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Nutritional value and intake of aquatic ferns (*Azolla filiculoides* Lam. and *Salvinia molesta* Mitchell.) in sows

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ABSTRACT

Aquatic ferns (AFs) such as *Azolla filiculoides* and *Salvinia molesta* are grown on swine lagoons in the tropics and used in diets for pigs. The present work is aimed at evaluating their potential as feed ingredients for sows. When presented with *ad libitum* AFs, gilts weighing 110 ± 14 kg (mean ± SD), were able to ingest 9.1–9.7 kg fresh AF per day (from 597 to 630 g dry matter (DM) per day) and from 1240 to 1428 g DM per day when presented in a dry, ground form. A digestibility study was conducted, using sows weighing 213 ± 9 kg (mean ± SD), which were fed diets containing maize, soybean meal and 0, 150 or 300 g AF kg^{-1} diet. The presence of AFs had a negative impact on the faecal digestibility of the crude protein, NDF and energy content of the whole diet ($P<0.001$) and on the ileal protein digestibility, especially with 300 g AFs kg^{-1} diet. The level of AFs in the diet had no effect on stomach weight ($P>0.05$) but increased the weight of the rest of the gastrointestinal tract ($P<0.001$). The rate of AF fibre fermentation in the pig large intestine was measured using an *in vitro* gas test. The rates were much lower than tropical tree foliage, which can also be used in pig diets in the tropics. This could partly explain the low apparent digestibility of AFs in pigs. In conclusion, the inclusion level of AFs in rations for sows should be limited to 150 g AFs kg^{-1} diet due to the low digestibility and energy density, as well as the negative impact on the digestibility of the whole diet.

There is a general need in tropical regions for increased livestock production to improve food security and alleviate poverty. In some countries, pork production is worth considering because pigs are very prolific, have a short generation interval and grow rapidly. Furthermore, pigs convert feed to meat relatively efficiently, production is not directly dependent on land – as compared with ruminants – and they are omnivorous animals (Holness, 1991; Leterme et al., 2007).

Sustainable systems in the tropics are based on perennial plants such as shrubs and trees that provide leaves with high protein and mineral content (Leterme et al., 2007). In this case, pig manure is used as a fertiliser, which ensures the sustainability of the system. Other systems involve aquatic ferns (AFs) such as *Azolla* sp. The latter are floating ferns with symbiotic N_2-fixing cyanobacteria that are used in Asia to fertilise rice fields (Arora and Singh, 2003). They are also used for pest and weed management (Kathiresan, 2007), as green manure (Bharati et al., 2000) or water purifiers (Oren Benaroya et

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al., 2004). They are usually integrated in more complex systems that include the production of fish and ducks (Kathiresan, 2007). More recently, there has been some interest to grow them on lagoons that collect pig slurry and to recycle them in swine or poultry nutrition due to their good protein quality (Becerra et al., 1990; Khatun et al., 1999) or mineral content (Chojnacka, 2006). However, despite the fact that millions of smallholders in the world feed their pigs with aquatic plants, very limited information is available on their actual nutritional value in pigs and on how to use them in swine nutrition, to improve productivity. In a previous study, we evaluated the nutritional value of two AFs, *Azolla filiculoides* Lam. and *Salvinia molesta* Mitchell, in growing pigs and concluded that the ferns are a good source of minerals and essential amino acids but that their interest is attenuated by their poor digestibility and energy density (Leterme et al., 2009).

In backyard production systems, AFs are primarily offered to sows, due to their high capacity of ingestion and also because they better digest and ferment fibrous diets, due to their more developed gastrointestinal tract (Noblet and Shi, 1993; Jorgensen et al., 2007).

The present study was aimed at determining the nutritional value of *Azolla filiculoides* and *Salvinia molesta* in sows, at estimating their capacity of ingestion and at studying the rate of AF fibre fermentation in the sows' gastrointestinal tract, by means of an *in vitro* model. The rate of fibre fermentation was compared with several tree leaves, which are also used in sustainable pork production systems in the tropics.

1. Materials and methods

1.1. Production of aquatic plants and analysis of their chemical composition

The AFs were produced in lagoons used to collect slurry coming from the swine barn of the National University of Colombia in Palmira (Colombia), as well as from a commercial farm. The slurry was collected into three consecutive lagoons, connected with a pipe. The first lagoon was used to produce common duckweed (*Lemna minor* L.) and the other two for production of *Salvinia* and *Azolla*, respectively. The AFs were collected each week, sun-dried and ground with a hammer-mill (5 mm mesh screen). The whole process was described in detail elsewhere (Leterme et al., 2009). In total, approximately 5 t of each species were produced, over the course of several weeks, of which approximately 0.5 t was used in fresh form and the rest in dried and ground form.

The AF samples collected for analysis were freeze-dried and ground with a Pulverisette 14 (Fritch GmbH, Idar-Oberstein, Germany), through a 1-mm-mesh screen. The flour was analysed for its content in dry matter (DM; oven at 105 °C for 24 h), ash (furnace at 550 °C for 8 h), nitrogen (Kjeldahl method) and oil (ether extract by the Soxhlet system, using petroleum ether). NDFom, ADFom and ADL were determined by means of an ANKOM fibre analyser (Ankom Technology, Madecon, NY, USA) using nylon bags. Gross energy (GE) was determined using a Parr 1341 calorimeter (Parr Instruments, Moline, MA, USA).

1.2. Experiment 1: intake experiment

This experiment aimed at measuring the maximal level of AF intake in sows fed a diet composed of 0.6% of commercial diet and 0.4% of AFs in fresh or dry and ground form and distributed separately.

1.2.1. Animals

Eight gilts (PIC Andina, Santiago, Chile) weighing 110 ± 14 kg (mean ± SD) were used. They were housed for 3 weeks in large individual stalls (2 m × 1.5 m), with concrete floors and permanent access to fresh water. The day/night temperature was 30/18 °C during the whole study. The housing was well ventilated and protected from the sun by a roof at approximately 5 m from the ground. The experiment was in agreement with the guidelines of the National University of Colombia for care and use of laboratory animals (Mrad de Osorio and Cardozo de Martinez, 1999).

1.2.2. Diets

A basal diet (600 g maize kg^{-1} DM, 180 g soybean meal, 100 g sucrose, 60 g rice hulls, 56 g mineral/vitamin premix, 1.8 g lysine and 2.2 threonine; estimated content of 14.2 MJ digestible energy kg^{-1}) was formulated to meet the nutrient requirements of gestating sows (NRC, 1998). The fresh ferns were collected with nets and kept one night in Hessian bags, for elimination of the free water. The preparation of the dry ferns is explained above.

1.2.3. Methodology

The experimental design was a Latin square with two repetitions, that is, two gilts per treatment and four treatments tested during four consecutive periods. The gilts were fed 5 times per day, every 2 h, from 8 a.m. to 4 p.m., in identical conditions for each meal. They first received the concentrate, mixed with an equal amount of water. They were then offered either the dry AF or the fresh ferns. The dry meal was mixed with an equal amount of water. Initially, the gilts received 80 or 90 g DM kg^{-1} metabolic weight ($W^{0.75}$) day of fresh or dry AF-based meals, respectively, with 0.4 coming from the basal diet and 0.6 from the AF. The amount was adapted daily according to the appetite of each individual gilt. Feed intake was measured for 5 days. The diets were then permuted and the experiment repeated.