[j]	2.96 ± 1.76	1.10 ± 1.18[u]
Cottonseed meal	3	[12-14]	90.7 ± 1.45	3219 ± 11.1 §	7.7± 1.18	45.2 ±2.07	26.3 ± 2.28	7.48 ± 2.0	0.24 ± 0.02	1.26 ± 0.19	0.46 ± 0.08	1.27 ± 0.88	0.53 ± 0.60[m]
Dayflower (*Commelina benghalensis*)[o]	9	[2]	83.7 ± 3.7	3575 ± 356.3	2.4 ± 0.11	20.8 ± 3.5	41.2 ± 3.3	16.2 ± 6.5	0.11	0.07	0.04[j]	0.9	0.50[u]
Gallant soldiers- (*Galinsoga parviflora*)	1	[15]	11.6	n/a	14.7	27.6	n/a	3.45	2.45	0.50	0.20[j]	n/a	n/a
Glycine (*Neonotonia wightii*)	6	[13, 16, 17]	33.3	1765†	11.8 ± 2.6	19.3 ±5.3	49.7 ± 6.4	2.40*	1.49*	0.25*	0.10*[j]	0.61 ± 0.12	0.34 ± 0.07[u]
Groundsel (*Senecio discifolius*)	1	[15]	13.7	n/a	19.0	19.0	n/a	5.11	1.45	0.39	0.16[j]	n/a	n/a
Guava fruit (*Psidium guajava*)	1	[1]	19.2	n/a	7.24	13.3	n/a	5.0	0.09	0.21	0.11[k]	0.38	0.15[v]
Hairy beggarticks (*Bidens spilosa*)[o]	1	[2]	92.2	1501	18.24	15.0	38.5	2.5	n/a	n/a	n/a	n/a	n/a
Commercially prepared ration (recommended for 25-50 kg growing pig)	1	[12]	90.0	3780	n/a	n/a	n/a	n/a	0.73	0.62	0.34	1.24	1.09
Jackfruit - flesh (*Artocarpus heterophyllus*)	1	[1]	26.5	n/a	3.54	6.48	n/a	2.41	0.09	0.08	0.04[k]	0.26	0.10[v]
Kale/ Collard Greens (*Brassica oleracea* var. *acephala*)	1	[1]	10.38	n/a	12.7	29.1	n/a	5.88	2.24	0.24	0.09[j]	1.13	0.63

Table 1. Dry matter (DM) concentration, estimated digestible energy concentration (DE) (kcal kg^{-1} of DM) and nutrient composition (% of DM) of locally available feed ingredients for pigs in Central Region, Uganda estimated from a review of the literature

Item	N	Source[a]	DM[b], % as fed	DE[c], kcalkg^{-1} of DM	Ash, % of DM	CP[d], % of DM	NDF[e], % of DM	EE[f], % of DM	Calcium, % of DM	Phosphorus, % of DM	Estimated STTD[g] Phosphorus, % of DM	Estimated Total Lys[h], % of DM	Estimated % of DM SIDLys[i], % of DM
Lablab (*Lablab purpureus*)	1	[13]	22.1	2003†	11.1	18.4	44.6	2.6	1.3	0.29	0.12[j]	1.03	0.58[u]
Lead tree leaves (*Leucaena*)	10	[3-5, 13, 16, 18]	29.9*	2677[13]	8.5*	23.4 ±3.0	32.9 ± 9.4	6.6 ± 2.3	1.9 ± 0.8	0.9 ± 1.2	0.3 ± 0.5[j]	1.18 ± 0.15	0.66 ± 0.08[u]
Limestone (calcium carbonate)	1	[12] n/a	n/a	n/a	n/a	n/a	n/a	43.3	0.02	n/a	n/a	n/a	
Maize bran	3	[12, 13]	90.86 ± 3.84	2847 ± 206.8 §	3.05 ± 2.77	10.51± 1.63	36.82 ± 0.6	5.03 ± 4.36	0.35 ± 0.27	0.25 ±0 .15	0.07 ± 0.04[n]	0.44 ± 0.09[n]	0.32 ± 0.07[n]
Maize grain, subSahara (*Zea mays*)	1	[13]	90.0	3965[13]	4.3	8.0	15.5	4.5	0.04	0.29	0.10[n]	0.23[n]	0.17[n]
Napier grass (*Pennisetum purpureum*)	6	[13, 16, 19, 20]	18.8 ± 2.2	535 ± 194.2 §	16.2 ± 9.1	17.1±21.1	71.7 ± 3.1	7.1 ± 6.9	0.4*	0.3*	0.12[j] *	0.3*	0.17[u]*
Papaya fruit – flesh+ skin+ seeds (*Carica papaya*)	2	[1,13]	10.1 ± 2.64	2916[13]	5.8 ± 3.6	7.6 ± 5.2	n/a	2.18*	0.2 ± 0.04	0.12 ± 0.05	0.07 ± 0.03[k]	0.21*	0.08[v]*
Papaya leaf (*Carica papaya*)	5	[13, 21]	20.9*	n/a	11.9 ± 0.64	23.8 ± 0.35	n/a	2.40 ± 2.55	0.87 ± 1.73	0.35*	0.14[j]	n/a	n/a
Pumpkin leaf (*Cucurbitamoschata*)	1	[1]	7.12	n/a	17.4	44.2	n/a	5.62	0.55	1.46	0.58[j]	2.81	1.57[u]
Russian Comfrey (*Symphytum x uplandicum*)	1	[13]	13.4	2629[13]	24.9	18.6	18.8	3.6	1.87	0.49	0.20[j]	0.67	0.38[u]
Spurge (*Euphorbia heterophylla*)	2	[22, 23]	19.0 ± 2.12	3116 †	8.10*	21.15 ± 5.73	27.5*	7.0*	n/a	n/a	n/a	n/a	n/a
Sun-dried fish (*Rastrineobola argentea*) [o]	9	[2]	90.9 ± 3.0	4209 ± 807.1	15.9 ± 4.4	59.9 ± 7.4	0	12.0 ± 2.6	1.6	1.6	1.4[p]	6.7 ± 0.7	5.80 ± 0.59[p]
Sunflower meal (*Helianthus annuus*)	3	[12-14]	88.9 ± 0.99	2350 ± 90.5§	6.9 ± 0.12	33.0 ± 1.82	44.0 ± 2.27	2.9 ± 0.83	0.43 ± 0	1.17 ± 0.13	0.38 ± 0.10[q]	1.21± 0.11	0.64 ± 0.56[q]
Sweet potato tuber (*Ipomoea batatas*)	2	[1, 13]	26.36 ± 5.15	3489 [13]	3.98 ± 0.52	6.21±1.00	11.3*	0.66 ± 0.62	0.13 ± 0.01	0.18 ± 0.04	0.10 ± 0.02[r]	0.26 ± 0.05	0.14 ± 0.03[r]
Sweet potato vine and leaf (*Ipomoea batatas*)	3	[2]	15.9 ± 3.5	2024 ±245.8	11.1 ± 0.7	14. 9 ± 3.2	39.3 ± 4.4	3.5 ± 1.8	0.5 ± 0.6	0.2 ± 0.2	0.09[j] ± 0.10	0.6	0.33[u]

