Method of using increasing levels of substitution of the basal diet by test feedstuffs in pig digestibility trials

[*Metodologia de uso de níveis crescentes de substituição da ração referência pelo alimento teste em ensaios de digestibilidade com suínos*]

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ABSTRACT

Two experiments were carried out to study the methodology of using increasing levels of substitution of the basal diet with fibrous test feedstuffs (sticky coffee hull - SCH) in digestibility trials with pigs. In Experiment 1, a digestibility trial was conducted using 30 crossbred barrows, allotted in a randomized block design. In Experiment 2, 42 growing and 42 finishing pigs were used, allotted in a completely randomized design, with six diets and seven replicates, with one animal per experimental unit. The six diets consisted of: a control diet, four diets using SCH ME values as obtained in Experiment 1 plus a diet using SCH ME value estimated by linear regression equation for 15% substitution. The digestibility study indicated that the use of increasing levels of substitution (7, 14, 21 and 28%) reduced SCH digestibility. ME values, as-fed basis, were 2,456, 2,377, 2,247 and 1,945kcal/kg. The overall results indicate that higher levels of substitution overestimate the energy value and that the method of increasing levels of substitution of the basal diet with feedstuffs test can be used to more accurately estimate the energy values of fibrous feedstuffs for pigs. For growing and finishing pigs respectively, up to 28% and 15% of sticky coffee hull can be used without impairing pig performance and economic feasibility.

Keywords: carcass traits, fibrous feedstuffs, nutritional value, performance

RESUMO

Dois experimentos foram realizados para se estudar a metodologia de uso de porcentagens crescentes de substituição da ração referência pelo alimento teste fibroso (casca de café melosa − CCM), em ensaios de digestibilidade com suínos. No Experimento I, foi realizado um ensaio de digestibilidade utilizando 30 machos castrados, distribuídos em delineamento de blocos ao acaso. No Experimento II, foram utilizados 42 suínos na fase de crescimento e 42 suínos na fase de terminação, distribuídos em delineamento inteiramente ao acaso, com seis rações, sete repetições e um animal por unidade experimental. As seis rações foram: uma ração controle, quatro rações usando os valores de energia metabolizável (EM) da CCM obtidos no Experimento I e uma ração com EM da CCM estimada por equação de regressão linear para 15% de substituição. Os estudos de digestibilidade indicaram que o uso de porcentagens crescentes de substituição − 7, 14, 21 e 28% − reduziu a digestibilidade da CCM. Os valores de EM, na matéria natural, obtidos para a CCM foram 2.456, 2.377, 2.247 e 1.945kcal/kg. Os resultados indicam que porcentagens mais elevadas de substituição superestimam o valor energético e que a crescente substituição da ração referência pelo alimento teste pode ser utilizada para estimar, de forma mais precisa, os valores energéticos de alimentos fibrosos para suínos. Para suínos em crescimento e em terminação, pode-se usar, respectivamente, até 28% e 15% de casca de café melosa sem prejudicar o desempenho e a viabilidade econômica.

Palavras-chave: alimento fibroso, característica de carcaça, desempenho, valor nutricional

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INTRODUCTION

Feeding represents the largest share of production costs in swine breeding. Consequently, there is great interest in the use of alternative ingredients, such as fibers, in order to achieve good productive performance while reducing costs. Dietary fiber is considered an alternative source of energy in pigs diets (Gomes *et al*., 2007). Although it reduces the digestibility of most nutritional components, it can be included in corn-based diets, resulting in adequate weight gain and satisfactory yield in lean meat, leading to improvements in carcass quality.

Traditionally, digestibility trials with pigs use only a single level of substitution of a test feedstuff for the basal diet (Sakomura and Rostagno, 2007). According to Nascimento *et al*. (2005), one factor that can influence the variation found in nutrient digestibility values is precisely the rate of substitution of the basal diet by the test feedstuff. To Adeola (2001), at least two levels of substitution of a basal diet component by a given test feedstuff should be used to estimate digestibility. This could be done by applying a digestibility regression of the components substituted at the different levels and extrapolating to 100% substitution. There is a risk in extrapolating the levels tested outside the substitution interval, and the errors associated are inversely related to the level of basal diet substituted by the test feedstuff. One solution would be to use several different levels of basal diet substitution and analyze the results using simple or multiple regression to estimate the parameters of desired energy contents (Villamide *et al*., 1998).

