



Corns with Different Nutritional Profiles on Growing and Finishing Pigs Feeding (30 to 90 kg)*

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ABSTRACT : Three experiments were carried out to determine the nutritional value and to verify the pig performance in growing and finishing phases (30 to 90 kg) fed on diets containing common corn (CC), high-lysine corn (HLC) and high-oil corn (HOC). In the total digestibility trial (Exp. I) 12 barrows were used. Values of digestible energy (DE) and metabolizable energy (ME) as-fed basis for CC, HLC and HOC, were: 3,396 and 3,275 kcal/kg; 3,248 and 3,139 kcal/kg; 3,445 and 3,308 kcal/kg, respectively. In order to determine the apparent and true ileal digestibility coefficients of amino acids, as well as the values of true digestible amino acids of the CC, HLC and HOC, an ileal digestibility trial was done (Exp. II) with T-cannulated barrows ("T" simple). The treatments consisted of three diets, with one of them as the sole source of protein (CC, HLC and HOC). In the performance experiment (Exp. III), 36 crossbred pigs, allotted in a completely randomized design with three treatments and 12 replications were used. Treatments consisted of three diets: 1 - CC; 2 - HLC and 3 - HOC. It was observed no difference for performance and carcass variables among the corns with different nutritional profiles. Results of the three experiments highlighted the importance of segregating corns in their real chemical and energetic composition as well as the values of true digestible amino acids for formulating diets for growing and finishing pigs. (**Key Words** : Bio Economic Studies, Carcass, Energetic Diets, Nutritional Values, Pig, Corn)

INTRODUCTION

Corn is an important ingredient used in diets for pigs in Brazil. About 80% of the Brazilian production of corn is used for the preparation of animal feed. It is characterized as energetic food source (3,930 kcal of GE/kg), rich in starch (63.00%) and contains around 8.00% of CP and 3.60% of crude fat (Rostagno et al., 2005).

Currently, there are in the market new varieties and hybrids of corn, developed with the genetic improvement and manipulation by the introduction of technologies of molecular biology, which have superior nutritional profile when compared to the traditional genotypes, thus they are more suitable for animal feed.

Corn with high levels of lysine has 0.35% lysine (the common corn has 0.24%), arousing the interest of its use in

feed for pigs because it gathers all the good agronomic characteristics when compared to the common corn, besides having higher content of tryptophan (Saldivar and Rooney, 1994). Corn with a high-oil content has 6.40% of crude fat (Rostagno et al., 2005) which increases the energy content allowing to formulate diets with higher energy density which can improve the performance of animals.

In many cases pig diets are formulated with values reported in tables of feed composition, although the average nutritional profile of the raw materials may differ. Thus, it has been constantly sought to formulate diets with values closer to the real chemical composition and energy value of the different types of corns available in the market (Vieira et al., 2007).

Beside the energy content it is also necessary to know the amount and the digestibility of amino acids present in the corn (Tanksley and Knab, 1993). However, values for the ileal digestibility of amino acids must be preferred due to the possible interference of the bacterial flora in the metabolism of amino acids in the large intestine (Fan and Sauer, 1995).

Formulation of diets based on standardized ileal digestible amino acids has been used by nutritionists,

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mainly because of the necessity to optimize the use of raw materials of high cost and to ensure a sufficient supply of digestible amino acids by the correction of deficiencies with supplementation of synthetic amino acids (Sakomura and Rostagno, 2007).

This study was carried out aiming to evaluate the use of corns with different nutritional profile in practical growing and finishing pig diets, and their effects on performance, carcass quality and economic return.

MATERIAL AND METHODS

The experiments were carried out at the Maringá State University Pig Farm in the State of Paraná (23° 21'S, 52° 04'W, at a height of 564 meters).

Three different corns were used: common corn (CC) - BR1030 hybrid, which was provided by Embrapa CNPMS; high-lysine corn (HLC) - BR473 variety, which is under development by Embrapa CNPMS and high-oil corn (HOC) - DAS766 hybrid, from the seed company DowAgroScience.

