STUDIES ON FACTORS AFFECTING FAECAL OUTPUT IN GROWING PIGS. AN APPROACH TO THE EFFECT OF LEVEL OF FEED INTAKE AND OF SEX

J. Ly

[1] Swine Research Institute, PO Box No.1, Punta Brava. Havana City, Cuba
email: julioly@utafoundation.org

SUMMARY

Two experiments designed as Latin squares were undertaken to study the effect of level of feed intake and sex in growing pigs on faecal output. The animals received diets of glucose and soybean meal (in both cases, 63:35 in dry basis). In experiment 1, four levels of feed intake were assayed in a unique daily ration served at 9:00 am: 0.05, 0.10, 0.15 and 0.20 kg DM/kg$^{0.75}$ per day. The feed was given to four Yorkshire female pigs averaging 35 kg initial live weight according to a 4 x 4 Latin square design. In experiment 2, three levels of feed intake, 0.05, 0.10 and 0.15 g DM/kg$^{0.75}$ per day, were given to nine castrate male pigs of the Cuban CC21 genotype, averaging 40 kg live weight, following a triple 3 x 3 Latin square.

A positive, highly significant (P<0.001) relationship between the level of feed intake and faecal output of fresh material, water and dry matter was encountered. Faecal output of fresh material could be described by an exponential function (R^2, 0.657; P<0.01). Faecal output of SCFA and ammonia appeared to behave in a curvilinear manner as a response to varying feed intake level. Sex appeared to be with no influence on faecal output of materials.

Further studies of factors affecting faecal output of materials in pigs, underlying those fitted to tropical and local conditions of pig production, are suggested.

Key words: *pigs, faecal output, level of feed intake, sex, protein*

Short title*: Factors affecting faecal output in pigs*

ESTUDIOS DE FACTORES QUE INFLUYEN EN LA SALIDA FECAL DE CERDOS. APROXIMACION AL EFECTO DEL NIVEL DE CONSUMO Y DEL SEXO

RESUMEN

Se diseñaron dos experimentos como cuadrados latinos para estudiar el efecto del nivel de consumo y del sexo en la salida fecal cerdos en crecimiento, en animales a los que se dieron dietas de glucosa y harina de soya (en ambos casos, 63:35 en base seca). En el experimento 1, cuatro niveles de consumo se ensayaron en una ración diaria única servida a las 9:00 am: 0.05, 0.10, 0.15 y 0.20 kg MS(kg$^{0.75}$ por día. El alimento se dio a cuatro cerdas Yorkshire con un peso inicial promedio de 35 kg según un cuadrado latino 4 x 4. En el experimento 2, se probaron tres niveles de consumo, 0.05, 0.10 y 0.15 g MS/kg$^{0.75}$ por día, dados a nueve cerdos de la raza cubana CC21, machos castrados, con un peso promedio inicial de 40 kg, siguiendo un triple cuadrado latino 3 x 3.

Se encontró una relación positiva, altamente significativa (P<0.001) entre el nivel de consumo de la ración y la salida fecal de material fresco, agua y materia sea. La salida fecal de material fresco pudo ser explicada por una función exponencial (R^2, 0.657; P<0.01). La salida fecal de AGCC y amoníaco pareció conducirse de una manera curvilínea como respuesta de variar el nivel de consumo de alimento. El sexo no pareció influenciar la salida fecal de materiales.

Se sugiere hacer más estudios sobre factores que influyen la salida fecal de materiales en los cerdos, haciendo énfasis en las condiciones tropicales y locales de producción porcina.

Palabras claves: *cerdos, salida fecal, nivel de consumo, sexo, proteína*

Títulos cortos: *Factores que influyen en la salida fecal de cerdos*

INTRODUCTION

Several reports related to the effect of feed intake level on nutrient digestibility of pigs have been published, among others, those of Oude et al (1986) and Noblet et al (1993).

Least information concerning interdependence between pig gastrointestinal tract and feed intake is available (Rayner and Gregory 1989). Overall, a trend has been noted of the existence of an inverse relationship between the level of feed intake and nutrient digestibility. In this connection, it is possible to assume that as long as feed indigestibility increases, more faecal material is exported from pigs to the environment.