In digestibility studies, the method of using increasing levels of substitution of the basal diet by a test feedstuff consists of using the test feedstuff mixed in ever-higher levels to a basal diet calculated according to the requirements established for the animal species in question (Villamide, 1996). It is expected that this method will improve the energy values estimates of diets.

This work aimed to evaluate the method of substitution increasing levels of the basal diet by a test feedstuff on the nutrient digestibility and energy value of sticky coffee hull (SCH) (fibrous feedstuff) for growing-finishing pigs, as well as validate the metabolizable energy values obtained from a performance experiment.

MATERIAL AND METHODS

The sticky coffee hulls (chosen as the fibrous feedstuff) were ground in a hammer mill using a 4mm screen size. The composition of SCH was as follows: 9.3% crude protein (CP); 3,734 kcal of gross energy/kg; 18.86% crude fiber (CF); 31.5% neutral detergent fiber (NDF); 25.4% acid detergent fiber (ADF); 0.31% calcium (Ca); 0.07% total phosphorus (tP); and a geometric mean diameter (GMD) of 1,533mm. The analyses of dry matter, organic matter, ash, CP, CF, NDF, ADF, Ca and tP were performed according to the methods described by Silva and Queiroz (2002). Particle size analyses were performed according to the method proposed by Zanotto and Bellaver (1996).

In Experiment 1 a digestibility trial was conducted using 30 commercial-line castrated male pigs, with 72.48±7.16kg initial body weight. The animals were individually penned in metabolism cages similar to those described by Pekas (1968) in a partially climate-controlled facility. Using the method of substitution increasing levels of the basal diet by a test feedstuff, according to Villamide (1996), four different diets were formulated with four levels of substitution (7%, 14%, 21% and 28%) of the basal diet (BD). SCH substituted, based on dry matter. The BD, based on corn and soybean meal, was calculated to meet the requirements indicated by the NRC (1998). In total, five diets were used: BD; BD (93%) + SCH (7%); BD (86%) + SCH (14%); BD (79%) + SCH (21%) and BD (72%) + SCH (28%).

Collection periods lasting 15 days, being 10 days for acclimation and five days for total feces and urine collection. The experimental design consisted of randomized blocks, with four diets, six replicates, and the experimental unit consisting of one pig. Feedings were at 8AM and at 4PM. To mark the beginning and end of each period of total feces collection, Fe_3O_2 2% was used as a fecal marker. Samples were collected once a day, conditioned in plastic bags and stored at -18°C.

The study obtained the digestibility coefficients (one for each level of substitution) of dry matter

(DCDM), gross energy (DCGE), organic matter (DCOM), crude protein (DCCP), neutral detergent fiber (DCNDF), acid detergent fiber (DCADF), crude fiber (DCCF) and metabolization coefficient of gross energy (MCGE) of SCH, according to Moreira *et al.* (1994). Next, the values were calculated for DDM, DE, ME, DOM, DCP, DNDF, DADF and DCF, according to Matterson *et al.* (1965). The remaining experimental procedures were performed according to Fialho *et al.* (1979).

The digestibility coefficients were submitted to polynomial regression analysis, as suggested by Villamide (1996), using SAEG software (Sistema..., 1997), according to the following statistical model: $Y_{ijk}= \mu+b1 (Ni–N)+b2 (Ni–N)+Bj+eijk$, in which: $Y_{ijk}=$ observed value of the studied variables, relative to each individual *j*, receiving level *i* of feedstuff substitution, $\mu=$ overall constant; $b1=$ linear regression coefficient of the level of substitution on variable *Y*; $b2 =$ quadratic regression coefficient of the level of substitution on variable *Y*; $Ni =$ levels of substitution in the diets, with $i = 7, 14, 21$ and 28%; $N =$ mean levels of substitution in the diets; $Bj =$ block effect on variable *Y*; $eijk=$ random error associated with each observation.

