DOI: 10.5216/cab.v13i3.14403

DIGESTIBILITY OF EXTRUDED SEMI-WHOLE SOYBEAN FOR PIGLETS IN THE INITIAL PHASE

MARIA CRISTINA THOMAZ[1], ANTONIO CARLOS SILVEIRA[2], RODOLFO NASCIMENTO KRONKA[1], SERGIO NASCIMENTO KRONKA[1], FÁBIO ENRIQUE LEMOS BUDIÑO[3]

[1]Professor, PhD, Faculty of Agricultural and Veterinary of Jaboticabal, Jaboticabal, SP, Brazil.
[2]Professor, PhD, Faculty of Veterinary Medicine and Animal Science, UNESP, Botucatu, SP, Brazil
[3]Researcher, PhD, Instituto de Zootecnia, Agência Paulista de Tecnologia dos Agronegócios, Nova Odessa, SP, Brazil. - fbudino@iz.sp.gov.br

ABSTRACT

Two assays were conducted to determine the digestibility coefficients (DC) and the digestible nutrients (DN) of the extruded semi-whole soybean (Assay 1 - conventional feeding and Assay 2 - feeding for sows, starting at 109 days of pregnancy and during the lactation and for lactating piglets and piglets in the initial phase, with rations without soybean meal). Each assay was divided into two phases (32 and 50 days of age). Eight piglets weaned at 25 days of age were used. Total feces collection method was used. The following variables were analyzed in feed and in feces: dry matter, crude protein, ether extract, crude fiber and gross energy. The following average values were obtained: DCDM - 88.87%; DCCP - 86.81%; DCEE - 85.41%; DCCF - 78.22%; DCGE - 80.21% and MCDE - 95.71%, which allowed the calculation of the digestible nutrients: DDM - 81.28%; DP - 34.49%; DEE - 14.02%; DF - 4.49%; DEa - 4087.86 kcal/kg and MEa - 3912.73 kcal/kg. The different coefficients of digestibility were not affected by the differential feeding for sows and piglets or by the different ages of the animals. Moreover, the extruded semi-whole soybean presented good levels of DN, concerning mainly the digestible and metabolizable energy.

KEYWORDS: protein sources; soybean; swine.

DIGESTIBILIDADE DA SOJA SEMI-INTEGRAL EXTRUSADA PARA LEITÕES NA FASE INICIAL

RESUMO

Com o objetivo de determinar os coeficientes de digestibilidade (CD) e os nutrientes digestíveis (ND) da soja semi-integral extrusada, foram conduzidos dois ensaios (Ensaio 1 - alimentação convencional e Ensaio 2 - alimentação das porcas a partir de 109 dias de prenhez, na lactação e dos leitões lactentes e na fase inicial, com rações sem farelo de soja), subdivididos, cada um, em duas fases (32 e 50 dias de idade). Foram utilizados oito leitões em cada fase, desmamados aos 25 dias de idade. Foi utilizado o método da coleta total de fezes. No alimento e nas fezes analisaram-se matéria seca, proteína bruta, extrato etéreo, fibra bruta e energia bruta. Os seguintes valores médios foram obtidos: CDMS - 88,87%; CDPB - 86,81%; CDEE - 85,41%; CDFB - 78,22%; CDEB - 80,21% e CMED - 95,71%, obtendo-se, assim, os valores médios para nutrientes digestíveis: MSD - 81,28%; PD - 34,49%; EED - 14,02%; FD - 4,49%; EDa - 4087,86 kcal/kg e EMa - 3912,73 kcal/kg. Os CD não foram afetados pela alimentação diferenciada das porcas e dos leitões ou pelas diferentes idades dos animais. Além disso, a soja semi-integral extrusada apresentou bons níveis de ND, principalmente no que se refere às energias digestível e metabolizável.

PALAVRAS-CHAVE: fontes proteicas; soja; suínos.

