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Nutritive value of tropical forage plants fed to pigs in the Western provinces of the Democratic Republic of the Congo

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ABSTRACT

The nutritive value of 20 forage plants commonly used for feeding pigs in the Democratic Republic of the Congo was studied to determine chemical composition, protein amino acid profiles, mineral content, and *in vitro* digestibility using a two-step method combining an enzymatic pepsin and pancreatin hydrolysis followed by a 72 h gas-test fermentation. The highest protein contents (270–320 g/kg DM) were obtained for *Vigna unguiculata, Psophocarpus scandens, Leucaena leucocephala, Manihot esculenta*, and *Moringa oleifera*. Grasses, *Acacia mangium*, and *Eichhornia crassipes*, showed the lowest crude protein (CP) and highest NDF contents. *Cajanus cajan* and *Trypsacum andersonii* had the most balanced amino acid profile, being deficient in lysine and slightly deficient in histidine, while *Megathyrsus maximus* displayed the highest number of essential amino acids deficiencies. High mineral contents were obtained from, in ascending order, with *M. oleifera, V. unguiculata, E. crassipes, Ipomea batatas* and *Amaranthus hybridus. In vitro* dry matter digestibility ranged from 0.25 to 0.52, *in vitro* CP digestibility from 0.23 to 0.80, *in vitro* energy digestibility from 0.23 to 0.52. *M. esculenta, M. oleifera, I. batatas, Mucuna pruriens, V. unguiculata, P. scandens and A. hybridus* showed high digestibilities for all nutrients. Gas production during fermentation of the pepsin and pancreatin-indigestible fraction of the plants varied from 42 ml/g DM for *A. mangium* to 202 ml/g DM for *I. batatas* (P<0.001). Short-chain fatty acid production during fermentation varied from 157 to 405 mg/g of the pepsin and pancreatin indigestible fraction. It is concluded that some of these species are interesting sources of proteins and minerals with a good digestibility that might be used more economically than concentrate, especially in smallholder production systems, to improve pig feeding, mineral intake and intestinal health in pigs reared in the tropics.

1. Introduction

In the tropics, pig production is only tolerated if pigs do not compete with humans for food (Leterme et al., 2006), especially in developing countries where monogastrics are in direct competition with humans for the resources required to produce concentrate feed. Because of the high and volatile prices of the latter (Braun, 2007; FAO, 2012), smallholders often replace the cereals and oilseed by-products in pig feeds with large amounts of cheap and unconventional fibre-rich ingredients such as

Abbreviations: AA, amino acid; ADF, acid detergent fibre; ADL, acid detergent lignin; CP, crude protein; DE, digestible energy; DM, dry matter; DP, digestible protein; DRC, Democratic Republic of the Congo; EE, ether extract; IVDMD, in vitro dry matter digestibility; IVCPD, in vitro crude protein digestibility; IVED, in vitro gross energy digestibility; NDF, neutral detergent fibre; SCFA, short-chain fatty acid.

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crop residues, agro-industrial by-products, and grass and legume forage collected in the forest or in fallow fields near pigsties (Kumaresan et al., 2009; Phengsavanh et al., 2010). A recent survey realised in the Kinshasa and the Bas-Congo Provinces of the Democratic Republic of the Congo (DRC) confirmed that less than 2% of the farmers use commercial feeds and the most abundant cereal resource, namely corn, is used as an ingredient in pig feed on less than 10% of the farms. Although the growth performances of forage-fed pigs is often lower than that of concentrate-fed and is negatively correlated with the inclusion rate of the forages (Phengsavanh and Lindberg, 2013; Régnier et al., 2013), farmers in Western DRC do not feed crop grains to their pigs because they consider it a waste of crops even in mixed farming systems producing both pigs and crops.