Three corns were ground in a hammermill equipped with a 2 mm screen. Chemical compositions and energy of the CC, of the HLC, of the HOC, of the diets and feces were obtained in the Laboratory of Food Analysis and Animal Nutrition at Maringá State University. Analysis of dry matter (DM), crude protein (CP), ashes, calcium (Ca), total phosphorus (Pt) and crude fat (CF) were carried out according to the methods described by Silva and Queiroz (2002). The determination of starch in food and in the feed and feces were carried out according to the enzymatic method proposed by Poor et al. (1989), adapted by Pereira and Rossi (1995). Values of gross energy (GE) were determined by means of adiabatic calorimeter (Parr Instrument Co. AC720), according to the procedures described by Silva and Queiroz (2002). Contents of amino acids in the corns were determined by HPLC in the CBO Laboratory Analysis in Campinas, Brazil.

Experiment I: Total digestibility trial

Initially, the three corns (CC, HLC and HOC) were analyzed for DM, GE, CP, organic matter (OM), CF, starch, ashes, Ca and Pt and total amino acids (Tables 3 and 5).

A total digestibility trial was carried out, using 12 crossbred barrows, from commercial line (TOPIGS), with initial body weight of 44.2±0.8 kg. The animals were individually allotted in metabolism cages type "PEKAS" in a controlled environment room and average room temperature with minimum of 18°C and maximum of 24°C.

CC, HLC and HOC were tested, replacing 30% of the reference diet, resulting in three test diets. Reference diet, based on corn and soybean meal was calculated to meet the requirements indicated by NRC (1998).

Four diets were studied: 1 = Reference Diet (RD); 2 =

RD (70%)+CC (30%); 3 = RD (70%)+HLC (30%); 4 = RD (70%)+HOC (30%).

Collections were done in two periods: the first one consisted of seven days of adaptation to the diets and cages follow by five days of collection of feces and urine; the second one consisted of 3-day interval and a five-day collection. From the first to the second period, the treatments were reallocated.

Other procedures for diets, feces and urine collection were carried out according to those described by Sakomura and Rostagno (2007), as below.

Pigs were fed twice daily (07:00 a.m. and at 01:30 p.m.) in the proportions of 60 and 40% of the total quantity, respectively. Daily total quantity was defined according to the feed intake in the adaptation phase, based on the metabolic weight ($\text{kg}^{0.75}$) of each experimental unit. Diets were humidified with 15% of water. After each meal, water (3.0 ml/g of diet) was offered in the same feeders. Fe_2O_3 (2% of inclusion) was used as a marker.

Feces were daily collected in the morning and packaged in freezer (-10°C). At the end of the collecting period, they were dried at 55°C for 72 hours for pre-drying. Later on, the samples were exposed to air in order to balance with room temperature and humidity. Then, they were weighed, ground and mixed and finally samples were collected for analysis.

Urine was collected once a day in plastic buckets with 20 ml of HCl 1:1, aiming not to have nitrogenous loss and the bacterial proliferation. A fabric known as "filó" was put on the collector funnel in order to hold possible fecal waste. Collection was done at 07:30 a.m. in which the liquid into the bucket was filled for fixed volumes to make the removal of the 20% aliquot easier. The urine was kept in flasks into the freezer for laboratory analysis, which were done in the Animal Nutrition Laboratory of Animal Science Department of Maringá State University (LANA/DZO/DEM) by Silva and Queiroz (2002).

Digestibility coefficients of dry matter (DCDM), of crude protein (DCCP), of organic matter (DCOM), of gross energy (DCGE) and the metabolization coefficient of gross energy (MCGE), of the corns with different nutritional profiles were calculated as described by Matterson et al. (1965), thereby obtaining the values of digestible dry matter (DDM), digestible protein (DP), digestible organic matter (DOM), digestible energy (DE) and metabolized energy (ME).

Experimental design was completely randomized, with three treatments, six replicates and the experimental unit was the single pig. In order to evaluate differences between the digestibility coefficients of the CC, HLC and HOC, the data was submitted to ANOVA and average test (Newman-Keuls test, $p < 0.05$), using the statistical software SAEG (UFV, 2000), in accordance with the following statistical

model: $Y_{ij} = \mu + T_i + e_{ij}$ where: Y_{ij} = digestibility coefficients of corn i , j of repetition; μ = constant associated with all observations; T_i = effect of type of corn i , where $i = 1, 2, 3$, ($1 = \text{CC}$, $2 = \text{HLC}$, $3 = \text{HOC}$), and ij = random error associated with each observation.