INTRODUCTION

The small growth of piglets, particularly those weaned at four weeks of age or less is associated with low food intake and low digestibility of energy and protein, which frequently results in an energy deficit with body fat loss after weaning. This happens because the digestive system of piglets is not yet fully developed, and therefore it is unable to adequately digest the ingredients that usually make up the ration, especially those of plant origin (BERTOL et al., 2001). For this reason, the incorporation of dairy products to the rations for weanling piglets has resulted in weight gain and better feed conversion, suggesting, thus, better digestibility. However, due to the high cost of these products, alternative replacements that do not affect performance and the use of nutrients are being studied (SOHN et al., 1994).

Restrictions on protein sources of animal origin in animal nutrition by the international market and, to a lesser extent, by the internal market, generated extra demand of soybean meal. The soybean, as a vegetable with high levels of protein and energy, constitutes a good protein alternative with about 17% to 18% oil and 35% to 37% crude protein of high biological value, and with a composition of essential amino acid favorable for feeding poultry and pigs (BELLAVER et al., 2002). The extruded semi-whole soybean, as a result of the process of partial extraction of oil, shows 9.0% to 10.0% ether extract and 44% to 46% crude protein, and may be used as a protein-energy supplement in the formulation of feed (CASTILLO et al. 2001).

Since it is known that soybean meal, the main protein source in diets for pigs, causes digestive problems to weanling pigs, and is poor in oil (less than 1%), fat sources have been frequently added, because it is not possible to meet the requirements of animals otherwise (TURLINGTON et al., 1990). However, the results of the addition of fat to the diets for piglets are conflicting. ATTEH & LEESON (1983) observed increases in weight gain and better feed conversion, while CERA et al. (1988b) found contrary results. These differences may be the result of some factors that influence the animals' response to the addition of fat, such as: the interference of one fatty acid absorption with another, the melting point, energy:amino acids relation, age of piglets and type or concentration of added fat (CERA et al., 1988a).

Therefore, both the whole grain or the semi-whole soybean emerged as alternatives, because, besides being an excellent source of protein and increasing the energy content of the diet, they eliminate the cost of extracting the oil. However, the digestibility of the extracted oil is higher, considering that the unextracted oil is encapsulated in the cell membrane, making it less susceptible to digestion (ADAMS & JENSEN, 1984).

Although raw soybean shows high oil content, it is rich in anti-nutritional factors, which prevent their use, especially for monogastric animals (BERTOL et al., 2001).

MOREIRA et al. (1994) stated that it is important to consider that the types (extrusion, micronization, roasting or jet sploder) and the parameters (temperature, humidity, pressure and heating time) of the processing influence the nutritional value of soybean, and the age of the piglet has an effect on the energy value of the ingredient.

Thus, two experiments were conducted aiming at determining the digestibility coefficients and the digestible nutrients of semi-whole extruded soybean for piglets at different ages in the initial stage and raised until weaning with or without contact with the soybean meal.

MATERIAL AND METHODS

We conducted two trials in the Swine Sector of the Animal Science Department, Faculty of Agriculture and Veterinary Sciences, UNESP / Jaboticabal. In each experiment, we used eight crossbred (Landrace x Large White) barrows weaned at 25 days of age. Both trials were divided into two phases. The first phase started when the animals were 32 days old (mean weight of 9.3 kg) and the second one when the same animals were 50 days old (mean weight of 12.7 kg).

The trials were conducted at the digestibility unit, which was closed by 1.80-m-high masonry walls, and had the remaining space (0.70 m) protected by a plastic curtain. There were eight metabolism cages similar to those described by PEKAS (1968).

In the first trial, the suckling piglets were fed the same diet offered to the sow (with soybean meal in the composition). Soon after weaning, they received the

control diet, which also contained soybean meal (Table 1). The same diet was used as a reference in both phases, at 32 and 50 days of age. The animals were housed in metabolic cages for 12 days in each trial, being the first seven for adaptation to cages and feed and the remaining five for feces and urine collection.