Manipulation of the nutrition of pigs should be a manner to manage faecal output (Kerr 2003), not only for determining the maximum efficiency of growth and feed utilization by animals, but for potential use of feeds as origin of faeces for fertilizers and biogas production, among other forms of neutralize the negative environmental impact of pig excreta. In this connection several attempts in this direction have been put forward (Canh et al 1997, 1998a,b; Mroz et al 2000; Leek et al 2004; Nyachoti et al 2006; Pierce et al 2006; Galasi et al 2007). On the other hand, sex has not been examined as an important factor influencing nutrient digestibility in pigs (Ly 2008), but enough information concerning the effect of sex on feed intake of pigs is lacking (for a review, see Whittemore et al 2001).

The objective of the present communication is to describe an attempt to determine the possible influence of the level of feed intake and sex on faecal output in growing pigs.

MATERIAL AND METHODS

Information originated in two experiments conducted to study the pattern of feed intake and digestibility in growing pigs was utilized to evaluate factors affecting faecal output (Ly 2008, unpublished data) in growing pigs. In both experiments, a simple diet was formulated to contain D-glucose of commercial origin as the only energy source, and soybean meal. The characteristics of the diets are presented in table 1.

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

	Soybean meal, %	
	35	**100**
Ingredients		
D-Glucose	63.0	-
Soybean meal	35.0	-
NaCl	0.5	-
$CaCO_3$	0.5	-
$CaPO_4H.2H_2O$	0.5	-
Premix[1]	0.5	-
Analysis		
DM	90.7-90-9[2]	91.1-91.9
Crude fibre	2.5-2.6	7-1-7.5
Water holding capacity, g H_2O/g DM[3]	0.90	2.57

[1] Trace elements and vitamins according to NRC (1998)
[2] Range of value corresponding to experiments 1 and 2
[3] See text for detail

A total of four 35 kg Yorkshire, castrated male and nine Cuban CC21 female pigs were employed in experiments 1 and 2 respectively.. The animals were allotted at random into either four treatments according to a 4 x 4 Latin square design or 3 x 3 Latin square design too. In experiment 1, the treatments consisted on offering four or three different levels of feed intake of the same diet, glucose plus soybean (table 1), to the pigs. Feed intake established were 0.05, 0.10, 0.15 and 0.20 kg DM per $kg^{0.75}$ given in only one ration at 9:00 am every day.
The pigs were assigned to three treatments consisting of three levels of feed intake in experiment 2. The pigs were nine castrate male pigs of the Cuban CC21 genotype, and averaged 40 kg initial live weight. The pigs received 0.05, 0.10 and 0.15 kg DM per $kg^{0.75}$ given in only one ration at 9:00 am every day, in the same manner as in experiment 1. The experimental periods were of seven days, six of them for adaptation to the specified feed intake, and one ending day for sampling by grabbing faecal material directly from the rectum at 8:00 am.

In both experiments, the animals were housed in individual pens of concrete floor placed in an open room with no environmental control of temperature. Water was always available through drinking devices. Feed consumption was recorded daily, by collecting feed refusal if any, left in the individual troughs of each pig. The determination of DM concentration in feeds and faeces was carried out by gravimetry (AOAC 2000), whereas feed indigestibility was determined through the determination of the acid insoluble ash, following the metjhod of Van Keulen and Young (1977).

Ammonia and total SCFA were determined in a faecal slurry prepared from fresh faeces (1:4, in weight basis) by microdiffusion (Conway 1957) and by steam distillation by means of a Markham apparatus, following the well known method of Pennington (1952). Water holding capacity was assayed by the centrifugation procedure as outlined by Kyriazakis and Emmans (1995), Ten grams of sample were weighed in a 100 mL centrifugue tube, then 40 mL of distilled water were added, thoroughly poured and led stand overnite. This operation was conducted at environmental temperature, approximately 25°C. After approximately 18 hours, the sample was centrifugued at 5 000 rpm during 15 min, then the supernatant was carefully discarded and the residue weighed. All analyses were undertaken at least by duplicate.