Experiment 2 was a performance assay using 42 crossbred, commercial-line growing pigs with 30.27 ± 1.95kg initial body weight and 60.00 ± 4.49kg final weight, and 42 finishing pigs with 60.02 ± 4.10kg initial body weight and 89.76 ± 8.89kg final weight.

Average minimum temperatures during the experimental periods were 17.9 ± 3.7ºC and 21.5 ± 4.6ºC, and maximum temperatures were 30.0 ± 5.5ºC and 30.2 ± 5.2ºC, respectively. Relative air humidity averages during growing and finishing stages stood at $38.5\pm16,0\%$ and $71.3\pm15.2\%$ in the morning and $40.2\pm16,0\%$ and $64.8\pm17.6\%$ in the afternoon, respectively.

Treatments consisted of six diets (Tables 1 and 2): one control diet, four diets formulated using the ME values of SCH (2,456, 2,377, 2,247 and 1,945kcal ME/kg), obtained with the different

levels of substitution (7, 14, 21 and 28%) of BD by the test feedstuff (SCH), respectively; and one diet using a ME value of 2,316kcal ME/kg, estimated for 15% substitution of SCH. In order to reach the estimate value of 2,316kcal ME/kg, initially a linear equation was obtained through a regression of ME values, in function of the levels of substitution. Once the equation was obtained, $ME_{15\%} = 2,672 – 23,757X$, the value of ME was estimated for $X = 15\%$. Likewise, ME was estimated for 100% substitution, according to Villamide (1996) and Adeola (2001), which resulted in a non-real value (296.3kcal ME/kg); therefore, no diet was formulated using that value.

Corn and soybean meal-based diets were formulated to meet requirements recommended by the NRC (Nutrient..., 1998) for growing pigs (30-60 kg) (Tab. 1) and finishing pigs (60-90kg) (Tab. 2). The level of SCH was set at 15%, as this level was indicated as best in previous study (Poveda-Parra *et al.*, 2008). For diet formulation, the chemical and energy composition of SCH was used, obtained during the digestibility assay. For corn and soybean meal, the values of CP, phosphorus and calcium were determined, while ME levels were indicated by Rostagno *et al.* (2005).

The pigs were allotted in a random blocks experimental design, with six diets, and experimental units consisting of one pig per pen.

At the end of the growing and finishing phases, backfat thickness and loin depth at the P2 position were measured using a Sono-Grader device (RENCO®). Likely, 36 finishing pigs were slaughtered and carcasses were evaluated, according to the Brazilian Method of Carcass Classification (Associação..., 1973). For a qualitative carcass evaluation, samples were taken from *Longissimus dorsi* muscle in the area of the 8th and 10th vertebrae for later measurements of intramuscular fat (marbling) and water loss from dripping, according to Bridi and Silva (2006). *Longissimus dorsi* and fat areas were determined using a digital table (Camara *et al.*, 1996).

Table 1. Composition of diets formulated with different values of metabolizable energy from sticky coffee hull – growing pigs