In both phases, extruded semi-whole soybean (ESWS) replaced 30% of basal diet, on a fresh matter basis, formulated to meet the requirements of the animals in the period (NRC, 1998), constituting the "test" diet. Four pigs received the basal diet and the other four, the test diet. The results of the analysis of chemical composition and the energy values of reference, test and ESWS diets are shown in Table 2.

The diets were offered ad libitum in two meals daily (8:00 a.m. and 4:00 p.m), and the total amount, determined in accordance with the intake in the adaptation phase, based on metabolic weight ($kg^{0.75}$). After each meal, the water was supplied in the same place as the feed, on a basis of 3 mL / g of food ingested.

We used the total collection method for feces, adding 2% ferric oxide (Fe_2O_3) to the feed as a fecal marker to define the beginning and the end of the collection.

Table 1 - Composition percentage and calculated values of the diets used in trials 1 and 2

Ingredients	Reference Diet		DM [1]
	Trial 1	Trial 2	Trial 2
Corn	66.02	54.71	66.26
Soybean meal	21.19	-	-
Skimmed milk powder	-	23.87	-
Whey	-	7.66	-
Gluten	-	4.00	-
Dry yeast	-	7.00	-
Wheat meal	-	-	13.80
Extruded whole soybean	-	-	13.13
Meat meal	3. 50	-	5.35%
Fish meal	3.00	-	-
Dicalcium phosphate	0.06	0.82	-
Limestone	0.13	0.72	0.49%
Mineral supplement [2]	0.24	0.24	0.24
Vitamin supplement [2]	0.40	0.40	0.22%
Salt	0.50	0.50	0.50
Antioxidant (BHT)	0,01	0,01	0,01
Sugar	3.00	-	-
Soybean oil	1.81	-	-
L-Lysine.HCl (78%)	0,14	0.07	-
* Calculated values			
Digestible energy (kcal / kg)	-	3471.79	-
Metabolizable energy (kcal / kg)	3272.57	-	3206.15
Crude protein	18.14	18.21	15.43
Lysine (%)	1.03	1.03	0.82
Calcium (%)	0.75	0.75	0.91
Total phosphorus (%)	0.65	0.65	0.71

[1] Diet for matrices, offered from 109 days of pregnancy until weaning, with access of suckling piglets used in the second trial;
[2] Vitamin Supplement - warranty levels per kg of product: vit A - 4,000,000 UI; vit D-3 - 1,000,000 UI; vit E - 10,000 mg; vit K-3 - 3000 mg; vit B_{12} - 9.000 µg; vit B_2 - 3.800 mg; biotin - 40 mg; calcium pantothenate - 6.000 mg; niacin - 14,000 mg; choline - 100 g; antibiotic - 150 g; antioxidant - 60g; vehicle qsp - 1000g. Mineral supplement - warranty levels per kg of product: iron - 40,000 mg; copper - 35,000 mg; manganese - 20.000 mg; zinc - 40.000 mg; cobalt - 360 mg; iodine - 840 mg; selenium - 120 mg; vehicle qsp - 1000 g.

Urine was collected in plastic buckets containing 20 mL of HCl (12N) 1:1 to avoid nitrogen loss and bacterial proliferation. These buckets were placed under the collection funnel of the cage, which was covered with glass wool to retain impurities such as fecal waste, feed and animal bristles. We collected samples every day at 7:00 a.m., by taking the contents of the bucket to a beaker and completing the volume to 2 liters with distilled water, constant value for all animals in both phases. The content of the beaker was homogenized and a 200 mL aliquot was withdrawn and placed in plastic bottles appropriately identified and kept in a refrigerator (3-4 ° C) for later laboratory analysis. We collected the total feces produced per animal every day at 8:15 a.m, in labeled plastic bags, and stored them at -18 ºC.

