**ILEAL AND RECTAL FLOW OF DIGESTA IN PIGS FED GRADED LEVELS OF TREATED GRAINS OF CANAVALIA (Canavalia ensiformis L.**)

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**SUMMARY**

*Six intact or three ileorectostomized pigs were allotted in three treatments according to a 3 x 3 Latin square design to determine the effect of autoclaved Canavalia ensiformis beans (0, 5 and 10%, dry basis) on ileal and rectal digesta flow in pigs fed on sugar cane molasses plus soybean meal based diets.*

*The introduction of canavalia beans in the diet determined an increase in pH values in distal ileum (P<0.01) and faeces. DM concentration was not influenced by the evaluated treatments, although an increase in DM values was noted in both studied gastrointestinal sites. There was no treatment effect on ileal and rectal flow of fresh and dry materials, but ileal flow of N significantly (P<0.05) increased from 5.44 to 6.82 g N/kg DM intake, and N disappearance in the large intestine increased from 1.71 to 3.06 g/kg DM intake when canavalia beans were introduced in the diet of pigs.*

*It is suggested that in highly digestible diets, as those assayed in the present investigation, the flow of digesta, except for N, is considerably reduced at the ileal site, with no effect of treated canavalia beans, when these grains are at least up to 10% in diets. This is reflected too in the rectum of the animals.*

***Key words:*** *digesta flow, ileum, rectum, pigs, canavalia beans*

***Short title:*** *Digesta flow in pigs fed canavalia beans*

**FLUJO DE DIGESTA ILEAL Y RECTAL EN CERDOS ALIMENTADOS CON NIVELES VARIABLES DE GRANOS TRATADOS DE FRIJOL DE CANAVALIA (Canavalia ensiformis L.)**

**RESUMEN**

*Seis cerdos intactos o tres ileorectostomizados fueron distribuídos en tres tratamientos de acuerdo con un diseño cuadrado latino 3 x 3 para determinar el efecto de frijoles de Canavalia ensiformis tratados con autoclave (0, 5 y 10% en base seca) en el flujo ileal y rectal de digesta de cerdos alimentados con dietas de mieles de caña de azúcar y harina de soya.*

*La introducción de frijoles de canavalia en la dieta determinó un incremento en los valores de pH en el íleon distante (P<0.01) y en las excretas. La concentración de MS no estuvo influída por los tratamientos evaluados, aunque se notó un incremento en los valores de MS en ambos sitios del tracto gastrointestinal que se estudiaron. No hubo efecto de tratamiento en el flujo ileal y rectal de materiales fresco y seco, pero el flujo ileal de N se elevó significativamente (P<0.05) desde 5.44 hasta 6.82 g N/kg MS ingerida y la desaparición de N en el intestino grueso aumentó desde 1.71 hasta 3.06 g/kg MS ingerida cuando los frijoles de canavalia se introdujeron en la dieta de los cerdos.*

*Se sugiere que en dietas altamente digestibles, como las ensayadas en la presente investigación, el flujo de digesta, ecrpto para el N, se reduce considerablemente en el íleon, sin efecto de los frijoles de canavalia, cuando estos granos están al menos hasta 10% en la dieta. Esto también se refleja en el recto de los animales.*

***Palabras claves****: flujo de digesta, íleon, recto, cerdos, frijol de canavalia*

***Título corto****: Flujo de digesta en cerdos alimentados con frijol de canavalia*

**INTRODUCTION**

Since the early work of Braude et al (1976), an attention has been drawn to studies on digestion and absorption of several nutrients in the gastrointestinal tract of pigs. In this connection, the examination of the characteristics of the flow of digesta and pH in several sites of pig's intestine has been conducted in different moments (Ivan and Farrell 1976; Low et al 1978; Jorgensen et al 1997). According to the current knowledge, the introduction of different types of foliage in the diet, tends to decrease nutrient digestibility and concomitantly, to increase the flow of either ileal or rectal digesta (Díaz et al 2005). On the

other hand, other possible source of variation on digesta flow in the alimentary canal of pigs, such as the nature of dietary protein (Alimon and Farrell 1980) or presence of phytase in the diet (Bruce and Sundstol 1995) has been explored too.

Canavalia (Canavalia ensiformis L.) is a tropical legume with high yields and valuable protein content (Dixon et al 1983; Arora 1995), which could be used for feeding pigs. However, the considerable high amount of diverse anti-nutritional factors contained in the grains is a constraint which has not been overcame as yet, in spite of different efforts conducted to neutralize of alleviate the deleterious consequences of feeding pigs with canavalia beans (Risso 1984; León et al 1993; Ly 1996, Pérez 1997; Nava et al 1999; Nava 2005).

In this paper, an information is provide related to the influence of including graded levels of treated canavalia beans on measurements of the flow of digesta and intestinal pH of growing pigs fed diets based on highly digestible sugar cane molasses.

## MATERIALS AND METHODS

The methods employed for the detoxification consisted of coarsely grinding, soaking, washing, autoclaving, and then washing again the seeds (Domínguez et al 2009), for thereafter mixing the beans with the other components of the diet. The composition of the diets is shown in table 1. The diets consisted of a highly digestible type of sugar cane molasses, named sugar cane molasses type B as the major source of energy. These diets were gradually substituted for none, 5 and 10% of canavalia beans.