Experiment II: Ileal digestibility trial

CC, HLC and HOC were analyzed for amino acid composition (Table 5).

Average minimum external temperatures were $13.9 \pm 3.0^\circ\text{C}$ and $19.1 \pm 2.4^\circ\text{C}$ and average maximum temperatures were $25.9 \pm 3.8^\circ\text{C}$ and $30.0 \pm 4.0^\circ\text{C}$, respectively. The mean air relative humidity in the growing and finishing phases in the morning were $71.5 \pm 14.9\%$ and $73.6 \pm 13.5\%$ and in the afternoon were $45.9 \pm 13.5\%$ and $46.6 \pm 16.9\%$, respectively.

Three crossbred pigs from commercial line (TOPIGS) were used, with 46.3 ± 2.1 kg of BW, which were submitted to a surgery for implantation of a T-shaped cannula, as described by Bellaver (1989). After the surgery, the animals were transferred to individual concrete pens ($3.80 \text{ m}^2/\text{each}$), with nipple drinker at the back and semi-automatic feeders at the front, which provided free access to feed and water. These animals were under recovery for 20 days.

Treatments consisted of three diets, with a single source of protein food (CC, HLC and HOC) and one protein-free diet (OFD) for estimating endogenous amino acid losses.

Three diets containing different corns (CC, HLC and HOC) were formulated according to Rostagno et al. (2005) and Apolônio et al. (2003). Test diet consisted of corn (85.00%), starch (9.88%), rice husk (1.50%), soybean oil (1.00%), dicalcium phosphate (1.20%), limestone (0.42%), salt (0.35%), vitamin-mineral supplement (0.15%) and chromium oxide (0.50%). One protein-free diet consisted of starch (50.10%), sugar (39.90%), rice husk (5.00%), dicalcium phosphate (1.24%), limestone (0.70%), soybean oil (2.00%), sodium chloride (0.30%), vitamin-mineral supplement (0.30%) and chromium oxide (0.50%).

Animals showed an average weight of 57.0 ± 0.7 kg and were submitted to a five-day adaptation in order to regulate the intestinal flow and to a one-day collection of ileal digesta of the OFD. The supply procedures for the diets and the collection and processing of the digesta were carried out according to Sakomura and Rostagno (2007).

Ileal digesta of the three test diets was collected (CC, HLC and HOC). Animals were allotted to a double 3×3 Latin square design. First period lasted six days with five days of adaptation and one day of collection of ileal digesta. In the following periods there was a three-day adaptation to the diet and a one-day collection of ileal digesta.

Analyzed digesta of each feed were compounded of the six samples of digesta performed during the six periods.

Experimental diets had 0.5% of chromic oxide (Cr_2O_3) as a marker in the digestibility determination. Daily

quantity of diet was provided to each animal twice a day (at 7 a.m. and 7 p.m.). It was calculated according to the metabolic weight ($\text{kg}^{0.75}$).

Digesta samples were collected in polyethylene bags, attached to the cannula and, later on, put into plastic pots which were identified and put into the freezer (-5°C) until the end of the collecting period. At the end of this period, the samples were defrosted, weighed, mixed and lyophilized in order to avoid the amino acid degradation. Dried samples were ground, packaged in glass flasks with lid for future analysis.

Levels of chromium oxide and DM in the digesta were determined according to the methods described by Silva and Queiroz (2002). The contents of amino acids in the diets and digesta samples were determined by HPLC in the CBO Laboratory Analysis in Campinas, Brazil.

Determination of ileal digestibility of amino acids was calculated based on the levels of chromium (Cr) in the diets and digesta of pigs by means of calculating the indigestibility factor (IF) using the formulas described by Sakomura and Rostagno (2007).

To determine the coefficients of SID amino acid digestibility of the corns with different nutritional profiles, the values of endogenous amino acid losses were used which were obtained from the animals that received OFD.