Table 2 - Chemical composition and energy values of reference (RD), test and ESWS diets used in trials 1 and 2

	Rations				
Nutrients	Trial 1		Trial 2		ESWS
	RD	Test	RD	Test	
Dry matter	89.21	90.23	89.48	90.11	91.46
Crude protein	18.39	26.39	18.22	23.89	39.72
Mineral matter (%)	5.46	5.03	5.08	5.18	5.12%
Ether extract (%)	5/32	8.78	3. 13	6.78	16.41
Crude fiber (%)	3.68	4.55%	2.55	3.98	6.31
Gross energy (kcal / kg)	4032.10	4448.90	3802.40	4147.60	5097.10

After the collection period, a sample (300 g) of feces was homogenized, weighed and placed in an oven with forced air circulation at 55 ºC for 48h. After drying and balancing moisture with the environment, the samples were weighed again, ground and sent for analysis. As for urine, 50 ml were withdrawn from each sample, placed in petri dishes and placed in an oven with forced ventilation and temperature of 50 °C for 24h. After this period, we added 50 ml, returning the samples to the oven for another 24 hours; the material was dried, and then sent to the laboratory.

Dry matter, crude protein, ether extract, crude fiber, ash and gross energy were analyzed in feces and food. Gross energy was analyzed in urine.

The digestibility coefficient of dry matter (DCDM); digestibility coefficient of crude protein (DCCP); digestibility coefficient of ether extract (DCEE); digestibility coefficient of crude fiber (DCCF); digestibility coefficient of gross energy (DCGE), and metabolizability coefficient of digestible energy (MCDE), which allowed the calculation of digestible nutrients, were obtained according to the method of MATTERSON et al. (1965).

The methodology used in trial 2 was identical to the one used in trial 1, differing only in the fact that the sows, from 109 days of pregnancy on, during lactation, and the suckling piglets were fed diet without soymeal (Table 1). During the pre-starter phase, the piglets were fed the same diet as the sows. This feeding practice, differentiated from the end of the pregnancy on, was intended to limit the passive transfer of anti-soy antibodies to piglets through colostrum (LI et al., 1991). in the initial phase, the animals received ration without soybean meal (Table 1), which was the same diet used as reference in trial phases. The chemical composition and reference energy values, and both test and ESWS diets are shown in Table 2.

In this assay, animals were housed in cages at 32 days of age (mean weight of 10.0 kg) in the first phase, and at 50 days of age (mean weight of 12.8 kg) in the second phase.

The experimental design for both trials was completely randomized in a 2 x 2 factorial arrangement (2 trials x 2 phases), with 4 replicates. The analyses were performed according to STEEL & TORRIE (1980).

For statistical analyses we used the following mathematical model:

$Yij = \mu \alpha + i + j + \beta (\alpha \beta) ij + eij$

Where:

Yij = observed value for the experiment i in phase j;

μ = overall mean;

I = α end of the experiment (i = 1 and 2);

J = β effect of the phase j (j = 1 and 2);

($\alpha \beta$) ij = effect of interaction between experiment phase i and j;

eij = random effect.

RESULTS AND DISCUSSION

The results for DC of the nutrients of extruded semi-whole soybean (ESWS) in different experiments and phases are shown in Table 3 while the results of the analyses of variance are displayed in Table 4.

We observed that for the animals in the Trial 1, the DCDM (87.42%) was lower ($P < 0.01$) than that of Trial 2 (90.31%), while we verified no effect ($P > 0.05$) of the phases (Table 4), suggesting that these results were affected in fact by the withdrawal of soybean meal from the ration for the sows and piglets and not by the age of the animals. The mean value of DCDM (Table 3) obtained in these trials (88.87%) for animals at 32 or 50 days of age was lower than the results found by HANCOCK et al. (1990), 89.30%, and by FRIESEN et al. (1993), 90.30%, who studied piglets at 35 days of age. The value was greater, however, than 83.30% (HANCOCK et al. 1,991) and 84.10% (ENRIGHT et al. 1993) for piglets at 35 days of age, and 85.70% (HENRIQUE et al., 1997) for piglets at 47 days of age. MOREIRA et al. (1994) worked with piglets at 21 days and three types of extruded whole soybeans (A, B and C), and verified DCDM of 83.50%, 90.81% and 91.57%, respectively. More recently, MENDES et al (2004) observed that the DCDM of ESWS was 81.85% for pigs within the range of 38 kg.