**Table 1. Characteristics of the experimental diets (per cent in dry basis)**

| | Canavalia beans, % | | |
|---|---|---|---|
| | - | 5 | 10 |
| **Ingredients** | | | |
| Cane molasses B | 66.5 | 63.8 | 61.1 |
| Soybean meal | 31.2 | 28.3 | 25.7 |
| Canavalia beans[1] | - | 5.5 | 10.8 |
| $CaPO_4H_2$. $2H_2O$ | 1.0 | 1.0 | 1.0 |
| $CaCO_3$ | 0.5 | 0.5 | 0.5 |
| NaCl | 0.5 | 0.5 | 0.5 |
| Vitamins and minerals[2] | 0.3 | 0.4 | 0.4 |
| **Analysis** | | | |
| Dry matter | 55.7 | 53.1 | 51.1 |
| Organic matter | 92.0 | 92.2 | 92.3 |
| Crude fibre | 2.02 | 2.60 | 3.21 |
| N | 2.42 | 2.46 | 2.50 |
| Gross energy, kJ/g DM | 15.32 | 15.40 | 15.50 |
| L-canavanine, % | - | 0.012 | 0.025 |
| TIA[3], mg/g | 1.2 | 1.3 | 1.3 |

[1] For details, see text
[2] According to NRC (1998) recommendations. For details see Domínguez et al (2009)
3 TIA expresses trypsin inhibition activity

L-canavanine content in treated canavalia beans revealed to be quite low, 0.25% in dry basis, in fact relatively lower as compared with previous results (Domínguez et al 2009) obtained with this same method for quantifying the presence of this non protein amino acid in the legume (Delgado et al 1999). In this connection, it was considered that extensive washing of the ground, soaked seeds before and after autoclaving was considerably effective. On the other hand, trypsin inhibitor activity was relatively low.

Two experiments were conducted to determine digesta flow characteristics in pigs fed on canavalia beans containing diets. In the first experiment, three ileorectostomized animals of 50 kg body weight were used following a 3 x 3 Latin square design. The anastomosis was conducted accoding to the procedure described by Domínguez et al (2000). In this second experiment, the same experimental treatments as in the first experiment were assayed. After an adaptation period of seven days, ileal digesta was continuously collected during 48 hours, and a two-24 hours pool was then prepared for analysis.

In the second experiment six intact pigs weighing 50 kg were allotted at random into three diets according to a duplicate 3 x 3 Latin square design to determine the effect of autoclaved canavalia beans on faecal characteristics of pigs. Every experimental period was of 14 days, where seven days were spent in adaptation of the animals to diets, then two subsequent days were employed for adaptation of the pigs to the metabolism cages, and finally the last five days was used for quantitative collection of faeces (Domínguez et al 2009).

In both experiments, DM and N were determined by duplicate in feeds, faeces and digesta. The DM content was determined by gravimetry by drying in an oven until constant weight whereas N analyses were conducted in fresh materials by the Kjeldhal procedure (AOAC 1990). The pH values were determined by a glass electrode attached to a digital pHmeter. L-canavanine concentration in the treated beans was assayed according to the colorimetric method of Bell (1958). Trypsin inhibitor activity was assayed following Martínez and Domínguez (2009) recommendations.

The technique of analysis of variance was used for contrasting means of treatments (Steel et al 1997), and the software recommended by Harvey (1990) was used for processing the experimental data.

## RESULTS AND DISCUSION

Animals employed in the current investigation did not reveal any alteration in its behaviour during the conduction of the trial. In fact, there were no symptoms of any distress, expressed by feed refusals, apparently caused by the nature of the feed eaten, except in diet containing 10% canavalia beans, where feed intake accounted for some 96% of that programmed. In this case, it was considered that the dietary level of L-canavanine (0.025%) could determine a slight inhibition of voluntary feed intake, as it has been shown in other experiments (Rosenthal 1977; Enneking et al 1993). On the other hand, during the experiment, all pigs gained in live weight as it was reported in a companion paper (Domínguez et al 2009).

Ileal characteristics of digesta and the ileal flow of digesta are shown in table 2. There was no clear difference among treatments for DM concentration in ileal digesta, although 10% of canavalia beans in the diet determined a slight increase in ileal DM concentration. The same phenomenum was true for ileal pH, which significantly ($P<0.01$) increased with increasing levels of canavalia beans in the feed. Accordingly, a non

significant (P>0.05) increase in ileal flow of fresh and dry material was noted when canavalia beans were included in the diet of pigs. From the point of view of ileal N flow, the introduction of canavalia seeds in the diet determined a significant (P<0.05) higher values for ileal N flow. Results from the current investigation are in accordance with other previous reports published by this same laboratory (Ly and Delgado 2007). In that opportunity, Ly and Delgado (2007) found that pigs fed on graded levels of canavalia beans treated in a similar manner as that used in this study, had a notable increase of ileal flow of N as influenced by the canavalia bean content in the diet. Jansman et al (2002) has suggested that obligatory ileal endogenous losses of protein account for 11.8 g/kg DM intake, or 1.89 g N/kg DM intake, considering the factor of 6.25 for the crude protein/N ratio. In these circumstances, values overcoming an ileal N flow near to 1.9 g/kg DM intake should be an expression of the direct influence of the nature of dietary N sources (Boisen et al 1996), in this particular case, canavalia beans. As regards to canavalia beans, this increase of endogenous N losses could be related to the influence of anti-nutritional factors remainining in the seeds, even after being treated by soaking, washing and autoclaving, as it was the case in the current investigation.