Item	Levels of substitution of basal diet to estimate metabolizable energy of sticky coffee hull[1] (%)					
	CD	7	14	21	28	15
Corn	73.43	57.78	57.46	56.92	55.66	57.20
Sticky coffee hull	0.00	15.00	15.00	15.00	15.00	15.00
Soybean meal	18.63	22.63	22.71	22.85	23.19	22.78
Soybean oil	0.41	2.15	2.40	2.80	3.73	2.59
Limestone	0.70	0.43	0.43	0.42	0.42	0.42
Dicalcium phosphate	0.85	1.13	1.13	1.13	1.14	1.13
Salt	0.40	0.40	0.40	0.40	0.40	0.40
Mineral-vitamin premix[2]	0.30	0.30	0.30	0.30	0.30	0.30
Growth promoter[3]	0.05	0.05	0.05	0.05	0.05	0.05
L-Lysine HCL	0.23	0.13	0.13	0.13	0.12	0.13
Weath bran	5.00	0.00	0.00	0.00	0.00	0.00
Calculated values[4]						
Metabolizable energy, kcal/kg	3,230	3,230	3,230	3,230	3,230	3,230
Protein, %	17.00	17.00	17.00	17.00	17.00	17.00
Lysine, %	0.91	0.91	0.91	0.91	0.91	0.91
Calcium, %	0.55	0.55	0.55	0.55	0.55	0.55
Total phosporus, %	0.480	0.480	0.480	0.480	0.480	0.480
Neutral detergent fiber, %	12.91	15.70	15.70	15.70	15.70	15.70
Acid detergent fiber, %	5.26	8.28	8.28	8.28	8.28	8.28
Crude fiber, %	3.28	5.62	5.62	5.62	5.62	5.62
Feed cost, R$/kg	0.58	0.65	0.65	0.66	0.68	0.66

[1]The values of metabolizable energy of sticky coffee hull (SCH) used to calculate the diets were 2,456, 2,377, 2,247, 1,945 and 2,316, respectively to 7, 14, 21, 28 e 15% of inclusion of SCH substituting basal diet. The level of 15% was estimated by regression. CD: control diet. [2]Vitamin and mineral premix for pigs in the growing. [3]Lincomicyn 30%. [4]Calculate based on Rostagno *et al.* (2005).

Table 2. Composition of diets formulated with different values of metabolizable energy from sticky coffee hull – finishing pigs

Item	Levels of substitution of basal diet to estimate metabolizable energy of sticky coffee hull[1] (%)					
	CD	7	14	21	28	15
Corn	81.45	65.83	65.59	64.96	63.71	65.25
Sticky coffee hull	0.00	15.00	15.00	15.00	15.00	15.00
Soybean meal	11.11	15.1	15.1	15.33	15.66	15.25
Soybean oil	0.00	1.74	1.98	2.38	3.31	2.17
Limestone	0.69	0.41	0.41	0.41	0.40	0.41
Dicalcium phosphate	0.70	0.97	0.97	0.97	0.98	0.97
Salt	0.40	0.40	0.40	0.40	0.40	0.40
Mineral-vitamin premix[2]	0.30	0.30	0.30	0.30	0.30	0.30
Growth promoter[3]	0.05	0.05	0.05	0.05	0.05	0.05
L-Lysine HCL	0.30	0.20	0.20	0.20	0.20	0.20
Weath bran	5.00	0.00	0.00	0.00	0.00	0.00
Calculate values[4]						
Metabolizable energy , Kcal/kg	3,197	3,197	3,197	3,197	3,197	3,197
Protein, %	13.85	13.85	13.85	13.85	13.85	13.85
Lysine, %	0.77	0.77	0.77	0.77	0.77	0.77
Calcium, %	0.49	0.49	0.49	0.49	0.49	0.49
Total phosporus, %	0.43	0.43	0.43	0.43	0.43	0.43
Neutral detergent fiber, %	13.02	15.80	15.80	15.80	15.80	15.80
Acid detergent fiber, %	5.74	8.69	8.69	8.69	8.69	8.69
Crude fiber, %	3.23	5.57	5.57	5.57	5.57	5.57
Feed cost, R$/kg	0.59	0.66	0.66	0.67	0.69	0.67

[1]The values of metabolizable energy of sticky coffee hull (SCH) used to calculate the diets were 2,456, 2,377, 2,247, 1,945 and 2,316, respectively to 7, 14, 21, 28 e 15% of inclusion of SCH substituting basal diet. The level of 15% was estimated by regression. CD: control diet. [2]Vitamin and mineral premix for pigs in the finishing. [3]Lincomicyn 30%. [4]Calculate based on the Rostagno *et al.* (2005).