Table 3 - Digestibility coefficients (DC %) and metabolization coefficient (MC) of ESWS in different trials and phases

DC	Trial 1			Trial 2			
	Phase 1 [(1)]	Phase 2 [(2)]	Mean	Phase 1 [(1)]	Phase 2 [(2)]	Mean	Overall mean
DM	86.52	88.32	87.42	89.80	90.82	90.31	88.87
CP	87.29	88.22	87.76	85.73	86.00	85.86	86.81
EE	84.52	86.23	85.38	84.40	86.47	85.44	85.41
CF	77.09	79.47	78.28	78.01	78.28	78.15	78.22
EB	77.74	79.05	78.40	82.58	81.43	82.01	80.21
MCDE	94.52	96.52	95.52	95.89	95.90	95.90	95.71

[(1)] 32 days of age.

[(2)] 50 days of age.

Table 4 - Results of analyses of variance for the DC (%) and MC (%) of ESWS nutrients

Factors	DM	CP	EE	CF	GE	DE [(1)]
Trial (T) 1	B 87.42 [(2)]	87.76 to	85.38 to	78.28 to	78.40 b	95.52 to
Trial (T) 2	90.31 to	85.86 b	85.44 to	78.15 to	82.01 to	95.90 to
Phase (P) 1 [(3)]	88.16 to	86.51 to	84,46 b	77.55 to	80.16 to	95.21 to
Phase (P) 2	89.57 to	87.11 to	86.35 to	78.88 to	80.24 to	96.21 to
F test:						
T	9.45 **	11.38	0.01 [ns]	0.27 [ns]	25.50 **	0.37 [ns]
P	2.26 [ns]	1.16 [ns]	9.41 **	2.54 [ns]	0.12 [ns]	2.63 [ns]
T x P	0.17 [ns]	0.35 [ns]	0.88 [ns]	1.62 [ns]	2.95 [ns]	2.60 [ns]
CV (%)	2.11	1. 29	1.44	2.12.	1.78	1. 29

[(1)] Metabolizability coefficient;

[(2)] Within each factor (T or P), means followed by the same letter in the column do not differ by F-test ($P > 0.05$);

[(3)] Mean of two experiments.

The results obtained for DCCP (Table 4) for the animals of Trial 1 (87.76%) was higher (P <0.01) than those observed in Trial 2 (85.86%), demonstrating that the change in the ration for sows and piglets influenced negatively the protein digestibility of ESWS. This may be explained because these piglets did not receive soybean meal in the diet (Table 1) during the whole period of the experiments, thus they did not show adaptation of the enzyme system to protein hydrolysis of the product. We would have expected a different response if the piglets were adapted to soybean protein, because the protein denaturation, assigned to the extrusion process, increases their susceptibility to enzymatic hydrolysis (MENDES et al. 2004).

Regarding age, there was no difference (P> .05). The mean result for DCCP (86.81%) obtained from the trials (Table 3) was higher than 80.60% for piglets at 35 days (HANCOCK et al. 1991), 84.25% for piglets at 21 days of age (MOREIRA et al. 1,994), and 85.90% for piglets with 4.7 kg (ENRIGHT et al. 1993), which is very similar to 86.80% for piglets with 16.9 kg (ADAMS & JENSEN, 1985), and 86.12% for piglets with 38 kg (MENDES et al. 2004). However, it was lower than 89.00% for piglets at 35 days (FRIESEN et al. 1993), and 87.32% for piglets at 47 days (HENRIQUE et al. 1997).