Experiment III: Performance experiment using corns with different nutritional profiles

Once obtained the chemical composition, the energy values and the SID digestible amino acid values of CC, HLC and HOC, they were used in the formulations of the experimental diets in the growing and finishing phases (from 30 to 60 kg of BW and from 60 to 90 kg BW).

Thirty-six crossbred pigs (TOPIGS) were used from a commercial line, with an initial BW of 31.1 ± 4.1 and a final body weight of 60.7 ± 6.2 in the growing phase and a final body weight of 91.1 ± 5.5 kg in the finishing phase.

Growing and finishing experiments were conducted during autumn season. Average minimum external temperatures were $19.1 \pm 1.3^\circ\text{C}$ and $12.5 \pm 4.3^\circ\text{C}$ and average maximum temperatures were $29.3 \pm 2.2^\circ\text{C}$ and $21.5 \pm 3.5^\circ\text{C}$, respectively. The mean air relative humidity during the growing and finishing phase was $82.4 \pm 11.6\%$ and $87.4 \pm 7.6\%$ in the morning and $58.3 \pm 12.6\%$ and $68.2 \pm 12.9\%$ in the afternoon, respectively.

Animals were allotted in shed, covered with fibercement tiles, with 36 pens ($1.90 \text{ m}^2/\text{each}$) with nipple drinker at the back and semi-automatic feeders at the front. Diets and water were given *ad libitum* throughout the experimental period.

Treatments consisted of three diets (Tables 1 and 2), where: 1 = basal CC, 2 = basal HLC and 3 = basal HOC. Diets had the same nutritional levels and they met the

Table 1. Chemical and energetic composition of experimental diets fed on growing pigs, containing corn with different nutrient profiles

Items	Common corn	High-lysine corn	High-oil corn
Corn, %	75.73	77.75	74.21
Soybean meal, %	20.00	15.70	22.10
Soybean oil, %	1.850	4.000	1.250
Limestone, %	0.870	0.900	0.830
Dicalcium phosphate, %	0.665	0.665	0.685
Sodium chloride, %	0.400	0.400	0.400
Vitamin and mineral mix, % ¹	0.300	0.300	0.300
L-lysine-HCl (99%), %	0.171	0.187	0.159
DL-methionine (99%), %	0.010	0.095	0.062
Growth promoter, % ²	0.005	0.005	0.005
Calculated values ³			
Metabolizable energy ³ , kcal/kg	3,260	3,260	3,260
Digestible lysine ³ , %	0.81	0.81	0.81
Digestible methionine+cystine ³ , %	0.47	0.47	0.47
Digestible threonine ³ , %	0.51	0.51	0.51
Calcium ³ , %	0.55	0.55	0.55
Available phosphorus ³ , %	0.21	0.21	0.21

¹ Composition per kg: Vit A, 2,333,000 IU; Vit D₃, 466,667 IU; Vit E, 5,000 IU; Vit K₃, 667mg; Vit B₁, 333 mg; Vit B₂, 1,000 mg; Vit B₆, 400 mg; Vit B₁₂, 4,000 mcg; Niacin, 6,666 mg; Pantothenic acid, 4,000 mg; Biotin, 17 mg; Pholic acid, 67 mg; Choline, 43 g; Iron, 26,667 mg; Copper, 41,667 mg; Cobalt, 183 mg; Manganese, 16,667 mg; Zinc, 26,667 mg; Selenium, 67 mg; Iodine, 267 mg; Antioxidant, 27 g; vehicle q.s.p., 1,000 g.

² Leucomag (leucomycin, 30%). ³ They were calculated based on composition of feed indicated by Rostagno et al. (2005).

requirements indicated by NRC (1998).