In order to study the economic viability of each experiment diet, diet cost (DC) was calculated along with feed cost per kg of body weight (ADI), according to Bellaver *et al*. (1985). The economic efficiency index (EEI) and cost index (CI) were calculated as well, according to the methodology proposed by Gomes *et al*. (1991). The supplies prices were obtained at local market and used to calculate the costs of the experimental diets: corn (grain), R$ 0.36/kg; soybean meal, R$ 0.92/kg; soybean oil R$ 2.14/kg; and sticky coffee hull, R$ 0.50/kg.

The results of the performance, carcass traits and feed costs were submitted to an analysis of variance. NCK test was applied when necessary the statistical analyses were done using the SAEG statistics software (Sistema..., 1997).

RESULTS AND DISCUSSION

For the digestibility assay, the sticky coffee hulls were ground into 4mm particle sizes, as a study by Poveda-Parra *et al*. (2008) demonstrated that sticky coffee hulls ground into that size present a better digestibility coefficient than hulls ground in a 2.5mm screen sieve. The particle sizes of the tested feeds were 533, 606, 628 and 656,

respectively, for levels 7, 14, 21 and 28% of hulls in the diets.

The digestibility coefficients (Table 3) for sticky coffee hulls were lower than those obtained by Poveda-Parra *et al*. (2008) and Ferreira *et al*. (1997) for DE (2,498 and 2,843 kcal/kg, respectively) and DCCP (45.7 and 65.5%, respectively). Similarly, the values found are lower than those observed by Oliveira *et al*. (2002) and Ferreira *et al*. (1997) for DDM (65.6 and 61.0%, respectively) and ME (2,684 and 2,694kcal/kg, respectively). In general, the coefficients of variation were high, which made more difficult the detection of differences (P≤0.05) among the digestibility coefficients.

Fiber is one of the factors that contribute to the reduction in the digestibility of ingredients used in pig diets (Noblet e Perez, 1993). There may be decrease in dry matter digestibility result of the partial substitution of a highly digestible carbohydrate source (corn starch) by another less digestible source, rich in non-starch polysaccharides (NSP), with lower fermentation or through an increase in intestinal transit, leading to a reduction in the fermentation of structural carbohydrates (Gomes *et al*., 2007).

Table 3. Digestibility coefficients and digestible nutrients of sticky coffee hull – growing-finishing pigs

Digestibility coeficients[1], %	Levels of sticky coffee hull[2]								Reg[3]
	7		14		21		28		
DC of Dry matter	74.46		74.73		73.10		66.68		NS
DC of Gross energy	67.91		66.84		63.34		57.35		NS
MC of Gross energy	65.77		63.68		60.18		52.10		NS
DC of OM	58.96		64.46		74.26		67.69		NS
DC of Crude protein	38.87		41.91		41.64		31.76		NS
DC of NDF	16.50		48.81		59.90		37.51		Q:0.000
DC of ADF	13.98		19.85		55.06		61.35		L:0.000
DC of Crude fiber	35.14		49.58		47.71		34.18		Q:0.001
Digestible nutrients[4]	DM[5]	NM[6]	DM[5]	NM[6]	DM[5]	NM[6]	DM[5]	NM[6]	
DDM, %	66.85	60.03	67.10	60.25	65.64	58.94	59.87	53.76	-
DE, kcal/kg	2,824	2,535	2,779	2,496	2,634	2,365	2,385	2,141	-
ME, kcal/Kg	2,735	2,456	2,648	2,377	2,502	2,247	2,166	1,945	-
DOM, %	54.87	49.26	59.99	53.86	69.11	62.05	63.00	56.57	-
DCP, %	4.05	3.63	4.36	3.92	4.34	3.98	3.31	2.97	-
DNDF, %	5.79	5.20	17.13	15.38	21.03	18.88	13.17	11.82	-
DADF, %	3.96	3.55	5.62	5.05	15.59	14.00	17.37	15.60	-
DCF, %	7.38	6.63	10.42	9.35	10.02	9.00	7.18	6.45	-