As for DCEE, we observed contrary response to the ones verified for the two nutrients previously discussed, i.e., there was no difference (P> 0.05) between trials 1 and 2 (Table 4), demonstrating that differentiated feed for sows and piglets did not influence this nutrient digestion. We found, however, significant effect (P <0.01) for the phases, indicating that the oil digestibility was better at 50 days of age (86.35%) than at 32 days of age (84,46%). These results agreed with those observed by CERA et al. (1988c), who verified an increase in ether extract digestibility with the aging of the piglets. TOKACH et al. (1989) observed a positive effect of adding oil to feed only from the third week after weaning. The mean value of DCEE (85.41%) obtained in these trials (Table 3) was greater than that observed by LI et al. (1990) for extracted soybean oil (80.10%), indicating that the extrusion process made the oil contained in the soybeans very digestible for piglets. It was also higher than the values observed for extruded soybean B (76.98%), verified by MOREIRA et al. (1994) for piglets at 21 days, and by MENDES et al. (2004), who found value of 81.48% for ESWS for pigs with 37 kg. Similar value was found by MOREIRA et al. (1994) for soybean A (85.50%). Higher coefficients, however, were obtained by MOREIRA et al. (1994) with soybean C (96.37%), and by HENRIQUE et al. (1997), who studied piglets at 47 days of age (98.78%).

We observed (Table 4) that neither the differentiated rations for sows and piglets (Trials) nor did the different ages (phases) affect DCCF (P > 0.05). The mean value observed (78.22%) in the trials (Table 3) was lower than the values of 84.41% and 81.78%, obtained by MOREIRA et al. (1994) for extruded soybean A and B, respectively, for piglets at 21 days of age, and lower than the mean of 80.14% found by HENRIQUE et al. (1997) for piglets at 47 days of age. The mean was greater, however, than 73.20% (extruded soybean C) obtained by MOREIRA et al. (1994).

As for DCGE, we observed that it was higher (P <0.01) for the animals in Trial 2 (82.01%) compared with those in Trial 1 (78.48% - Table 4), indicating that the use of energy of the diet was higher for animals fed different diets. The age, however, did not affect (P> 0.05) this parameter. The mean value (80.21% - Table 3) was lower than 81.95%, 86.87% and 91.06% (soybeans A, B and C, respectively) for piglets at 21 days of age (MOREIRA et al. 1994), 86.19% for piglets at 47 days of age (HENRIQUE et al. 1997), and 83.59% for piglets with 37 kg (MENDES et al. 2004). The low DCGE obtained for the soybean studied can be due to the crude fiber content (6.31%), since it is known that every 1.00% increase in dietary fiber level decreases 3.50 % of gross energy digestibility (NRC, 1998). MOREIRA et al. (1994) observed 6.07% crude fiber in extruded soybean A, which showed lower DCGE (81.95%) than soybean B and C. MENDES et al. (2004) observed value of 9.10% CF in the ESWS.

Regarding MCDE, there was no effect (P>

0.05) for experiments or phases (Table 4), indicating that neither age nor differentiated feed influenced this parameter. The mean value observed (Table 3) in the trials (95.71%) was lower than the 96.53% found by HENRIQUE et al. (1997), although it was within the limits (94.00% to 97.00%) cited by the NRC (1998).

Based on the results shown in Tables 2 and 3, we calculated the values of digestible dry matter (DDM), digestible protein (DP), digestible ether extract (DEE), digestible fiber (DF), apparent digestible energy (ADE) and apparent metabolizable energy (AME) (Table 5).

It is noteworthy that the extruded semi-whole soybean has 16.41% ether extract against 18.00% to 20.00% of the whole soybean, and almost all authors previously mentioned worked with the whole grain, except MOREIRA et al. (1994) who, studying the extruded soybean B, found 15.58% of EE. However, they used the reference diet containing soybean meal, which allowed comparing the values for digestible nutrients only in Trial 1, Mean 1. Therefore, we found that the values obtained in this experiment (Table 5) for DDM (79.96%), DF (4.94%), ADE (3995.84 kcal / kg) and AME (3817.16 kcal / kg) were lower than 80.47%; 5.42%, 4240.00 kcal / kg, and 3898.00 kcal / kg, respectively, while higher values were obtained for DP (34.86%) and DEE (14.01 %) compared with those values (33.80% and 12.10%, respectively) found by MOREIRA et al.(1994).

