Digestion of sweet potato (*Ipomoea batatas* (L.) Lam) foliage in pigs. *In situ* digestibility measured with mobile nylon bags

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The *in vivo* and *in situ* rectal digestibility of sweet potato foliage meal was studied through mobile nylon bags. Four pigs of 40 kg were used, canulated in duodenum and fed maize/soybean diets, partially substituted with 0, 10, 20 and 30 % of sweet potato (*Ipomoea batatas* (L.) Lam) foliage meal, according to a Latin squeare design 4 x 4. There was no significant effect of the treatment on the *in vivo* rectal digestibility of sweat potato foliage in the pigs. The diet supplied only influenced significantly ($P < 0.05$) on the rectal digestibility of the OM measured in *in situ*. Coincidence was found in the rectal digestibility of the DM (49.4 and 50.2%), nitrogen (N) (44.7 and 45.4%) and the energy of sweet potato foliage (45.6 and 46.7%), when the nutritive value was measured *in vivo* and *in situ*. It is suggested that the nutritive values of sweet potato foliage diets can be determined in mouth-rectum of pigs by *in vivo* and *in situ* procedures differently, through the technique of mobile bag.

Key words: *swine, digestion, ileum, rectum, foliar sweet potato*.

In Venezuela, assessing alternative raw materials for the total or partial substitution of imported cereals for pigs is of vital importance (Pérez 1997). The roots and tubercles may contribute to this purpose (González 1994). Therefore, deepening in their nutrients use is necessary so a data base is created to formulate balanced rations for pigs.

For this goal, studies on the digestibility of raw materials with agroecological advantages in the tropics are necessary. In the case of sweet potato (*Ipomoea batatas* (L.) Lam) foliage, for having a notable protein content (González 1994), assessing the nutrients digestibility, including N, is required. It has been proposed to measure the digestibility up to the rectum by using the technique of mobile nylon bag (Sauer *et al*. 1983). The advantage of this technique is to determine the nutrients digestibility with small amounts of feeds, rapidly and cheap. Besides, it allows doing it simultaneously in a lot of samples and with few animals. The mobile nylon bags have been used in the digestive assessment of other tropical foliages (Allen and Ly 2007 and Ly *et al*. 2008, 2010).

The assessment of sweat potato foliage in pigs is a subject of continuous interest in different labs of tropical countries such as Cuba (Domínguez 2010 and Domínguez *et al*. 2011), Vietnam (Giang 2003, Hong 2003, An and Lindberg 2004, An *et al*. 2004, 2005 and Hang *et al*. 2009), Camboya (Phiny *et al*. 2010) and Venezuela (Rodríguez *et al*. 2003, Ly *et al*. 2010 and González *et al*. 2011).

The objective of this experiment was to determine the *in situ* digestibility of nutrients in pigs fed sweet potato foliage meal of Venezuelan origin.

Materials and Mehtods

Only one lot of sweet potato foliage meal was used. The meal was prepared from a mixture of the air part of varieties cultivated in plantations of the Agronomy Faculty, Maracay. There were seven cultivated varieties: UCV-2, UCV-5, UCV-7, UCV-8, Carolina, Catemaco and Topera (Arrioja 1995). They were all mixed in equal parts. The air part was obtained from a harvest at 100 d of cultivation. The work routine established was followed to prepare the foliage meal. It was air-dried, mixed carefully and later milled in a hammer mill. The meal was packaged in sacks for its immediate use in the experiment. In order to determine the chemical composition of the foliage, a random sample was taken, representing 20 % of the whole lot. The volume for the sample was reduced to a proper size and divided into four parts. The two opposite parts were taken to form a new one, until reaching at about 0.5 kg.

Four Yorkshire x Landrace pigs, castrated males, with average initial weight of 40 kg were used. The animals had a simple canula in the duodenum, according to a described surgical procedure (Allen *et al*. 2004). The pigs were allocated in metabolism cages during the whole recovery period, lasting 21 d. From that moment on, they were weighed and adapted to diets with different levels of sweet potato foliage meal (table 1).