Avocado leaf and seed were sampled but are toxic to pigs so not included here as a feed ingredient for pigs.

[a]References are provided for values found in the literature. C
[b]Dry matter.
[c]Digestible energy. Not calculated for samples with ash concentration ≥ 25.0 % of DM.
[d]Crude protein
[e]Neutral detergent fibre
[f]Ether extract
[g]STTD P = Standardized total tract digestible phosphorus concentration. Calculated from P content and estimates of STTD of P from CVB (2003) for closely related ingredient grass meal and alfalfa[j] and dehydrated cassava[r], and from NRC (2012) for closely related ingredient citrus pulp[k], sorghum[l], cottonseed meal[m], cornbran[n] fishmeal combined[p], and sunflower meal solvent extracted[q] , respectively, as the nearest approximation. See the text for further details.

Table 1. Dry matter (DM) concentration, estimated digestible energy concentration (DE) (kcal kg^{-1} of DM) and nutrient composition (% of DM) of locally available feed ingredients for pigs in Central Region, Uganda estimated from a review of the literature

[h]Lys = Lysine. In this study amino acid analyses were not conducted. Estimated from CP content and the Lys to CP ratio in closely related sorghum[l] (NRC 2012), and from calculated mean[§] of closely related ingredients glycine, Russian comfrey, dayflower, and sweet potato vine from (Feedipedia (2014) and Tokita et al (2006); Feedipedia (2014); Carter et al. (2015)) respectively, and from Feedipedia (2014) in closely related ingredient Napier grass[t], respectively, as nearest approximation. See the text for further details.

[i]SID Lys = Standardized ileal digestible lysine concentration. In this study amino acid analyses were not conducted. Calculated using the estimate of SID Lys from CVB (2003) for closely related ingredient dehydrated cassava[r], and citrus pulp[v], and from NRC (2012) for closely related ingredient sorghum[l], cottonseed meal[m], corn bran[n], fishmeal combined[p], sunflower meal solvent extracted[q], and alfalfa meal[u], respectively, as the nearest approximation. See the text for further details.

* One sample only

[†]Calculated from mean crude protein, ether extract, ash, and neutral detergent fibre

[§]Mean of digestible energy literature values

1 Agricultural Research Service United States Department of Agriculture (USDA) 2015
2 Carter et al. 2015b
3 Barahona et al. 2003
4 Hess et al. 2008
5 Hove et al. 2003
6 Kaitho and Kariuki 1998
7 Salawu et al. 1997
8 Salawu et al. 1999
9 Wambui et al. 2006
10 Apata and Babalola 2012
11 Regnier et al. 2012
12 NRC 2012
13 Feedipedia Animal feed resources information system 2014
14 Rodriguez et al. 2013
15 Wehmeyer and Rose 1983
16 Njarui et al. 2003
17 Tokita et al. 2006
18 Mtenga and Laswai 1994
19 Abdulrazak et al. 1996
20 Kidder 1945
21 Ayoola and Adeyeye 2010
22 Bindelle et al. 2009
23 Kouaou et al. 2013

concentration ranged from 1.59 to 96.3% of DM. Shells, limestone, and ground sun-dried fish had the highest ash concentration. Avocado and sweet potato tuber had low ash concentration. NDF concentration ranged from 1.92 to 71.7% of DM. *P. purpureum, S. discifolius*, banana leaf, and *C. calothyrus* had high NDF concentration. Ground sun-dried fish and limestone had low NDF concentration.