Both experiments were conducted during the summer season, with no great differences between both trials from the environmental point of view. Average air temperature at 12:00 m was 28°C.

Faecal output of materials was calculated as outlined elsewhere (Ly 2008), and was determined considering feed indigestibility. Feed DM indigestibility was calculated as the ratio of percent of inner marker in feed (A) to faeces (B), expressed as per 100 g of DM intake, as described by the following expression:

Feed indigestibility = (A/B) x 100, in g

The above aequation was adjusted to one kg of DM intake.. Faecal output of materials other than DM was determined taking into account its faecal concentration, either in fresh or dry basis. Data were subjected to analysis of variance according to Steel et al (1997). In cases that significant differences ($P<0.05$) were encountered among means per treatment, these means were separated according to the multiple range and multiple F test of Duncan (Steel et al 1997). The software package of Harvey (1990) was used for manipulation of data.

RESULTS

Animal behaviour appeared to be normal during the entire experimental period. Major prandial activity followed the supply of feed, in the morning. In both treatments designed to give the two lowest feed intake level, feed consumption was complete during the first two hours after receiving the assigned ration. In the case of the third treatment, pig behaviour was similar to those in the other treatments, and there was no feed considerable feed consumption after midday.

Experiment 1

Data concerning faecal output are listed in table 2. It was not possible to achieve the planned levels of feed intake in two treatments (0.150 and 0.200 kg DM/W$^{0.75}$), and data from these animals are referred to the current feed intake occurring during the experiment (Ly 2008, unpublished data).

In this experiment, a net disminution of faecal DM concentration and rectal DM digestibility was encountered. A highly significant (P<0.001) increase in faecal fresh material, water and DM was observed in this study. Faecal output of SCFA and ammonia was increased when feed intake of pig was inceased too. This effect appeared to be curvilinear for both types of microbial metabolites. In this case, ammonia output showed a maximum, 36.2 mmol/kg DM intake (P<0.01) when pigs where given 0.090 kg DM/kg$^{0.75}$. This same treatment determined a minimum for SCFA output, 35.9 mmol/kg DM intake (P<0.001). Overall, a trend was observed to encounter a greater faecal SCFA output as compared to ammonia output in faeces.

Table 2. Effect of the level of feed intake on faecal output in growing female pigs fed diets of glucose and soybean meal (experiment 1)

	Feed intake, 0.1 kg DM/kg$^{0.75}$				
	0.45	0.90	1.14	1.16	SE ±
n	4	4	4	4	-
Faecal DM, %[1]	26.2	25.6	15.6	13.5	-
DM digestibility, %[1]	90.4	88.5	83.6	82.2	-
Fresh material output, g/kg DM intake	366[a]	449[a]	1 051[b]	2 097[c]	110***
Water output, g/kg DM intake	270[a]	334[a]	887[b]	1 919[c]	105***
DM output, g/kg DM intake	96[a]	115[b]	164[c]	178[c]	10***
NH_3 output, mg/kg DM intake	14.2[a]	36.2[b]	22.1[b]	27.2[b]	5.5**
SCFA output, mmol/kg DM intake	36.0[a]	35.9[a]	64.0[b]	67.6[b]	10.1***

[1] From Ly et al (1990)
** P<0.01; *** P<0.001
[abc] Means without letter in common in the same row differ significantly (P<0.05) among them

Experiment 2

As it was observed in experiment 1, a consumption accounting for 0.150 kg DM/W$^{0.75}$ could not achieve in any case. Then the data from this treatment were recorded reflecting the true level of feed intake, 0.150 kg DM/W$^{0.75}$ (table 3). Animals employed in experiment 2 had significant (P<0.001) decrease in faecal DM concentration when the level of feed intake augmented (table 3). An inverse relationship was noted between DM digestibility of diet and feed intake level, but this effect was not significant (P>0.05). In contrast, it was very evident that faecal output response, either of fresh or dry material, apparently was a direct consequence of the elevation of the level of feed intake.