The use of forage resources as pig feeds does have several drawbacks including low digestibility of forage owing to their high content in fibre, the presence of anti-nutritive compounds and the lack of suitable conservation methods. However, compared to cereals, they have distinct advantages justifying their use by farmers: low cost, non-competitiveness with human food, high levels of protein, minerals and vitamins (reviewed by Martens et al., 2012). As feed is the most critical expense in pig rearing activity, it can be profitable to substitute a significant part of a concentrate-based diet with some forage ingredients (Kaensombath et al., 2013). Unfortunately, the lack of information on the nutritive value of most of the forage resources used in tropical areas in general and in Western DRC specifically can lead to unbalanced diets, low pigs growth and reproduction performances, low incomes for the farmers and less locally produced animal protein available on the market. The aim of this work is to assess using an *in vitro* model of the pigs gastro-intestinal tract, the nutritive value of the forage species the most commonly used by smallholder farmers in Western DRC in order to provide information that could guide them in the choice of forage resources for improved pig performances.

2. Materials and methods

2.1. Plant material

Samples of 20 forage species used as pig feed by farmers in the Kinshasa and Bas-Congo Provinces of the DRC and identified as the most commonly used during a survey of 319 pig smallholders were gathered from the smallholders' farms (Table 1). For each species, 4 independent samples were collected on different farms. All forage samples were harvested during the vegetative growth phase before flowering and, depending on the species, whole plants or only leaves were sampled according to the farmers' common practices.

2.2. In vitro digestion and fermentation

Forage samples were oven-dried at 60 °C and ground to pass through a 1 mm mesh screen in a Cyclotec 1093 Sample Mill (FOSS Electric A/S, Hilleroed, Denmark). The digestibility of their nutrients was assessed using the *in vitro* model developed by Bindelle et al. (2007a). Briefly, this method simulates the digestion in the pig gastro-intestinal tract in two steps. The stomach and small intestinal digestion are mimicked by an enzymatic hydrolysis with porcine pepsin (2 h, 39 °C, pH 2) and porcine pancreatin (4 h, 39 °C, pH 6.8), respectively. The indigestible residue recovered by filtration through a nylon cloth (42 μm), after washing with ethanol and acetone, is subsequently fermented with faecal bacteria of sows in a carbonate-based buffer (72 h, 39 °C, pH 6.8) to simulate the fermentation processes occurring in the large intestine. The volume of gas produced during fermentation was modelled according to Groot et al. (1996). Four parameters describing the fermentation kinetics were calculated: final gas volume (A, ml g/DM)), mid-fermentation time (B, h), maximum rate of gas production (R_M, ml g/DM) and time at which the maximum rate of gas production is reached (tR_M, h). Fermentation broth collected after 72 h was centrifuged at 13,000 g for 15 min and the supernatants were sampled and frozen at −18 °C until further short-chain fatty acid (SCFA) analysis.

For each of the 4 samples of each forage species, hydrolysis was performed between 4 and 6 times on 2 g samples to yield sufficient amounts of indigestible residues for the subsequent analyses and fermentation. *In vitro* fermentation was performed in quadruplicate on the pooled residues of each initial forage sample.

2.3. Chemical analysis

Forage ingredients and hydrolysis residues pooled by forage sample ($N = 4$ per species) were analysed for their content in dry matter (DM) by drying at 105 °C for 24 h (method 967.03; AOAC, 1990), ash by burning at 550 °C for 8 h (method 923.03; AOAC, 1990), N according to the Kjeldahl method and calculating the crude protein (CP) content ($N \times 6.25$; method 981.10; AOAC, 1990), and gross energy by means of an adiabatic oxygen bomb calorimeter (1241 Adiabatic Calorimeter, PARR Instrument Co., Illinois, USA). Forage ingredients were also analysed for their content in ether extract (EE) with the Soxhlet method by using diethyl ether (method 920.29; AOAC, 1990), in neutral detergent fibre (aNDFom) using thermostable amylase (Termamyl®, Novo Nordisk, Bagsværd, Denmark) and corrected for ash, in acid detergent fibre (ADFom) corrected for ash, in acid detergent lignin (ADL(sa)) according to Van Soest et al. (1991) using an ANKOM-Fiber Analyzer (ANKOM-Technology, Fairport, NY), and in total amino acids (excluding methionine, cysteine and tryptophan) by HPLC after hydrolysis with a mixture of 6 mol HCl/l containing 1 g phenol/l at 110 °C for 24 h and derivatization with AccQ-Fluor reagent Kit. DL-2-aminobutyric acid was used as internal standard. Ca, P, Mg, K, Cl, S, Se, Ni, Na, Fe, Mn, Cu and Zn contents of one sample per