Across ingredients Ca concentration ranged from 0.09 to 12.96% of DM. Crushed oyster shell, limestone, Russian comfrey, *N. wightii*, and *M. esculenta* leaf had high Ca concentration. Guava fruit, jackfruit, and maize bran had low Ca concentration. Phosphorus concentration ranged from 0.04 to 1.46% of DM, while estimated STTD P content ranged from 0.02 to 0.58% of DM. Ground sun-dried fish, pumpkin leaf, cottonseed meal, and sunflower meal had high P concentration. *S. discifolius* and *C. benghalensis* had low P concentration. Maize bran and cottonseed meal had high estimated STTD P concentration and *C. calothyrus, A. graveolens* var. *dulce*, papaya fruit, banana peel, *C. benghalensis*, and *S. discifolius* had low estimated STTD P concentration.

Crude protein and estimated total Lys concentration ranged from 0.04 to 59.9 and from 0.08 to 6.7% of DM, respectively, while estimated SID Lys concentration ranged from 0.05 to 5.80% of DM. Ground sun-dried fish, cottonseed meal, sunflower meal, and brewers waste had high CP concentration. Limestone, crushed oyster shells, banana peel, and sugar cane had low CP concentration. Ground sun-dried fish and pumpkin leaf had high estimated total Lys concentration while banana peel had low estimated total Lys concentration. Ground sun-dried fish had the highest estimated SID Lys concentration while banana peel, guava fruit, and papaya fruit had the lowest.

The nutrient concentration variability among samples was large for some of the ingredients. Estimated DE concentration varied considerably between samples of brewers waste (CV = 47), cottonseed meal (CV = 33), *B. oleracea* var. *acephala* (CV = 35), and *C. benghalensis* (CV = 6). Ash concentration varied considerably between samples of grain and co-products including sunflower meal (CV = 101.8), cottonseed meal (CV = 97.3), brewers waste (CV = 83.8), and maize bran (CV = 75.7). Ash concentration also varied between samples of avocado with peel (CV = 37.8), maize stalk and leaf (CV = 32.5), and papaya leaf (CV = 30.6). Crude protein and EE concentration varied between samples of very mature *Colocasia* root (CV = 68.2 and 102.5, respectively), papaya leaf (CV = 57.4 and 104.0, respectively) and papaya fruit (CV = 29.9 and 60.5, respectively). Crude protein concentration in maize stalk and leaf (CV = 32.5) also varied between samples. Ether extract concentration varied between samples of avocado with peel (CV = 67.8) and samples of pumpkin leaf (CV = 73.8).

The NDF concentration varied between samples of

Table 2. Dry matter (DM) concentration, estimated digestible energy concentration (DE) (kcal kg^{-1} of DM) and nutrient composition (% of DM) of locally available feed ingredients for pigs in Central Region, Uganda estimated from laboratory analysis[a]