From the point of view of microbial metabolites, faecal ammonia and SCFA output significantly differed (0.01<P<0.001) among treatments, when the control, lower level of feed intake was compared to the other two assayed levels. In the case of ammonia output, a mean value from the lowest level of feed intake attained 17.4 mmol/kg DM intake, whereas for SCFA, in this same treatment, faecal output was 40.0 mmol/kg DM intake. On the other hand, microbial metabolite output in faeces appeared to behave in a curvilinear manner, as in experiment 1, exhibiting an inflexion point around 0.100 kg DM/kg$^{0.75}$.Overall, a coincidence did exist between data from experiments 1 and 2 concerning the status of microbial metabolites output as it was found in faeces.

Table 3. Effect of the level of feed intake on faecal output in growing castrated male pigs fed diets of glucose and soybean meal (experiment 2)

	Feed intake, 0.1 kg DM/kg$^{0.75}$			
	0.50	1.00	1.15	SE ±
n	9	9	9	-
Faecal DM, %	25.5[a]	22.2[b]	16.1[b]	1.3***
DM digestibility, %[1]	90.9	89.1	84.4	-
Fresh material output, g/kg DM intake	357[a]	490[a]	975[b]	116***
Water output, g/kg DM intake	266[a]	381[a]	819[b]	121***
DM output, g/kg DM intake	91[a]	109[a]	156[b3]	15***
NH_3 output, mg/kg DM intake	17.4[a]	43.5[b]	30.0[c]	4.7**
SCFA output, mmol/kg DM intake	40.0[a]	30.9[a]	50.1[b]	11.1***

[1] From Ly et al (2008)
** P<0.01; *** P<0.001
[abc] Means without letter in common in the same row differ significantly (P<0.05) among them

The pattern of output of faecal material did not appear to be rectilinear in nature. In fact, when data of fresh material output from both experiments were pooled an exponential response was found (figure 1).

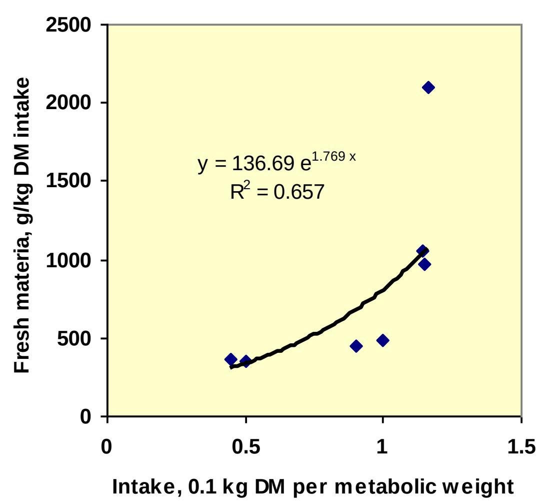

Figure 1. Interdependence between level of feed intake (x) and faecal output of fresh materials (y) in pigs fed glucose and soybean meal diets. Each point is the mean per treatment from experiments 1 and 2 respectively

The resulting regressive aequation was highly significant (R^2, 0.657; P<0.01) in the range of values where the independent variable moved in.

When data from experiment 1 and 2 were examined aside, an exponential expression was the best fitted aequation in both cases for describing the pattern of fresh material emission by pigs, but a somewhat difference was encountered between the expression from castrated male and that for female animals (table 4).

Table 4. Interdependence between level of feed intake and faecal output of fresh material in female and castrated male pigs[1]

	Sex of pigs	
	Female	**Castrated males**
n	16	27
a	110.83	173.43
b	2.047	1.316
R^2	0.705	0.760
Sig	***	***

*** P<0.001
[1] Interdependence described by the aequation $y = a.e^{bx}$

DISCUSSION

Faecal output or fresh material

The herein evaluated diet was in fact very poor in its water holding capacity (see table 1). Measurements were made in order to know the possible influence of the capacity of water retention of digesta on faecal output. In this connection, Eastwood (1992) has discussed the ability of dietary fibre for taking up and hold water. Then it could be thought that faecal output of fresh materials would change accordingly (Stephens and Cummings 1979). Nevertheless, Cherbut et al (1988) have suggested that the mechanical properties of the indigestible part of the diet only should partially explain its effect on facecal excretion in pigs.