Once determined the chemical composition, the energy and amino acid values of the corns with different nutritional profiles (Tables 3, 4, 5, 6 and 7), such data were used for

the formulations of the diets (Tables 1 and 2). For the other ingredients, the chemical composition and energy value determined by Rostagno et al. (2005) were used. L-lysine, DL-methionine and L-threonine were added, complying

Table 2. Chemical and energetic composition of experimental diets fed on finishing pigs, containing corn with different nutrient profiles

Items	Common corn	High-lysine corn	High-oil corn
Corn, %	85.01	84.02	80.12
Soybean meal (45%), %	11.25	10.00	17.00
Dicalcium phosphate, %	0.514	0.488	0.488
Limestone, %	0.868	0.888	0.828
Soybean oil, %	1.500	3.820	0.850
Sodium chloride, %	0.400	0.400	0.400
Vitamin and mineral mix, % ¹	0.150	0.150	0.150
L-lysine·HCl (99%), %	0.265	0.168	0.130
DL-methionine (99%), %	0.000	0.063	0.025
L-threonine (98%), %	0.045	0.000	0.000
Growth promoter, % ²	0.005	0.005	0.005
Calculated values ³			
Metabolizable energy ³ , kcal/kg	3,260	3,260	3,260
Digestible lysine ³ , %	0.67	0.67	0.67
Digestible methionine+cystine ³ , %	0.39	0.39	0.39
Digestible threonine ³ , %	0.44	0.44	0.44
Calcium ³ , %	0.49	0.49	0.49
Available phosphorus ³ , %	0.17	0.17	0.17

¹ Composition per kg: Vit A, 2,666,660 IU; Vit D₃, 533,300 IU; Vit E, 4,667 IU; Vit K₃, 1,200 mg; Vit B₁, 200 mg; Vit B₂, 13.336 mg; Vit B₆, 133 mg; Vit B₁₂, 6,667 mcg; Niacin, 10,000 mg; Pantothenic acid, 666,666 mg; Biotin, 20 mg; Pholic acid, 34 mg; Choline, 62 g; Iron, 40 mg; Copper, 86,805 mg; Cobalt, 334 mg; Manganese, 30,000 mg; Zinc, 46,666 mg; Selenium, 67 mg; Iodine, 400 mg; Antioxidant, 40 g; vehicle q.s.p., 1,000 g.

² Leucomag (leucomycin, 30%). ³ They were calculated based on composition of feed indicated by Rostagno et al. (2005).

with the pattern of the ideal protein in terms of digestible amino acids, as indicated by NRC (1998).

Pigs were distributed in a completely randomized design with three treatments and 12 replications, both in the growing and finishing phases. Experimental unit was the single pig. At the end of the growing phase, the animals were redistributed at random to the treatments for the finishing phase.

Pig and feeder weights were measured at the beginning and at the end of the experiment to calculate the daily feed intake (DFI), daily weight gain (DWG) and feed:gain rate (FGR) of each experimental unit. At the end of the growing and finishing phases the backfat thickness (BT) and loin depth (LD) at the P2 position were measured using a Sono-Grader equipment (Renco®).

At the end of the finishing phase, all the pigs were slaughtered in the slaughterhouse of the Maringá State University Pig Farm. Carcasses were refrigerated (1-2°C) for 24 hours to be subsequently submitted to quantitative evaluation, according to the Brazilian Method of Carcass Classification (ABCS, 1973). For qualitative evaluation of the carcass, samples were taken from *M. Longissimus dorsi* at the 8th and 10th vertebrae for subsequent measurement of intramuscular fat, that is, of marbling and the drip loss, as NPPC (1991). Areas of *M. Longissimus dorsi* and of fat were determined using digitizing tablet and the software SPRING (Câmara et al., 1996).

Economic analysis was calculated by the following expression adapted from Guidoni et al. (1997):

$$MPC \leq (PRP (Gain_i - Gain_0) - \sum_{j \neq L=1}^N P_j (C_{ji} \times FI_i - C_{j0} \times FI_0)) / (C_{ii} \times FI_i)$$

where: MPC = maximum price of the corn (HLC and HOC) so that the diet which will be used has the same

economic efficiency as the reference diet (CC); PRP = price per kilo of pig; Gain_i = average weight gain of pigs of the treatment with corn (HLC or HOC); Gain₀ = average weight gain of pigs of the reference treatment (CC); P_j = price of the other ingredients in each diet; C_{ji} = percentage of the ingredient j in the diet i; FI_i = average total feed intake per animal inherent to diet i; C_{j0} = percentage of the ingredient j in the reference diet; FI₀ = average total feed intake per animal on the reference diet; C_{ii} = percentage of the corn (HLC or HOC) in the diet i.