Item	N	DM[b], % as fed	DE[c], kcal·kg^{-1} of DM	Ash, % of DM	CP[d], % of DM	NDF[e], % of DM	EE[f] % of DM	Calcium, % of DM	Phosphorus, % of DM	Estimated STTD[g] Phosphorus, % of DM	Estimated Total Lys[h], % of DM	Estimated % of DM SIDLys[i], % of DM
Amaranthus- big	3	13.4 ± 2.1	1508 ± 224.66	20.6 ± 1.93	26.1 ± 2.05	37.4 ± 3.25	1.6 ± 1.0	0.4 ± 0.02	0.3 ± 0.16	0.12 ± 0.06[j]	1.3 ± 0.11	0.8 ± 0.06[u]
Amaranthus – local *(Amaranthus lividus)*	7	13.9 ± 1.00	1728 ± 182.59	19.4 ± 2.62	24.3 ± 3.33	33.7 ± 6.51	1.87 ± 0.77	0.42 ± 0.05	0.46 ± 0.24	0.19 ± 0.10[j]	1.26 ± 0.17	0.70 ± 0.10
Amaranthus – red *(Amaranthus cruentus or dubius)*	1	15.4	1266	20.1	19.9	40.4	0.19	0.32	0.25	0.10[j]	1.03	0.58[u]
Avocado + peel *(Persea americana)*	6	18.37 ± 3.14	3326 ± 633.18	5.05 ± 1.91	6.52 ± 1.36	34.28 ± 7.49	20.1 ± 13.64	0.14 ± 0.02	0.63 ± 0.19	0.35 ± 0.11[k]	0.44 ± 0.09	0.18 ± 0.04[v]
Banana leaf *(Musa sapientum)*	8	23.5 ± 5.72	1796 ± 171.01	10.26 ± 0.79	16.13 ± 3.07	54.66 ± 5.28	5.74 ± 2.10	0.29 ± 0.02	0.71 ± 0.35	0.29 ± 0.14[j]	0.86 ± 0.16	0.48 ± 0.09[u]
Banana peel- sun-dried *(Musa sapientum)*	7	17.54 ± 3.33	2072 ± 163.34	8.04 ± 1.81	5.21 ± 0.49	44.1 ± 5.21	3.22 ± 1.19	0.19 ± 0.03	0.53 ± 0.29	0.21 ± 0.11[j]	0.08 ± 0.01	0.05 ± 0.0[u]
Banana peel – cooked *(Musa sapientum)*	1	13.07	2128	7.91	24.75	52.83	2.85	0.23	n/a	n/a	n/a	n/a
Brewer's waste	2	42.7 ± 24.13	2747 ± 1304.6	11.3 ± 9.48	31.9 ± 6.16	34.3 ± 5.85	6.11 ± 2.93	0.15 ± 0.02	0.52 ± 0.07	0.21 ± 0.03[l]	0.68 ± 0.13[l]	0.3 ± 0.07[l]
Calliandra calothyrus	2	32.3 ± 9.12	2237 ± 52.70	5.49 ± 0.30	23.0 ± 0.19	53.4 ± 0.64	1.41 ± 0.16	0.17 ± 0.01	0.61 ± 0.15	0.24 ± 0.06[j]	1.52 ± 0.01	0.85 ± 0.01[u]
Cassava leaf *(Manihot esculenta)*	9	22.9 ± 5.15	2709 ± 327.85	8.1 ± 0.26	22.9 ± 2.46	36.4 ± 9.20	3.2 ± 1.26	0.3 ± 0.03	0.7 ± 0.44	0.3 ± 0.18[j]	1.3 ± 0.14	0.7 ± .08
Celery leaf *(Apium graveolens var. dulce)*	1	17.9	1666	19.8	17.5	30.8	1.87	0.22	0.17	0.07[j]	0.69	0.38[u]
Cocoyam leaf *(Colocasia)*	10	11.4 ± 2.86	2516 ± 269.93	13.5 ± 3.02	24.3 ± 4.09	29.0 ± 5.71	4.04 ± 1.71	0.33 ± 0.05	0.55 ± 0.24	0.22 ± 0.10[j]	3.01 ± 0.51	1.69 ± 0.28[u]
Commercially prepared ration (mash)	4	87.6 ± 0.73	1328 ± 348.99	22.8 ± 6.01	16.8 ± 2.29	31.0 ± 8.83	0.78 ± 0.39	0.44 ± 0.08	0.51 ± 0.31	n.a	n.a	n.a
Cottonseed meal	3	91.7 ± 0.75	3666 ± 127.4	12.8 ± 12.5	35.3 ± 2.20	23.1 ± 5.77	6.01 ± 0.96	0.16 ± 0.03	0.31 ± 0.21	0.11 ± 0.07[m]	1.41 ± 0.08	0.89 ± 0.05[m]
Dayflower *(Commelina benghalensis)*	8	9.03 ± 1.19	1249 ± 284.3	23.8 ± 6.42	18.9 ± 1.29	40.3 ± 5.38	1.55 ± 0.74	0.34 ± 0.09	0.67 ± 0.34	0.27 ± 0.14[j]	0.82 ± 0.06	0.46 ± 0.03[u]
Gallant soldiers -*(Galinsoga* spp.)	8	11.9 ± 2.8	1802 ± 244.79	17.7 ± 3.0	21.6 ± 3.72	34.2 ± 10.5	1.67 ± 0.67	0.38 ± 0.03	0.60 ± 0.27	0.21 ± 0.13[j]	1.15 ± 0.20[s]	0.65 ± 0.11[u]
Glycine *(Neonotonia wightii)*	1	27.10	1911	12.18	22.52	45.10	1.21	0.26	0.88	0.35[j]	0.71	0.40[u]
Groundsel *(Senecio discifolius)*	1	16.5	1457	12.09	11.39	53.85	2.87	0.19	0.04	0.02[j]	0.61[s]	0.34[u]
Guava fruit *(Psidium guajava)*	2	14.2 ± 1.09	3073*	3.97 ± 0.47	6.53*	33.6 ± 5.89	3.7 ± 0.97	0.16 ± 0.003	0.64 ± 0.50	0.35 ± 0.28[k]	0.19*	0.07[v]*
Hairy beggarticks *(Bidens pilosa)*	7	12.0 ± 1.79	1770 ± 235.36	15.0 ± 1.58	24.7 ± 2.53	43.6 ± 5.56	1.50 ± 0.47	0.33 ± 0.04	0.57 ± 0.40	0.23 ± 0.16[j]	1.32 ± 0.14	0.74 ± 0.08[u]
Home-mixed dry ration (mash)	8	84.6 ± 2.31	2334 ± 514.43	14. ± 5.28	17.4 ± 3.44	25.0 ± 4.65	1.22 ± 1.04	0.17 ± 0.11	0.49 ± 0.24	n/a	n/a	n/a
Jackfruit - flesh +peel +seeds *(Artocarpus heterophyllus)*	2	15.5 ± 3.25	3327 ± 18.96	4.8 ± 0.66	8.25 ± 1.67	18.4 ± 1.12	2.56 ± 0.18	0.18 ± 0.02	1.05 ± 0.52	0.58 ± 0.29[k]	0.33 ± 0.07	0.13 ± 0.03[v]
Jackfruit remains after people eat flesh *(Artocarpus heterophyllus)*	2	15.9 ± 0.53	n/a	6.53 ± 0.75	8.02 ± 1.15	23.3 ± 2.43	n/a	0.18 ± 0.02	0.46 ± 0.23	0.25 ± 0.13[k]	0.32 ± 0.05	0.13 ± 0.02[v]
Kale/ Collard Greens *(Brassica oleracea var. acephala)*	4	10.3 ± 0.58	214 ± 742.83	19.6 ± 4.33	23.4 ± 1.44	21.2 ± 10.9	2.14 ± 0.60	0.48 ± 0.06	0.38 ± 0.11	0.15 ± 0.04[j]	0.91 ± 0.06	0.51 ± 0.03[u]
Lablab *(Lablab purpureus)*	1	14.52	2565	10.75	24.53	33.33	2.79	0.29	0.49	0.20[j]	1.37	0.77[u]
Lead tree leaves *(Leucaena)*	1	26.50	3199	8.22	29.11	24.53	2.80	n/a	0.93	0.37[j]	1.47	0.82[u]
Limestone (Calcium carbonate)	2	99.8 ± 0.04	n/a	96.3 ± 1.5	0.04 ± 0	1.92 ± 0.05	0.63 ± 0.07	2.90 ± 0.50	0	0	0	0
Maize bran	8	84.7 ± 3.58	2690 ± 546.20	6.81 ± 5.15	13.0 ± 11.8	31.9 ± 11.8	0.93 ± 0.42	0.10 ± 0.02	0.56 ± 0.29	0.13 ± 0.09[n]	0.58 ± 0.06[n]	0.43 ± 0.04[n]
Maize bran – wet	1	91.18	2586	9.55	24.37	34.00	1.22	0.19	0.56	0.15[n]	1.10[n]	0.81[n]
Maize – whole grain crushed twice *(Zea mays)*	1	84.17	3260	1.59	8.56	26.42	0.64	n/a	n/a			
Maize stalk and leaf at maize field thinning time *(Zea mays)*	4	13.9 ± 7.39	1404 ± 199.83	16.2 ± 5.26	14.4 ± 4.69	45.34 ± 11.8	1.74 ± 0.33	0.27 ± 0.08	0.65 ± 0.17	0.26 ± 0.07[j]	0.25 ± 0.08[t]	0.14 ± 0.05[u]
Napier grass *(Pennisetum purpureum)*	6	15.3 ± 2.65	1139 ± 297.75	15.4 ± 1.71	15.7 ± 1.52	55.8 ± 5.54	2.02 ± 0.39	0.24 ± 0.03	0.54 ± 0.32	0.22 ± 0.13[j]	0.27 ± 0.03	0.15 ± 0.01[u]
Oyster shells crushed	2	99.3 ± 0.006	n/a	95.9 ± 0.06	0.41 ± 0.48	0	0.43 ± 0.38	12.96 ± 0.47	0.28 ± 0.04	n/a	n/a	n/a
Papaya fruit – flesh+ skin+ seeds *(Carica papaya)*	4	8.0 ± 2.89	3182 ± 158.87	8.2 ± 0.95	10.8 ± 3.21	14.8 ± 5.02	2.3 ± 1.42	0.2 ± 0.06	0.7 ± 0.14	0.4 ± 0.07[k]	0.3 ± 0.09	0.1 ± 0.04[v]