Pierce et al (2006) have reported a faecal output as high as 499 g fresh material/kg DM intake when growing pigs received a diet based on wheat and soybean meal (68.5:28.2). Data of Pierce et al (2006) are in coincidence with those from the present study when animals were given approximately 0.1 kg DM/$kg^{0.75}$ (see for example, table 3). In this connection, Pierce et al (2006) reported similar faecal DM concentration and digestibility, 26.2% and 88.3% respectively. In the case of the experiment of Leek et al (2004), pigs given a barley/soybean based diet (50.0:19.5), faecal output of fresh material was in the order of approximately 480 g/kg DM intake.

In agreement with other previous study (Piloto and Ly 2001), a clear direct influence of feed intake on the pattern of faecal output of materials was observed in both experiments herein described. On the other hand, although a strict comparison was not possible in the present investigation, it could be considered that sex appeared to have no influence in faecal output of materials. Nevertheless, it has been observed that castrated male animals do have an slightly increased feed intake compared with females, when full potential of feed intake is let to be expressed (Cole and Chadd 1989; Hsia and Lu 1989). Then, it could be hypothetized that faecal output should be greater in castrated males than in female pigs, although digestibility values had no influence at the rectum site of animals (Ly 2008). Undoubtely, more research is needed in this direction.

Faecal output of microbial metabolites

As it is well known (Canibe and Bach Knudsen 2001; Wang et al 2004; Serena et al 2008), an enhanced microbial fermentation in caecum and colon of pigs should not be expected in the present investigation, due to the low level of fibre in the diet. In this connection, semi-purified diets given to pigs have determined very low concentrations of total SCFA in faeces of pigs (Sambrook 1979; Bardon and Fioramonti 1983). However, Varel et al 1984) found a lower concentration of SCFA in faeces from pigs fed high levels of fibre in the diet. On the other hand, when diets were manipulated to enhance microbial fermentation in the large intestine of pigs, SCFA concentration in pig faeces did not change in an outstanding manner (Leek et al 2004; Pierce et al 2006).

Values of faecal SCFA corresponding to the present examination were in the range of 30 to 40 mmol/100 g DM, are in accordance with previous data from this laboratory which were obtained with pigs fed diets based on glucose and torula yeast (Piloto and Ly 2001). On the other hand, an increase in SCFA output was observed in direct correspondence to the increase of the level of feed intake.

Varel et al (1984) reported higher values for ammonia concentration in faeces of pigs fed a fibrous diet containing alfalfa, as compared to other with a low level of fibre, approximately 17 and 5 mmol NH_3/100 g DM. In anyway these values are relatively lower than that recorded in the current study. Compared to SCFA, ammonia origin could be not only from bacterial activity in the hindgut, but endogenous urea secretion into the lumen of the large intestine (Biagi and Piva 2007). This rather complex status of resulting faecal ammonia could not be examined in the current investigation.

This experiment clearly showed that feed intake has a marked influence on faecal output in pigs. Implications derived from the present investigation could be useful not only from the point of view of pig nutrition, but also for achieving a friendly animal production from the angle of environmental conditions of pig husbandry.

Further studies of factors affecting faecal output of materials in pigs, underlying those fitted to tropical and local conditions for pig production, are suggested.

ACKOWLEDGMENTS

Technical personnel and especially O. Novo and Martha Carón are acknowledged for technical assistance in the stable and in the laboratory.