The following prices were used as inputs (region of Maringá, Paraná, Brazil; current prices of February 2008): common corn R\$ 0.41, soybean meal R\$ 0.76, limestone R\$ 0.16, dicalcium phosphate R\$ 2.10, sodium chloride R\$ 0.34, vitamin and mineral mix for pigs in the growing phase R\$ 5.00, vitamin and mineral mix for pigs in the finishing phase R\$ 6.40, L-lysine R\$ 7.08, DL-methionine R\$ 24.00, L-threonine R\$ 8.25 and growth promoter R\$ 135.00. Price of the pig was R\$ 3.50.

Results of the different variables were submitted to ANOVA and to the average test (Newman-Keuls test, p<0.05). Observations were analyzed with the following statistical model: Y_{ijk} = μ + C_j + e_{ijk}, where Y_{ijk} = observed value of variables for each individual j, receiving the corn i; μ = general constant; C_j = effect of type of corn j (j = 1, 2 and 3); and e_{ij} = random error associated with each observation. Statistical analyses were carried out using the statistical software SAEG (UFV, 2000).

RESULTS AND DISCUSSION

CP, lysine and threonine levels of the HLC were increased by 29.68; 57.14 and 31.25% respectively, compared to the CC, as expected. While the crude fat level of the HOC was increased by 5.47% compared to the CC (Tables 3 and 5).

CP, lysine and threonine levels of the HLC were

Table 3. Chemical composition and energy value of corns with different nutritional profiles

Items	Common corn		High-lysine corn		High-oil corn	
	DM ^a	AB ^b	DM ^a	AB ^b	DM ^a	AB ^b
Dry matter, %	100.00	88.88	100.00	87.90	100.00	86.97
Gross energy, kcal/kg	4,413	3,923	4,458	3,919	4,517	3,929
Crude protein, %	8.66	7.70	11.23	9.87	8.46	7.36
Calcium, %	0.01	0.01	0.01	0.01	0.02	0.02
Total phosphorus, %	0.24	0.21	0.28	0.25	0.21	0.18
Available phosphorus, %	0.08	0.07	0.09	0.08	0.07	0.06
Ash, %	1.35	1.20	1.45	1.27	1.41	1.22
Organic matter, %	98.65	87.68	98.55	86.63	98.59	85.74
Crude fat, %	4.75	4.22	4.58	4.03	5.01	4.36
Starch, %	74.65	66.35	69.40	61.01	69.96	60.84

^a Dry matter. ^b As-fed basis.

Table 4. Apparent digestibility coefficients of (ADC), metabolization coefficient (MC) and values of digestible nutrients of the common corn, high-lysine corn and high-oil corn studied in the growing phase¹

Digestibility (%)	Common corn		High-lysine corn		High-oil corn	
ADC of dry matter	94.75		98.52		97.72	
ADC of crude protein	86.43		90.09		87.09	
ADC of organic matter	94.41		96.74		96.52	
ADC of gross energy	86.57 ^{ab}		82.88 ^b		87.69 ^a	
MC of gross energy	83.48		80.10		84.20	
Digestible nutrients	DM ²	AB ³	DM ²	AB ³	DM ²	AB ³
Digestible dry matter, %	-	74.85	-	76.12	-	73.92
Digestible protein, %	7.49	6.66	10.12	8.89	7.37	6.41
Digestible organic matter, %	93.13	82.78	95.33	83.80	95.15	82.76
Digestible energy, kcal/kg	3,821	3,396	3,695	3,248	3,961	3,445
Metabolizable energy, kcal/kg	3,684	3,275	3,571	3,139	3,804	3,308
ME:DE	0.96		0.97		0.96	

¹ Values of CAD with different letters in the same row are different ($p < 0.05$). ² Dry matter. ³ As-fed basis.

increased by 20.21 and 20.21; 63.48 and 12.10; 16.32 and 9.48% respectively, if compared to the corn and high-lysine corn in the tables by Rostagno et al. (2005) when converted to the same basis of DM (Tables 3 and 5). Similarly, the crude fat level of the HOC was increased by 20.98% if compared to the corn (Rostagno et al., 2005). However, it was decreased by 31.76% if compared to the high-oil corn (Rostagno et al., 2005) and decreased by 9.74% if compared to DAS766 corn (Silva et al., 2006).