Table 2. Dry matter (DM) concentration, estimated digestible energy concentration (DE) (kcal kg^{-1} of DM) and nutrient composition (% of DM) of locally available feed ingredients for pigs in Central Region, Uganda estimated from laboratory analysis[a]

Item	N	DM[b], % as fed	DE[c], kcal·kg^{-1} of DM	Ash, % of DM	CP[d], % of DM	NDF[e], % of DM	EE[f], % of DM	Calcium, % of DM	Phosphorus, % of DM	Estimated STTD[g] Phosphorus, % of DM	Estimated Total Lys[h], % of DM	Estimated % of DM SIDLys[i], % of DM
Papaya leaf *(Carica papaya)*	3	20.4 ± 4.33	3341 ± 54.96	10.71 ± 3.28	19.0 ± 10.9	18.0 ± 7.36	5.40 ± 5.62	0.31 ± 0.10	0.42 ± 0.21	0.17 ± 0.08[j]	1.01 ± 0.58	0.57 ± 0.33[u]
Pumpkin leaf *(Cucurbita moschata)*	10	13.1 ± 3.73	182 ± 475.70	18.8 ± 3.64	30.4 ± 4.32	34.9 ± 5.95	1.19 ± 0.87	0.44 ± 0.06	0.79 ± 0.52	0.32 ± 0.21[j]	1.93 ± 0.27	1.08 ± 0.15[u]
Russian Comfrey *(Symphytum x uplandicum)*	4	12.6 ± 6.35	155 ± 382.70	20.8 ± 1.86	25.1 ± 1.02	34.1 ± 6.26	0.90 ± 0.47	0.37 ± 0.03	0.36 ± 0.31	0.14 ± 0.12[j]	1.22 ± 0.10	0.68 ± 0.05[u]
Spurge *(Euphorbia* spp.)	8	15.2 ± 2.81	2738 ± 347.53	12.1 ± 1.33	25.1 ± 3.77	26. ± 6.94	3.54 ± 1.49	0.30 ± 0.03	0.78 ± 0.55	0.31 ± 0.22[j]	1.34 ± 0.20[s]	0.75 ± 0.11[u]
Sugar cane *(Saccharum* spp.)	1	16.41	4080	5.00	5.45	30.77	35.17	0.16	0.67	n/a	n/a	n/a
Sun-dried fish ground *(Rastrineobola argentea)*	3	92.2 ± 2.72	n/a	58.1 ± 11.1	25.9 ± 1.79	10.9 ± 6.79	1.65 ± 0.98	0.80 ± 0.06	0.6 ± 0.17	0.52 ± 0.14[p]	0.29 ± 0.02	0.25 ± 0.02[p]
Sunflower meal *(Helianthus annuus)*	3	93.2 ± 0.87	2536 ± 774.45	10.3 ± 10.44	22.4 ± 0.47	38.3 ± 7.70	6.52 ± 3.66	0.13 ± 0.03	0.58 ± 0.35	0.17 ± 0.10[q]	0.84 ± 0.01[q]	0.67 ± 0.01[q]
Sweet potato tuber *(Ipomoea batatas)*	1	35.2	3282	2.84	17.8	28.3	1.36	0.13	0.86	0.21[r]	0.75	0.41[r]
Sweet potato vine and leaf *(Ipomoea batatas)*	9	13.8 ± 2.65	2156 ± 389.27	11.4 ± 3.16	18.5 ± 3.15	38.9 ± 6.3	1.88 ± 0.40	0.28 ± 0.08	0.39 ± 0.25	0.1 ± 0.10[j]	0.74 ± 0.13	0.42 ± 0.07[u]