REFERENCES

AOAC. 2000. Official Methods of Analysis. Association of Official Analytical Chemists. Gaithersburg (Maryland), pp

Biagi, G. and Piva, A. 2007. In vitro effects of some organic acids on swine cecal microflora. Italian Journal of Animal Science, 6:361-374

Canh, T.T., Aarnink, A.J.A., Verstegen, M.W.A. and Schrama, J.W. 1998a. Influence of dietary factors on the pH and ammonia emission of slurry from growing finishing pigs. Journal of Animal Science, 76:1123-1130

Canh, T.T., Sutton. A., Aarnink, A.J.A., Verstegen, M.W.A., Schrama, J.W. and Bakker, G.C.M. 1998b. Dietary carbohydrates alter the fecal composition and pH and the ammonia emission from slurry of growing pigs. Journal of Animal Science, 76:1887-1895

Canh, T.T., Verstegen, M.W.A., Aarnink, A.J.A. and Schrama, J.W. 1997. Influence of dietary factors on nitrogen portioning and composition of urine and feces of fattening pigs. Journal of Animal Science, 75:700-706

Canibe, N. and Bach Knudse, K.E. 2002. Degradation and physichochemial changes of barley and pea fibre along the gastrointestinal tract of pigs. Journal of the Science of Food and Agriculture, 82::27-39

Cherbut, C., Barry, J.L., Wyers, M. and Delort-Laval, J. 1988. Effect of the nature of dietary fibre on transit time and faecal excretion in the growing pig. Animal Feed Science and Technology, 20:327-333

Cole, D.J.E. and Chadd, S.A. 1989. Voluntary food intake of growing pigs. In: The Voluntary Food Intake of Pigs (J.M. Forbes, M.A. Varley and T.L.J. Lawrence, editors). British Society of Animal Production No. 13. Edinburgh, p 61-70

Conway, E.B. 1957. Microdiffusion Analysis and Volumetric Error. Crosby, Lockwood Limited. London, pp 467

Eastwood, M.A. 1992. The physiological effect of dietary fiber: an update. Annual Review of Nutrition, 12:19-35

Galassi, G., Malagutti, L. and Crovetto, G.M. 2007. Growth and slaughter performance, nitrogen balance and ammonia emission from slurry in pigs fed high fibre diets. Italian Journal of Animal Science, 6:227-239

Harvey, W.R. 1990. User´s Guide for LSMLMW mixed model least square and maximum likelihood computer program (PC-2 version). Ohio State University Press. Columbus, pp 91

Hsia, L.C. and Lu, G.H. 1989. The effect of season, sex and breed on pig food intake and performance. In: The Voluntary Food Intake of Pigs (J.M. Forbes, M.A. Varley and T.L.J. Lawrence, editors). British Society of Animal Production No. 13. Edinburgh, p 119-120

Kerr, B.J. 2003. Dietary manipulation to reduce environmental impact. In: 9th International Symposium of Digestive Physiology in Pigs (R.O. Ball, editor). University of Alberta. Edmonton, p 139-158

Kyriazakis, I. and Emmans, G.C. 1995. The voluntary feed intake of pigs given feeds based on wheatbran, dried citrus pulp and grass meal in relation to measurements of feed bulk. British Journal of Nutrition, 73:191-207

Leek, A.B.G., Beattie, V.E. and O´Doherty, J.V. 2004. The effects of dietary oil inclusion and oil source on apparent digestibility, faecal volatile fatty acid concentration and manure ammonia emission. Animal Science, 79:155-164

Ly, J. 2008. Fisiología Digestiva en Cerdos (J. Ly y C. Lemus, editores). Universidad Autónoma de Nayarit. Tepic, pp 139

Ly, J., Novo, O., Plasencia, J.R. and Rosas, B. 1990. Nivel de consumo e índices digestivos de cerdos jóvenes alimentados con dietas de glucosa y harina de soya. Ciencia y Técnica en la Agricultura. Serie Ganado Porcino, 13(1):61-73

Ly, J., Pok Samkol, Grageola, F. and Lemus, C. 2008. Level of feed intake and digestibility in young pigs fed diets of glucose and soybean meal. Revista Computadorizada de Producción Porcina, 15:

Mroz, Z., Moeser, A.J., Vreman, K., Van Diepen, J.T,M., Van Kempen, T, Canh, T.T. and Jongbloed, A.W. 2000. Effect of dietary carbohydrates and buffering capacity on nutrient digestibility and manure characteristics in finishing pigs. Journal of Animal Science, 78:3096-3106

NRC. 1998. Nutrient Requerements of Domestic Animals. Nutrient Requirement of Swine. National Research Council. National Academy Press. Washington DC, pp 189

Noblet, J., Shi, X.S., Karege, C. and Dubois, S. 1993. Effects du type sexuel, du niveau d´alimentation, du poids vif et du stade physiologique sur l´utilisation digestive de l´energie et des nutriments chez le porc. Journées de la Recherche Porcine en France, 25:165-180

Nyachoti, C.M., Artnfield, S.D., Guenter, W., Cenkowski, S. and Opapeju, F.O. 2006. Effect of micronized pea and enzyme supplementation on nutrient utilization and manure output in growing pigs. Journal of Animal Science, 84:2150-2156

Oude, G., Mentink, A., Everts, J., Smits, B. and Jongbloed, A.W. 1986. Verteerbaarheid bij varkens in afhankelijkheid van een aantal faktoren: literatuuronderzoek en verslag van enkele proeven. Instituut voor Veevoedingsonderzoek (IVVO) Report No. 174, pp 81

Pennington, R.J. 1952. The metabolism of short chain fatty acids in the sheep. 1. Fatty acid utilization and ketone body production by rumen epithelium and other tissues. Biochemical Journal, 51:251-262

Pierce, K.M., Sweeney, T., Callan, J.J., Byrne, C., McCarthy, P. and O´Doherty, J.V. 2006. The effect of a high lactose supplement in finishing diets on nutrient digestibility, nitrogen excretion, volatile fatty acid concentrations and ammonia emission from boars. Animal Feed Science and Technology, 125:45-60

Piloto, J.L. and Ly, J. 2001. Nivel de consumo e indices digestivos en cerdos alimentados con dietas de glucosa y levadura torula. Revista Computadorizada de Producción Porcina, 8(1):45-54

Rayner, D.V. and Gregory, P.C. 1989. The role of the gastrointestinal tract in the contol of voluntary feed intake. In: The Voluntary Food Intake of Pigs (J.M. Forbes, M.A. Varley and T.L.J. Lawrence, editors). British Society of Animal Production No. 13. Edinburgh, p 27-39

Sambrook, I.E. 1979. Studies on digestion and absorption in the intestines of growing pigs. 8. Measurements of the flow of total lipids, acid-detergent fibre and volatile fatty acids. British Journal of Nutrition, 42:279.287

Serena, A., Jorgensen, H. and Bach Knudsen, K.E. 2008. Digestion of carbohydrates and utilization of energy in sows fed diets with contrasting levels and physicochemical properties of dietary fiber. Journal of Animal Science, 86:2208-2216

Steel, R.G.D., Torrie, J.H. and Dickey, M. 1997. Principles and Procedures of Statistics. A Biometrical Approach. McGraw and Hill Book Company In Company (segunda edición). New York, pp 666

Stephens, A.M. and Cummings, J.H. 1979. Water-holding by dietary fibre in vivo and its relationship to faecal output in man. Gut. 20:722-729

Van Keulen, J. y Young, S.A. 1977. Evaluation of acid insoluble ash a natural marker in ruminant digestibility studies. Journal of Animal Science, 44:262-266

Varel, V.H., Pond, W.G. and Yen, J.T. 1984. Influence of dietary fiber on the performance and cellulose activity of growing-finishing swine. Journal of Animal Science, 59:388-393

Wang, J.F., Zhu, Y.H., Li, D.F., Wang, M. and Jensen, B.B. 2004. Effect of type and level of dietary fibre and starch on ileal and faecal microbial activity and short-chain fatty acid concentrations in growing pigs. Animal Science, 78:109-117

Whittemore, C.T., Green, D.M. and Knap, P.W. 2001. Technical review of the energy and protein requirements of growing pigs: food intake. Animal Science, 73:3-17