The intake was of 0.08 kg DM/LW$^{0.75}$ and the feed was offered twice a day, at 9:00 a.m. and at 3:00 p.m. in two equal rations. The drinking water was always available. Each experimental period lasted fourteen days. Out of them, eight days were for the adaptation to the diet and two for the quantitative collecting of feces. These were homogenized and frozen immediately to determine later the nutrients digestibility with the indirect method,

Table 1. Ingredients of the diets (percentages on dry basis)

Indicator	Sweet potato foliage, %			
	0	10	20	30
Maize meal	82.60	74.34	66.08	57.82
Soybean meal	13.75	12.38	11.00	9.63
Sweet potato foliage meal	0.00	10.00	20.00	30.00
$CaCO_3$	0.85	0.77	0.68	0.60
$CaPO_4H.2H_2O$	1.15	1.02	0.92	0.81
NaCl	0.85	0.77	0.68	0.54
Premixture[1]	0.80	0.72	0.64	0.60
Analysis				
DM	89.51	89.92	90.33	90.74
OM	93.79	93.00	92.20	91.42
Crude fiber	3.64	5.17	6.69	8.21
ADF	5.01	7.24	9.48	11.72
NDF	15.00	16.68	18.36	20.04
N	14.00	13.94	14.00	13.94
Energy, kJoule/g DM	17.87	17.78	17.71	17.64

[1] Vitamin and trace elements according to NRC (1998)

through the insoluble acid ash as internal marker (van Keulen and Young 1977).

At the eleventh day, ten sealed nylon bags of 10 x 25 mm containing 1.0 g of sweet potato foliage meal were introduced through the duodenal canula. The nylon was mono-filamentous, with a pore size of 48 µm, equal to that used by Sauer *et al*. (1989). The insertion of the bags in the duodenum was conducted when the pigs consumed the ration in the morning. The sweet potato foliage meal is the product from milling the samples to use a sieve of 1 mm the bags were previuosly incubated in pepsin solution, 1 g/L of HCl 0.1 N, at 37 ºC, during 4 h, following the procedure of Sauer *et al*. (1983, 1989), described by Ly *et al*. (2008). From that time on, during the three following days, the bugs excreted throughout the feces were collected with inspection every two hours. They were examined and those broken were thrown away, while the others were carefully washed with water and frozen until the analysis.

In the samples of feeds, feces and content of the nylon bags, the contents of DM, ash, crude fiber and N were determined by well-known procedures (AOAC 1995), while the ADF and NDF were determined according to van Soest *et al*. (1991). In the samples of feed and previously incinerated feces, the insoluble acid ash was determined following van Keulen and Young (1977). The energy content of the samples was determined in an adiabatic calorimeter pump. All the samples were determined per triplicate. In the particular case of the bags, the DM content was determined in all corresponding to the same treatment, while the concentration of ash, crude fiber, ADF, NDF and N was measured in two bags by analytic determination.

The nutrients digestibility in the experiment of *in vivo* rectal digestibility was determined by difference, as established by Crampton and Harris (1969). The digestibility data were compared to find out any treatment effect, that is, of the consumption of 10, 20 or 30 % sweet potato foliage meal on the nutritive value of the sweet potato foliage. The analysis of variance technique was applied, according to simple classification (Steel *et al*. 1997). In the case of *in situ* digestibility, the comparison was conducted following the same experimental design. After determining the treatment effect ($P < 0.05$) through the analysis of variance, the means were compared with the Tukey test. The statistical handling of the data was made with the statistic software Minitab (2002).

Results

In vivo rectal digestibility. There was no significant effect of the treatment on the rectal *in vivo* digestibility of the sweet potato foliage of pigs canulated in the duodenum. The digestibility was determined by difference for different nutrients (table 2), from the data of the diets digestibility. However, as the foliage inclusion level increased in the diet, the numeric value of examined nutrients digestibility also increased.

In situ rectal digestibility. During the three days of collecting bags in the feces, 80 % of the bags was recovered, eight out of ten introduced per each sample type. Out of these, 5 % were broken. Table 3 shows the values for the *in situ* digestibility of the sweet potato foliage in pigs fed diets with different inclusion levels of it. There was no treatment effect on the digestibility of DM, N, energy, and on the fractions of assessed fibers. There was only treatment effect ($P < 0.05$) on the *in situ* digestibility of OM, which seemed to diminish when

Table 2. Influence of consuming diets with variable levels of sweet potato foliage meal on the *in vivo* digestibility of nutrients of the sweet potato foliage in pigs, estimated by difference

	Sweet potato foliage meal, %			SE ±
	10	20	30	
n	4.00	4.00	4.00	-
DM	45.56	54.45	49.98	4.51
OM	44.88	50.50	55.68	4.58
ADF	40.07	50.15	58.86	7.67
NDF	32.25	40.08	50.50	7.47
N	40.28	42.58	51.25	4.62
Energy	43.38	45.57	47.89	1.81

[1] Estimated according to Crampton and Harris (1969)

the animals consumed growing levels of foliage. This increased when the pigs consumed 30 % of sweet potato foliage in the ration.