Avocado leaf and seed were sampled but are toxic to pigs so not included here as a feed ingredient for pigs.

[a] Values from analyses done in this study.
[b]Dry matter.
[c]Digestible energy. Not calculated for samples with ash concentration $\geq$ 25.0 % of DM.
[d]Crude protein
[e]Neutral detergent fibre
[f] Ether extract
[g]STTD P = Standardized total tract digestible phosphorus concentration. Calculated from P content and estimates of STTD of P from CVB (2003) for closely related ingredient grass meal and alfalfa[j] and dehydrated cassava[r], and from NRC (2012) for closely related ingredient citrus pulp[k], sorghum[l], cottonseed meal[m], cornbran[n] fishmeal combined[p], and sunflower meal solvent extracted[q], respectively, as the nearest approximation. See the text for further details.
[h]Lys = Lysine. In this study amino acid analyses were not conducted. Estimated from CP content and the Lys to CP ratio in closely related sorghum[l] (NRC 2012), and from calculated mean[s] of closely related ingredients glycine, Russian comfrey, dayflower, and sweet potato vine from Feedipedia (2014) and Tokita et al. (2006); Feedipedia (2014); Carter et al. (2015); Carter et al. (2015) respectively, and from Feedipedia (2014) in closely related ingredient Napier grass[t], respectively, as nearest approximation. See the text for further details.
[i]SID Lys = Standardized ileal digestible lysine concentration. In this study amino acid analyses were not conducted. Calculated using the estimate of SID Lys from CVB (2003) for closely related ingredient dehydrated cassava[r], and citrus pulp[v], and from NRC (2012) for closely related ingredient sorghum[l], cottonseed meal[m], corn bran[n], fishmeal combined[p], sunflower meal solvent extracted[q], and alfalfa meal[u], respectively, as the nearest approximation. See the text for further details.
* One sample only
[†]Calculated from mean crude protein, ether extract, ash, and neutral detergent fibre
[§] Mean of digestible energy literature values

Table 3. Seasonal availability and relative importance of 45 locally available feed ingredients for pigs in Central Region, Uganda

Ingredient	Relative importance according to pig farmers[a]	Months in which available											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Amaranthus – big	9			Yes	Yes	Yes				Yes	Yes	Yes	
Amaranthus – local – (*Amaranthus lividus*)	9			Yes	Yes	Yes				Yes	Yes	Yes	
Amaranthus – red (*Amaranthus cruentus or dubius*)	9			Yes	Yes	Yes				Yes	Yes	Yes	
Avocado + peel (*Persea americana*)	8	Yes	Yes				Yes	Yes	Yes				Yes
Banana flower (*Musa sapientum*)	7			Yes	Yes	Yes				Yes	Yes	Yes	
Banana leaf (*Musa sapientum*)	7		Yes	Yes	Yes	Yes			Yes	Yes	Yes	Yes	
Banana peel – sun-dried (*Musa sapientum*)	10	Yes	Yes				Yes	Yes	Yes				Yes
Banana peel – cooked (*Musa sapientum*)	10	Yes	Yes				Yes	Yes	Yes				Yes
Brewer's waste	8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Callidandra calothyrus	7												
Cassava leaf (*Manihot esculenta*)	3				Yes	Yes	Yes				Yes	Yes	Yes
Celery leaf (*Apium graveolens var. dulce*)	0												
Cocoyam leaf (*Colocasia* spp.)	9			Yes	Yes	Yes	Yes			Yes	Yes	Yes	Yes
Commercially prepared ration (mash)	2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cottonseed meal	8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Oyster shells crushed	8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dayflower (*Commelina benghalensis*)	8			Yes	Yes	Yes				Yes	Yes	Yes	
Glycine (*Neonotonia wightii*)	6			Yes	Yes	Yes				Yes	Yes	Yes	
Guava fruit (*Psidium guajava*)	7	Yes	Yes	Yes	Yes							Yes	Yes
Hairy beggarticks (*Bidens pilosa*)	9			Yes	Yes	Yes				Yes	Yes	Yes	
Home-mixed dry rations (mash)	8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Jackfruit – flesh +peel +seeds (*Artocarpus heterophyllus*)	7	Yes	Yes				Yes	Yes	Yes				Yes
Jackfruit- remains after people eat flesh (*Artocarpus heterophyllus*)	5	Yes	Yes				Yes	Yes	Yes				Yes
Gallant soldiers (*Galinsoga parviflora*)	9			Yes	Yes	Yes	Yes				Yes	Yes	Yes
Kale/Collard Greens (*Brassica oleracea var. acephala*)	2			Yes	Yes	Yes	Yes				Yes	Yes	Yes
Spurge (*Euphorbia heterophylla*)	7			Yes	Yes	Yes	Yes				Yes	Yes	Yes
Lablab (*Lablab pupureus*)	8					Yes	Yes			Yes	Yes	Yes	Yes
Lead tree leaves (*Leucaena*)	2				Yes	Yes	Yes			Yes	Yes	Yes	
Limestone (calcium carbonate)	1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Maize bran	10	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Maize stalk and leaf at maize field thinning time (*Zea mays*)	8			Yes	Yes					Yes	Yes		
Maize bran – wet	10	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Maize – whole grain crushed twice	9	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Groundsel (*Senecio discifolius*)	7			Yes	Yes	Yes					Yes	Yes	Yes
Napier grass (*Pennisetum purpureum*)	8			Yes	Yes	Yes	Yes				Yes	Yes	Yes
Papaya fruit – flesh+ skin+ seeds (*Carica papaya*)	8			Yes	Yes	Yes	Yes			Yes	Yes	Yes	Yes