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**Table 2. Ileal flow of digesta in pigs fed diets containing treated canavalia beans**

| | Canavalia beans, % | | | |
|---|---|---|---|---|
| | - | 5 | 10 | SE ± |
| **Ileal characteristics** | | | | |
| Dry matter, % | 9.37 | 9.25 | 10.82 | 1.12 |
| pH | 5.70[a] | 5.93[a] | 6.50[b] | 0.72** |
| N, %MS | 3.97 | 4.52 | 3.88 | 0.35 |
| **Flow, g/kg DM intake** | | | | |
| Fresh material | 1 526 | 1 578 | 1 617 | 113 |
| Water | 1 383 | 1 432 | 1 442 | 120 |
| Dry material | 143 | 146 | 175 | 15 |
| N | 5.44[a] | 6.76[b] | 6.82[b] | 0.45* |

* P<0.05; ** P<0.01
[ab] Means without letter in common in the same row differ significantly (P<0.05)

There was no treatment effect on neither faecal characteristics nor on rectal flow of materials (table 3). However a non significant trend was observed of faecal DM concentration and flow of faecal material to increase or decrease respectively with increasing levels of canavalia beans in the diets. As compared to other results concerning the use of sugar cane molasses in the diet (see Ly et al 1998), a noticeable decrease in fresh and dry material was observed at the rectal site of pigs used in the current experiment. This data could be understood if the highly digestible diet used as control treatment could be taken into account (Domínguez et al 2009). In fact, Domínguez et al (2009) found a value as high as more than 92% of DM digestibility of the diet containing no canavalia beans.

With respect to N flow at the rectum site, there was no effect of treatment on neither faecal N concentration, nor on rectal flow of N, which was practically the same in all circumstances (3.7 g N/kg DM intake). Compared to corresponding data at the distal ileum site, these values were considerably low. In this regard, Wünsche et al (1987) indicated that endogenous protein losses are higher at the ileal level than at the faecal level.

**Table 3. Rectal flow of digesta in pigs fed diets containing treated canavalia beans**

| | Canavalia beans, % | | | |
|---|---|---|---|---|
| | - | 5 | 10 | SE ± |
| **Faecal characteristics** | | | | |
| Dry matter, % | 36.83 | 36.01 | 37.20 | 1.50 |
| pH | 7.15 | 7.10 | 7.20 | 0.50 |
| N, %MS | 4.91 | 4.45 | 5.01 | 0.41 |
| **Flow, g/kg DM intake** | | | | |
| Fresh material | 206 | 233 | 191 | 52 |
| Water | 130 | 149 | 120 | 16 |
| Dry matter | 76 | 84 | 71 | 8 |
| N | 3.73 | 3.74 | 3.76 | 0.33 |

Table 4 shows an estimation of digesta disappearance between ileum and rectum of the pigs. In fact, there were not great changes in fresh and dry materials, and water, when the control treatment was compared to the other containing 5% of canavalia beans. As a contrast, when canavalia beans accounted for 10% of the given feed, more water and dry material apparently disappeared in caecum and colon of the animals. It could be assumed that this last finding could be related to a rather low ileal DM digestibility in pigs fed 10% canavalia beans in the diet, since faecal DM digestibility was practically constant, if a detailed examination of Domínguez et al (2009) is considered. Overall, water disappearance in the large intestine was evidently more important than dry material, in pigs fed diets containing a highly digestible sugar cane molasses based diet. N disappearance in caecum and colon was considerable high in pigs fed canavalia beans introduced in the diet, as compared to the control diet. This canavalia effect may be undesirable for the metabolism of animals, since N disappearance in the large intestine of pigs does not correspond to any amino acid (Zebrowska 1973; Zebrowska and Horsczaruk 1975), and therefore N compounds, probably ammonia to great extent, should be detoxified by the liver to be excreted as urea.

**Table 4. Digesta disappearance in the large intestine of pigs fed diets containing treated canavalia beans**

| | Canavalia beans, % | | |
|---|---|---|---|
| | - | 5 | 10 |
| **Disappearance, g/kg DM intake** | | | |
| Fresh material | 1 320 | 1 345 | 1 426 |
| Water | 1 253 | 1 283 | 1 322 |
| Dry material | 67 | 62 | 104 |
| N | 1.71 | 3.02 | 3.06 |

It is suggested that in highly digestible diets, as those assayed in the present investigation, the flow of digesta is considerably reduced at the ileal site, with no effect of treated canavalia beans, when these grains are at least up to 10% in diets. This is reflected too in the rectum of the animals.

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