Table 5 - Digestible nutrients (DN) of ESWS

DN	Trial 1			Trial 2			
	Phase 1 [(1)]	Phase 2 [(2)]	Mean	Phase 1 [(1)]	Phase 2 [(2)]	Mean	Overall mean
DDM (%)	79.13	80.78	79.96	82.13	83.06	82.60	81.28
DP (%)	34.67	35.04	34.86	34.05	34.16	34.11	34.49
DEE (%)	13.87	14,15	14.01	13.85	14.19	14.02	14.02
DF (%)	4.86	5.01	4.94	4.92	4.94	4.93	4.94
ADE (kcal / kg)	3962.41	4029.26	3995.84	4209.19	4150.57	4179.88	4087.86
AME (kcal / kg)	3745.27	3889.04	3817.17	4036.19	3980.40	4008.30	3912.73

[(1)] 32 days of age.
[(2)] 50 days of age.

CONCLUSIONS

In general, the differential feed for sows and piglets or the age of the animals did not interfere decisively in the digestibility of extruded semi-whole soybeans.

The use of this product proved to be of great viability in the rations for piglets, regarding mainly the energy content, with high levels of digestible and metabolizable energy compared with soybean meal.

REFERENCES

ADAMS, K.L.; JENSEN, A.H. Comparative utilization of in-seed fats and the respective extracted fats by the young pig. **Journal Animal Science**, v. 59, p. 1557-1566, 1984.

ATTEH, J.O.; LEESON, S. Effect of increasing dietary fat, calcium and phosphorus levels on pigs. **Canadian Journal Animal Science**, v. 63, p. 699-705, 1983.

BELLAVER, C.; COTREFAL, G.; GRECCO, M. Soja integral: processamento e uso. **Alimento Animal**, v.7, p.28-30, 2002.

BERTOL, T.M.; MORES, N.; LUDKE, J.V.; FRANKE, M.R. Proteínas da soja processadas de diferentes modos em dietas para desmame de leitões. **Revista Brasileira de Zootecnia**, v. 30, n.1, p. 150-157, 2001.

CASTILLO, W.L.; KRONKA, R.N.; BARBOSA, H.P.; THOMAZ, M.C.; GOMES DA SILVA, L.P.; RIBEIRO, P.R.; CARVALHO, L.E.; TRINDADE NETO, M.A. Efeito da utilização da soja semi-integral extrusada sobre o desempenho e as características das carcaças de suínos. **ARS Veterinária**, v.17, n.2, p.137-143, 2001.

CERA, K.R.; MAHAN, D.C.; CROSS, R.F.; REINHART, G. A.; Whitmoyer, R. E. Effect of age, weaning and postweaning diet on small intestinal growth and jejunal

morphology in young swine. **Journal Animal Science**, v. 66, p. 574-584, 1988a.

CERA, K.R.; MAHAN, D.C.; REINHART, G.A. Effect of dietary dried whey and corn oil on weaning pig performance, fat digestibility and nitrogen utilization. **Journal Animal Science**, Champaign, v. 66, p. 1438-1445, 1988b.

CERA, K.R.; MAHAN, D.C.; REINHART, G.A. Weekly digestibility of diets supplemented with corn oil, lard or tallow by weanling swine. **Journal Animal Science**, v. 66, p. 1430-1437, 1988c.

ENRIGHT, K.L.; KIM, I.; HANCOCK, J.D.; REDY, P.G.; KENNEDY, G. A.; HINES, R. H. Nutrient digestibility and utilization in extruded and low-trypsin inhibitor soybeans for weanling pigs. **Journal Animal Science**, v. 71 (Suppl. 1), p. 157, 1993.