[a]10= most important and 1 = least important

Table 3. Seasonal availability and relative importance of 45 locally available feed ingredients for pigs in Central Region, Uganda

Ingredient	Relative importance according to pig farmers[a]	Months in which available											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Papaya leaf (*Carica papaya*)	4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pumpkin leaf (*Cucurbita moschata*)	5				Yes	Yes	Yes				Yes	Yes	Yes
Russian comfrey (*Symphytum x uplandicum*)	8			Yes	Yes	Yes				Yes	Yes	Yes	
Sugar cane (*Saccharum spp.*)	5	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sun-dried fish – ground (*Rastrineobola argentea*)	8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sunflower meal (*Helianthus annuus*)	7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sweet potato tuber (*Ipomoea batatas*)	9		Yes	Yes	Yes				Yes	Yes	Yes		
Sweet potato vine and leaf (*Ipomoea batatas*)	10		Yes	Yes	Yes				Yes	Yes	Yes		

[a]10= most important and 1 = least important

ground sun-dried fish, *B. oleracea* var. *acephala*, pumpkin leaf, papaya leaf, maize bran, very mature *Colocasia* root, papaya fruit, and *Galinsoga* spp. (CV = 62.5; CV = 51.6; CV = 41.0; CV = 37.0; CV = 35.0; CV = 34.0; and CV = 30.7, respectively). The Ca concentration varied between samples of home-mixed ration (CV = 63.5), very mature *Colocasia* root (CV = 37.6.0), and papaya leaf (CV = 31.6). Lastly, total P concentration varied considerably between Russian comfrey samples (CV = 84.4), guava fruit (CV = 78.6), *Euphorbia* spp. (CV = 70.0), B. *pilosa* (CV = 69.9), cottonseed meal (CV = 66.9), and samples of pumpkin leaf (CV = 65.0).

In some instances nutritional values differed greatly between analyses conducted in this study and literature values. In particular for ground sun-dried fish, differences in ash (mean values, analyzed vs literature: 58.1 ± 1.11 vs 15.9 ± 4.4% of DM), CP (25.9 ± 1.79 vs 59.9 ± 7.4 of DM), NDF (10.9 ± 6.79 vs 0% of DM), and EE (1.65 ± 0.98 vs 12.0 ± 2.6% of DM) were large.

For maize bran there were large differences in ash (6.81 ± 5.15 vs 3.05 ± 2.77% of DM) and EE concentration (0.93 ± 0.43 vs 5.3 ± 4.36% of DM). Differences in ash concentration for cottonseed meal (12.8 ± 12.5 vs 7.7 ± 1.18% of DM) were also large.

Differences in NDF concentration for banana peel (44.1 ± 5.21 vs 29.4 ± 1.8% of DM), *C. calothyrus* (53.4 ± 0.64 vs 35.6 ± 10.5% of DM), *P. purpureum* (55.8 ± 5.54 vs 71.7 ± 3.1% of DM), and Russian comfrey (34.1 ± 6.26 vs 18.8% of DM) were large between samples from this study and those reported in the literature as were EE concentration in *C. benghalensis* (1.55 ± 0.74 vs 16.2 ± 6.5% of DM), pumpkin leaf (1.19 ± 0.87 vs 5.62% of DM), Russian comfrey (0.37 ± 0.03 vs 1.87% of DM). These differences may be due to the types of cultivars and the maturity of the plants sampled here and in the literature. Differences in ether extract concentration in sunflower meal (6.52 ± 3.66 vs 2.9 ± 0.83% of DM) was also large. These differences may be due to variation in sunflower oil extraction and dehulling methods.

Differences in Ca concentration between analyses conducted in this study and literature values for forages *B. oleracea* var. *acephala*, lablab, *Galinsoga* spp., *S. discifolius*, and Russian comfrey (0.48 ± 0.06 vs 2.24%; 0.29 vs 1.3%; 0.38 ± 0.03 vs 2.45%; 0.19 vs 1.45%; and 0.90 ± 0.47 vs 3.6% of DM, respectively) were large. Differences in P concentration for jackfruit (1.05 ± 0.52 vs 0.08%) and cottonseed meal (0.31 ± 0.21 vs 1.26 ± 0.19%) were also large.