Table 4 presents the nutritive value of the foliage, estimated by the *in situ* or *in vivo* technique in the same animals. There was a coincidence in the rectal digestibility of DM (49.4 and 50.2 %), N (44.7 and 45.4 %) and energy (45.6 and 46.7 %) of the sweet potato foliage, when the nutritive value was measured *in vivo* and *in situ*. There was no significant effect of the treatment when comparing the digestibility of DM, ADF, NDF, N and energy. This comparison was not conducted in the data of OM digestibility.

Discussion

The data of *in vivo* rectal digestibility of nutrients particularly that of DM, measured in pigs canulated in the duodenum are within the range recorded in Venezuela (González 1994, Arrioja 1995 and González *et al*. 2011) with intact pigs consuming the same type of diet. The

Table 3. Influence of consuming diets with variable levels of sweet potato foliage meal on the *in situ* digestibility (duodenum-rectum) of nutrients in pigs

	Sweet potato foliage meal, %				SE ±
Digestibility, %	-	10	20	30	
n	4.00	4.00	4.00	4.00	-
DM	52.10	51.62	47.24	49.06	2.55
OM	51.06[a]	49.08[ab]	47.72[ab]	42.56[b]	2.50*
ADF	57.67	37.84	42.66	53.50	12.18
NDF	47.93	38.95	42.53	37.29	17.96
N	38.93	37.31	37.09	45.49	6.18
Energy	49.62	49.49	48.79	46.73	4.91

[ab] Means without letter in common in the same row differ significantly ($P < 0.05$)
*$P < 0.05$

Table 4. Comparison of the rectal digestibility of sweet potato foliage meal in growing pigs

	Rectal digestibility, %		SE ±
	In vivo	*In situ*	
n	4.00	4.00	-
DM	49.43	50.25	2.90
OM[2]	50.35	47.60	-
ADF	49.69	51.20	7.53
NDF	40.94	42.07	9.96
N	44.70	45.49	4.08
Energy	45.61	46.73	1.88

[1] the analysis of variance was not conducted

lack of differences between animals, intact or not, in the rectal digestibility indexes was previously reported under other experimental conditions (Huisman *et al*. 1985). When existing, they were very small (Jorgensen *et al*. 1985).

In this experiment, the same trend observed by Ly *et al*. (2008) was proved, in regards to the *in situ* rectal digestibility, lightly superior in values, compared to those measured in animals through the direct conventional method. However, they did show apparent digestibility. These data contradict the statement of Taverner and Campbell (1985), who suggested the contrary, that these methods were linearly related. Actually, there is no a concluding trend when comparing different determination techniques of the rectal digestibility in pigs. Originally, Handloss (1974) found that the diet offered to the animals did not influence on the result. Later, De Lange *et al*. (1991) did not find it for the N digestibility in cereals, but did occur when assessing the rectal digestibility of energy. Probably, if there were differences, they would be only revealed when the data dispersion degree is too small, as the mean values of the corresponding means are much closed to the different procedures for determining the nutrients digestibility, at least, in swine. Considering this reality, further researches on this topic are needed.

Another aspect to be highlighted is the high variability of the digestibility results, mainly *in situ*, for the fibrous fractions and the N. This should affect the comparison between both methods (table 4). Maybe this did not influence on the final result, but it did on the data precision, maybe suggesting the necessity of increasing the population size, in case both methods are compared with the use of other non-conventional feeding resources of the tropics.

In these results, the exceptional aspect seems to eliminate the influence of the treatment on the *in situ* digestibility of OM, which seemed to be numerically inferior to that found *in vivo*. The explanation of this result is not evident. Anyway, it should be considered that the OM value depends on the corresponding percentage of ash in the sample, and this detail was not examined in the experiment. Frequently, there is good coincidence between both procedures, in respect to measuring the *in vivo* and *in situ* OM in tests with conventional feeds or varied products of grains and cereals. (Thacker and Qiao 2004). Nevertheless, Taverner and Campbell (1985) informed that they found in the pigs, effect of the fiber consumed on passage rate of the bags. This brought about lower nutrients digestibility. This aspect deserves further studies.

It is suggested that the nutritive value of diets with sweet potato foliage can be determined in mouth-rectum of pigs by *in vivo* and *in situ* techniques, differently. In this last case, through the mobile bag technique, a great part of the most important indexes can be determined, such as those of DM, N and energy. The assessment of other non-conventional feeding resources of tropical origin should be also considered.

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