In general, the results obtained from chemical composition are between the minimum and maximum values shown by van Mileen and Noblet (2004). These possible variations in the levels of the nutrients among the corns may be attributed to several other factors, such as the genetic potential of the seeds for this attribute, the level of fertilization used (especially N), the soil fertility and the climatic conditions (Noblet and van Mileen, 2004).

Experiment I: Total digestibility trial

There were no differences ($p > 0.05$) in digestibility coefficients of DM, CP and of OM and in the metabolization coefficient of gross energy among the three corns. However, digestibility coefficient of GE was superior ($p < 0.05$) for HOC compared to HLC (Table 4).

Comparing the DCGE and MCGE of the CC and HOC to those shown in the guides of Embrapa (1991) and Rostagno et al. (2005) for dry common corn (87.59 and 88.15% for DCGE and 83.37 and 85.10% for MCGE respectively, it is observed that the CC and HOC have similar values with the Brazilian guides. By comparing the DCGE and MCGE of the HOC to those published by Silva et al. (2006) for the DAS766 corn (89.88 for DCGE and 88.02% for MCGE) it is observed that the values of HOC are inferior.

However, when comparing the three studied corns (CC, HLC and HOC) among themselves, the HOC had the highest level of CF (Table 3) and thus showed the best digestible energy and the best values of DE and ME. The same was observed by Adeola and Bajjalieh (1997) when examined different hybrids of corns with high level of oil and found variation from 3,400 to 3,570 kcal DE/kg compared to 3,290 kcal DE/kg of common corn.

HLC presented (Table 4) lower DCGE and MCGE, when compared to HOC, as well as the values in the guide by Rostagno et al. (2005), for high-lysine corn (89.76 for DCGE and 87.25% for MCGE). These results are similar to those published by Burgoon et al. (1992) who studied common corn, QPM corn (quality protein maize) and two types of corn with high protein level. They reported a DCGE of 89% for all the corns studied.

ME:DE ratios of the three studied corns give a mean value of 0.96 which is in accordance with that one reported by NRC (1998), van Mileen and Noblet (2004) and Pozza et al. (2005).

Experiment II: Ileal digestibility trial

Amino acids values of the CC and HOC were similar to each other. However, the values of some essential amino acids (lysine, threonine, arginine, histidine and valine) of the HLC were numerically superior compared to the other corns (Table 5).

The amino acid composition of the three corns, the apparent digestibility coefficients (ADC), the true digestibility coefficients (TDC) and the true digestible amino acids (Tables 6 and 7) had similar values when compared to those presented by Rostagno et al. (2005) for corn, high-lysine corn and high-oil corn, as well as when compared to those listed by Fontes et al. (2007) for common corn and high-protein corn.

Table 5. Amino acid composition¹ of the corns with different nutritional profiles used in the experiments during the growing and finishing phases

Amino acid (%)	Common corn		High-lysine corn		High-oil corn	
	DM ^a	AB ^b	DM ^a	AB ^b	DM ^a	AB ^b
----- Essential amino acids (EAA) -----						
Arginine	0.52	0.46	0.81	0.71	0.44	0.38
Phenylalanine	0.48	0.43	0.57	0.50	0.43	0.37
Histidine	0.24	0.21	0.41	0.36	0.28	0.24
Isoleucine	0.35	0.31	0.43	0.38	0.31	0.27
Leucine	1.00	0.89	0.99	0.87	0.94	0.82
Valine	0.46	0.41	0.61	0.54	0.45	0.39
Lysine	0.28	0.25	0.44	0.39	0.25	0.22
Threonine	0.32	0.28	0.42	0.37	0.29	0.25
Methionine	0.27	0.24	0.22	0.19	0.21	0.18
Methionine+cystine	0.37	0.33	0.33	0.29	0.29	0.25
----- Non essential amino acids (NEAA) -----						
Aspartic acid	0.60	0.53	0.83	0.73	0.53	0.46
Alanine	0.68	0.60	0.69	0.61	0.61	0.53
Glutamic acid	1.67	1.48	1.89	1.66	1.59	1.38
Cystine	0.10	0.09	0.11	0.10	0.08	0.07
Glycine	0.34	0.30	0.49	0.43	0.31	0.27
Serine	0.39	0.35	0.47	0.41	0.37	0.32
Tyrosine	0.36	0.32	0.40	0.35	0.32	0.28

¹ Analysis carried out in Laboratory of Analyses CBO - Campinas, São Paulo, Brazil; ^a Dry-matter. ^b As-fed basis.