There were 3 main periods of pig feed ingredient availability in the study districts; January and February, March through May plus September through December; and June through August. Opportunistic legumes and fresh forages were available soon after the rains begin (March and September) and while rain continues to fall (April, May, October, November, December). Fruit was available from June through August and November through February. Agricultural co-products banana peel and leaf, *M. esculenta* leaf, papaya leaf, brewers' waste, maize bran, cottonseed meal, and sunflower meal were available all year as were sugar cane, oyster shells, limestone, and ground sun-dried fish. Opportunistic legumes and forages were not available in January or February making these the months in which availability of local feed ingredients for pigs was most limited.

The ingredients ranked most important were banana peel, sweet potato vine and maize bran. Opportunistic legumes, crop co-products, purchased grain co-products and ground sun-dried fish were ranked highly important. *B. oleracea* var. *acephala* and *A. graveolens* var. *dulce* were ranked low in importance. *M. esculenta* leaf was also ranked low.

DISCUSSION

The relatively high protein concentration of *N. wightii, B. pilosa*, *Galinsoga* spp., *B. oleracea* var. *acephala*, and *Euphorbia* spp. and the estimated SID Lys concentration in pumpkin leaf, *Colocasia* leaf, *B. pilosa*, *Amaranthus* spp., and *Euphorbia* spp. is notable. This research indicates that forages are available as CP and Lys sources for pigs. Variability within feed ingredients analyzed in this study, and between literature values and feed ingredients analyzed in this study, can be attributed to a variety of factors including cultivar, maturity and seasonal effects (fruits, vegetables, and plants), and processing procedures (grain, grain co-products and ground sun-dried fish). Differences in Ca concentration between analyses conducted in this study and literature values for forages *B. oleracea* var. *acephala*, lablab, *Galinsoga* spp*., S. discifolius*, and Russian comfrey differences may be due to calcium deficient soil in the study area (Wortmann and Eledu, 1999). Differences in P concentration for jackfruit and cottonseed meal which may be due to the types of cultivars and maturity of jackfruit, and method of cottonseed meal production methods.

The higher ash concentration in grains, grain co-products, and ground sun-dried fish samples from the current study compared to the literature indicate that contamination or adulteration may be occurring at some point(s) in the feed supply chain. The Ugandan National Animal Feeds Policy recognizes the poor quality of concentrates available in Uganda and the resulting inadequate nutrition and reduced performance of livestock, and outlines a need to improve the quality of concentrates (MAAIF, 2005) but no law has been passed to enforce feed quality standards (Katongole et al., 2012). High quality unadulterated concentrates are needed for pigs to achieve potential growth performance. Research and interventions into processing systems and constraints hindering feed processors' and stockists' ability to provide high quality feed are needed.

Opportunistic legumes and crop co-products are inexpensive and widely available because they can be gathered by farmers from their own fields. Purchased grain co-products and ground sun-dried fish are widely available to buy at feed stockists. *B. oleracea* var. *acephala* and *A. graveolens* var.. *dulce* are rarely grown on pig farms which may be the reason for their low relative importance. Some farmers report *M. esculenta* leaf makes their pigs vomit and this may be the reason for its relative low importance.

This study is the first effort to describe the nutrient concentration of locally available feed ingredients for pigs in Uganda. This information provides a basis for developing low-cost balanced rations for pigs for use in different seasons. When formulating rations using local feed ingredients for pigs characterized here, consideration of possible nutritional risks including anti-nutritional factors and toxins, extreme nutrient compositions, and contamination (e.g. with sand) is recommended. These are discussed in more detail in a subsequent manuscript where pig nutrient requirements, ingredient constraints, actual ration composition and estimated pig performance are reported (Carter et al., 2015a).

The study has some limitations. First, for some of the ingredients few samples were collected ($n < 3$). Despite effort being made to sample at many locations, the variability between samples of these ingredients was unknown, raising a concern that the samples collected in this study may not be representative of ingredients throughout the study area. Second, not enough material was available to conduct EE analysis on the one sample of jackfruit after people had eaten the flesh. This meant it was not possible to estimate DE. The last limitation is that all samples were collected during a 7-day period so nutritional concentration may not be representative of the same ingredient in other seasons or years.

This data base should be expanded through future studies to include sampling in all seasons and stages of plant maturity. It should also include ensiled plants, co-products, and tubers, and co-products such as blood and rumen contents which are potentially important pig ingredients but are not widely used in Uganda. The opportunity costs and benefits of using alternative local ingredients, such as labour required to produce and/or collect them should be evaluated in a cost-benefit analysis. Further analyses should also include toxins and anti-nutritional factors that could restrict the use of local ingredients in pig rations.

CONCLUSIONS

Local feed ingredients of adequate nutritional value for pig rations are available seasonally in Uganda. Analyzed nutritional value varies considerably between samples of the same type of ingredient. Furthermore, for several ingredients the analyzed nutritional values observed in this study and values reported in the literature differ considerably. Therefore, additional sampling and analysis of these local ingredients is recommended. Knowledge about the seasonal availability and nutritional value of locally available feed ingredients for pigs in sub-Saharan regions such as Uganda will enable nutritionists to develop balanced, low-cost rations for use by smallholder farmers. These are expected to lead to improvements in pig growth performance and poverty reduction.

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