[1] DC = Digestibility coefficients, MC = Metabolization coefficient, OM = Organic matter, NDF = Neutral detergent fiber, ADF = Acid detergent fiber; [2] Represents the levels of substitution of basal diet for food test (sticky coffee hull); [3] Regression: NS= not significant, L= linear effect, Q= quadratic effect, DCNDF= - 46,4167 + 10,8099X - 0,278166X^2, CDFDA= -5,80232 + 2,52783X e DCCF= 7,63523 + 4,96461X – 0,14378X^2; [4] Digestible dry matter (DDM); Digestible energy (DE); Metabolizable energy (ME); Digestible organic matter (DOM); Digestible crude protein (DCP); Digestible neutral detergent fiber (DNDF); Digestible acid detergent fiber (DADF) and Digestible crude fiber (DCF); [5] Dry matter; [6] Natural matter

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The digestible coefficients (DC) and metabolizable coefficients (MC) of gross energy were not influenced (P>0.05) by the levels of substitution, but for Pond *et al.* (1988) found a reduction in the digestibility of energy in diets with high fiber inclusion. According to Kempen (2001) for each 1% of fiber added to the diet of pigs, energy digestibility also falls by at least 1%.

The DCs of NDF and CF showed a quadratic response (P≤0.05) to the levels of substitution, featuring higher estimated DC (58.6% and 50.5%) at the levels of substitution of 19.43% and 17.25% of basal diet by the test feedstuff (SCH). On the other hand, as the level of substitution increased, there was a linear increase (P≤0.05) in the DC of ADF. Applying the mean value (18.3%) among the best levels obtained for DCNDF and DCCF, the value of 40.6% was obtained for the DC of ADF. Compared with the results obtained by Poveda-Parra *et al.* (2008),

who found values of 54.6% for DCNDF, 50.1% for DCCF, and 50.3% for DCADF, the results in this experiment (Table 3) were lower for NDF, similar for CF, and higher for ADF.

Traditionally in pig digestibility trials, only one level of substitution of the basal diet by the test feedstuff is used, from 25% to 30% (Sakomura and Rostagno, 2007), but as cited by Villamide (1996) and Adeola (2001), it is important to use more than one level of substitution.

In the performance experiment, when SCH was included at a fixed level of 15% in growing diets and the different ME values obtained in the digestibility assay were used, a similar performance was obtained (Table 4). This suggests that the energy value (ME) of fibrous feedstuffs (SCH) indeed varies according to the level of substitution of the basal diet by the test feedstuff (SCH).

Table 4. Performance[1] and carcass traits[2] of grow-finishing pigs fed on diets formulated with different metabolizable energy values of sticky coffee hulls

| Item | CD[4] | Levels of substitution of basal diet used in digestibility trials to estimate metabolizable energy of sticky coffee hull [3] (%) | | | | | Mean | SE[5] |
		7	14	21	28	15		
			Growing					
DFI, kg	1.89	1.75	1.87	1.95	1.73	1.92	1.85	±0.03
DWG, kg	0.753	0.713	0.752	0.818	0.716	0.776	0.755	±0.01
FGR	2.49	2.48	2.51	2.44	2.48	2.50	2.48	±0.02
BT - P2, mm	9.00	7.00	7.29	7.86	7.29	8.00	7.74	±0.24
LD, mm	45.71	36.71	41.86	40.29	36.43	43.00	40.67	±1.01
			Finishing					
DFI, kg	2.44	2.26	2.35	1.99	1.97	2.17	2.20	±0.05
DWG, kg	0.831a	0.678ab	0.723ab	0.576b	0.605b	0.645ab	0.676	±0.02
FGR	2.94	3.37	3.39	3.63	3.34	3.45	3.36	±0.07
BT - P2, mm	11.57	10.00	12.29	10.51	8.71	10.00	10.51	±0.36
LD, mm	56.57	50.43	49.14	52.12	51.86	52.43	52.09	±1.25

[1]DFI = Daily feed intake, DWG = Daily weight gain, FGR = Feed to gain ratio; [2]BT – P2 = Backfat thickness in position 2, LD = Loin depth; [3]The values of metabolizable energy of sticky coffee hull (SCH) used to calculate the diets were 2,456, 2,377, 2,247, 1,945 and 2,316, respectively to 7, 14, 21, 28 e 15% of inclusion of SCH substituting basal diet. The level of 15% was estimated by regression; [4]Control diet (CD); [5]Standard error.