FRIESEN, K.G.,; NELSSEN, J.L.; GOODBAND, R.D.; BEHNKE, K.C.; KATS, L.J. The effect of moist extrusion of soy products on growth performance and nutrient utilization in the early-weaned pig. **Journal Animal Science**, v. 71, p. 2099-2109, 1993.

HANCOCK, J.D.; LEWIS, A.J.; JONES, D.B.; GIESEMANN, M.A.; HEALY, B.J. Processing method affects the nutritional value of low-inhibitor soybeans for nursery pigs. Kansas: Kansas State University. **Swine Day Report**, p. 52-55, 1990.

HANCOCK, J.D.; LEWIS, A.J.; REDDY, P.G.; JONES, D.B.; GIESEMANN, M.A. Extrusion processing of low-inhibitor soybeans improves growth performance of nursery pigs fed protein-adequate diets. Kansas: Kansas State University. **Swine Day Report**, p. 40-43, 1991.

HENRIQUE, A.P.F.; THOMAZ, M.C.; KRONKA, R.N. Digestibilidade da soja integral extrusada para leitões na fase inicial. **ARS Veterinária**, v. 13, p. 68-74, 1997.

LI, D.F.; THALER, R.C.; NELSSEN, J.L.; HARMON, D.L.; ALLEE, G. L.; WEEDEN, T.L. Effect of fat sources and combinations on starter pig performance, nutrient digestibility and intestinal morphology. **Journal Animal Science**, v. 68, p. 3694-3704, 1990.

MATTERSON, L.D.; POTTER, L.M.; STUTZ, M.W. The metabolizable energy of feed ingredients for chickens. **Research Report,** v. 7, p. 3-11, 1965.

MENDES, W.S.; SILVA, I.J.; FONTES, D.O.; RODRIGUEZ, N. M.; MARINHO, P. C.; SILVA, F. O.; AROUCA, C. L. C.; SILVA, F. C. O. Composição química e valor nutritivo da soja crua e submetida a diferentes processamentos térmicos para suínos em crescimento. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia,** v.56, n.2, p.207-213, 2004.

MOREIRA, I.; ROSTAGNO, H.S.; COELHO, D.T.; COSTA, P. M. A.; TAFURI, M. L. Determinação dos coeficientes de digestibilidade, valores energéticos e índices de controle de qualidade do milho e soja integral processados a calor. **Revista da Sociedade Brasileira de Zootecnia**, v. 23, p. 916-929, 1994.

NATIONAL RESEARCH COUNCIL. **Nutrient Requirement of Swine**. 10.ed. Washington,DC: National Academic Science, 1998. 189 p.

PEKAS, J. Versatile swine laboratory apparatus for physiologic and metabolic studies. **Journal Animal Science**, v. 27, p. 1303-1306, 1968.

SOHN, K.S.; MAXWELL, C.V.; SOUTHERN, L.L.; BUCHANAN, D S. Improved soybean protein sources for early-weaned pigs. II: Effects on ileal amino acid digestibility. **Journal Animal Science**, v. 72, p. 631-637, 1994.

STEEL, R.G.D.; TORRIE, J.H. **Principles and procedures of statistics**. 2 ed. Nova York, McGraw Hill, 1980. 633p.

TOKACH, M.D.; CORNELIUS, S.G.; RUST, J.W. The appropriate level of fat addition to high milk product diets for the early weaned pigs. **Journal Animal Science**, v. 67 (Suppl. 1), p. 231, 1989.

TURLINGTON, W.H.; POLLMANN, D.S.; ENDRES, J.G.; COALSON, J.A. Soy protein concentrates: An alternative to milk proteins. **Feedstuffs**, n.3, p. 16-18, 1990.

Submitted on May, 18, 2011. Acccepted on June, 29, 2012.