This response in performance: daily feed intake (DFI), daily weight gain (DWG) and feed-to-gain ratio (FGR); and carcass (backfat thickness and loin depth), during the growing phase, indicates that the energy values (ME) estimated during the digestibility trial, using different levels of substitution of the basal diet by SCH,

represent the true energy values of SCH, for that phase (growing).

For the finishing phase, the DWG (Table 4) was lower (P≤0.05) for levels 21% and 28% compared to the control diet, which may indicate energy deficiency in those diets. If energy

deficiency occurred, it means the energy value of SCH obtained with 21% and 28% of BD substitution has been overestimated.

These responses suggest that, for fibrous feedstuffs, the addition of high levels of substitution of BD by the test feedstuff (fibrous) for finishing pigs may lead to an overestimated ME value. Thus, increasing levels of substitution can be used to determine which level provides the best energy value of the feedstuff tested (Villamide, 1996).

Some carcass traits (Table 5) such as hot carcass weight, cold carcass weight, ham weight and backfat thickness, support the performance

responses that suggest overestimated SCH energy values for the 21% and 28% levels, with emphasis on the higher level of substitution. The 28% diet, which supposedly provided lower energy levels than the control diet, showed smaller carcass and with less fat, which again supports the possibility that the ME value for SCH was overestimated for this level of substitution in the performance experiment. In regard to the above mentioned results, for Gomes *et al.* (2007) the reduction in body fat and increase in muscle mass result in improved carcass quality, although it is common for these traits to be associated with lower weight gain in pigs fed with fibrous diets.

Table 5. Carcass traits of pigs fed on diets with different values of metabolizable energy of sticky coffee hull

| Item[2] | CD[3] | Levels of substitution of basal diet used in digestibility trials to estimate metabolizable energy of sticky coffee hull[1] (%) | | | | | Mean | SE[4] |
		7	14	21	28	15		
				Carcass traits				
SW, kg	93.48	86.07	87.48	82.87	80.63	84.57	85.97	±1.24
HCW, kg	77.74	68.80	70.78	67.83	65.04	68.58	69.85	±1.01
YHC, %	83.09	80.00	80.88	81.83	80.59	81.13	81.20	±0.28
CCW, kg	75.73a	66.96b	68.84ab	65.79ab	63.11b	66.73ab	67.92	±1.06
YCC, %	80.95	77.85	78.66	79.38	78.19	78.91	78.94	±0.25
LI, %	2.56	2.67	2.75	3.00	2.99	2.73	2.77	±0.10
HW, kg	12.18b	10.92a	11.23b	10.78b	10.03b	10.87b	10.99	±0.15
IH, kg	32.25c	32.61a	32.63bc	32.75bc	32.05b	32.58bc	32.40	±0.20
BT, cm	2.84	2.50	2.58	2.24	2.04	2.29	2.42	±0.07
CL, cm	91.75	90.14	92.35	89.62	90.78	91.77	91.10	±0.49
EAL, cm[2]	49.55	39.37	38.55	40.83	38.45	41.06	41.30	±1.07
LM,	66.13	55.85	55.92	57.40	55.07	57.81	58.03	±1.14
PLM,	85.05	81.42	79.05	84.64	84.83	84.15	83.13	±1.24
DL, %	3.79	3.16	3.31	3.33	4.22	2.91	3.47	±0.27
MAR	2.50	1.75	1.83	1.80	1.83	2.00	1.97	±0.11
COL	2.25b	2.17b	2.33a	2.23a	2.17a	2.17a	2.24	±0.07
FIRM	2.42b	2.58b	2.75a	2.69a	2.75a	2.67a	2.65	±0.04

[1]The values of metabolizable energy of sticky coffee hull (SCH) used to calculate the diets were 2,456, 2,377, 2,247, 1,945 and 2,316, respectively to 7, 14, 21, 28 e 15% of inclusion of SCH substituting basal diet. The level of 15% was estimated by regression. [2]SW = Slaughter weight, HCW = hot carcass weight, YHC = yeld hot carcass, CCW = cold carcass weight, YCC = yeld cold carcass, LI = loss of income, HW = ham weight, IH = income ham, BT = backfat thickness, CL = carcass lenght, ELA = eye loin area, LM = lean meat in the carcass, PLM = percentage of lean meat in the carcass, DL = drip loss, MAR = marbling of the *longíssimus dorsi*, COL = color and FIRM = firmness of meat. [3]Control diet (CD). [4]Standard error.

The results obtained in this study are similar to those obtained by Oliveira *et al.* (2002) and Quadros (2007), using fibrous feedstuffs such as sticky coffee hulls and soybean hulls, respectively, who all observed a reduction in fat percentage and backfat thickness in the diets that contained fiber. Gomes *et al.* (2006) highlight that some factors may interfere in carcass quality results, such as the quality of the fiber used, fermentation rate, and fiber concentration in the diet.

The economic analysis (Table 6) indicated that for growing animals, the increasing levels of substitution did not influence ($P>0.05$) diet costs (DC), whereas it indicated an increase ($P≤0.05$) for the higher levels of substitution of the basal diet by the test feedstuff in finishing pigs. The results reflect the weaker performance (Table 4), particularly of DWG, during the finishing phase.

Both the SCH energy values found in the digestibility trial and the results of the validation of these values in the animal performance experiment indicate that the method of using increasing levels of substitution of the basal diet by the test feedstuff can be used to better estimate the energy values of feedstuffs for pigs.

Table 6. Economic analysis of growing-finishing pigs fed on diets with different values of metabolizable energy of sticky coffee hull

Item[2]	CD[3]	Levels of substitution of basal diet used in digestibility trials to estimate metabolizable energy of sticky coffee hull[1] (%)					Mean
		7	14	21	28	15	
Growing							
Initial weight, kg	30.07	29.91	30.21	30.15	30.28	30.01	-
Final weight, kg	60.30	58.04	59.93	62.03	58.01	61.70	-
Diet cost, R$/kg	0.58	0.65	0.65	0.66	0.68	0.66	-
ADI, R$/kg LW gain	1.44	1.61	1.64	1.61	1.69	1.64	1.60
EEI	100.00	111.63	113.80	112.10	117.01	113.94	-
CI	100.00	89.58	87.88	89.21	85.46	87.77	-
Finishing							
Initial weight, kg	60.00	59.94	59.86	59.96	59.99	60.40	-
Final weight, kg	97.53	89.59	91.39	85.23	86.03	88.81	-
Diet cost, R$/kg	0.59	0.66	0.66	0.67	0.69	0.67	-
ADI, R$/kg LW gain	1.73b	2.08a	2.08a	2.27a	2.13a	2.09a	2.05
EEI	100.00	120.12	120.07	130.79	122.69	120.44	-
CI	100.00	83.24	83.29	76.46	81.51	83.03	-

[1]The values of metabolizable energy of sticky coffee hull (SCH) used to calculate the diets were 2,456, 2,377, 2,247, 1,945 and 2,316, respectively for 7, 14, 21, 28 e 15% of inclusion of SCH substituting basal diet. The level of 15% was estimated by regression. [2]ADI = Feed cost per kg of body weight, EEI = Economic Efficiency Index, Cost Index (CI). [3]CD = Control Diet.

CONCLUSIONS

The digestibility coefficients and performance results indicate that, for fibrous feedstuffs, higher levels of substitution of the basal diet by the test feedstuff result in an overestimated value of the fibrous ingredient. It is further concluded that the method of using increasing levels of substitution of the basal diet by the test feedstuff can be used as a tool to more precisely estimate the energy values of fibrous feedstuffs for pigs. The results suggest that for growing and finishing pigs, it can be used up to 28% and 15%, respectively, of sticky coffee hull (fiber) without impairing performance and economic feasibility. For higher levels of inclusion (21% and 28%) there is a reduction on pig performance and increase the diets cost.

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