Table 6. Apparent digestibility coefficients of (ADC) and true digestibility coefficients (TDC) of the amino acids of corns with different nutritional profiles used during growing and finishing phases

Amino acid	Common corn		High-lysine corn		High-oil corn	
	ADC	TDC	ADC	TDC	ADC	TDC
----- Essential amino acids (EAA) -----						
Arginine	87.46	90.89	86.83	88.57	75.52	79.79
Phenylalanine	94.04	96.06	93.00	94.37	90.55	92.96
Histidine	96.39	98.39	92.07	92.98	87.41	89.21
Isoleucine	92.29	95.80	91.36	93.60	87.63	91.77
Leucine	95.15	96.68	93.27	94.50	92.54	94.24
Valine	91.33	94.79	90.61	92.67	86.14	89.88
Lysine	84.85	90.24	85.54	88.24	72.90	79.19
Threonine	89.59	95.70	89.39	93.01	83.78	90.81
Methionine	94.90	96.59	92.49	94.16	90.28	92.60
Methionine+cystine	90.99	93.14	85.73	87.64	81.56	84.47
Average (EAA)	91.78	95.02	90.51	92.46	85.19	88.94
----- Non essential amino acids (NEAA) -----						
Aspartic acid	93.84	97.12	90.71	92.57	84.97	88.85
Alanine	90.87	94.32	86.31	88.97	83.65	87.67
Glutamic acid	94.17	95.86	92.56	93.74	93.84	95.69
Cystine	80.58	83.95	72.87	75.25	59.12	63.58
Glycine	61.54	71.97	57.00	62.70	24.04	35.94
Serine	89.68	94.60	87.46	90.76	83.11	88.64
Tyrosine	92.35	94.89	91.84	93.66	88.08	91.05
Average (NEAA)	86.15	90.39	82.68	85.38	73.83	78.77

Table 7. Values of the true digestible amino acids of the corns with different nutritional profiles used during growing and finishing phases

True digestible amino acids, %	Common corn		High-lysine corn		High-oil corn	
	DM ¹	AB ²	DM ¹	AB ²	DM ¹	AB ²
----- Essential amino acids (EAA) -----						
Digestible arginine	0.47	0.42	0.72	0.63	0.35	0.30
Digestible phenylalanine	0.46	0.41	0.54	0.47	0.40	0.34
Digestible histidine	0.23	0.21	0.38	0.33	0.25	0.21
Digestible isoleucine	0.33	0.30	0.40	0.36	0.28	0.25
Digestible leucine	0.97	0.86	0.94	0.82	0.89	0.77
Digestible valine	0.44	0.39	0.57	0.50	0.40	0.35
Digestible lysine	0.25	0.23	0.39	0.34	0.20	0.17
Digestible threonine	0.30	0.27	0.39	0.34	0.26	0.23
Digestible methionine	0.26	0.23	0.20	0.18	0.19	0.17
Digestible methionine+cystine	0.35	0.31	0.29	0.25	0.24	0.21
----- Non essential amino acids (NEAA) -----						
Digestible aspartic acid	0.58	0.51	0.77	0.68	0.47	0.41
Digestible alanine	0.64	0.57	0.62	0.54	0.53	0.46
Digestible glutamic acid	1.60	1.42	1.77	1.56	1.52	1.32
Digestible cystine	0.09	0.08	0.09	0.08	0.05	0.04
Digestible glycine	0.24	0.22	0.31	0.27	0.11	0.10
Digestible serine	0.37	0.33	0.42	0.37	0.33	0.28
Digestible tyrosine	0.34	0.30	0.37	0.33	0.29	0.25

¹ Dry-matter. ² As-fed basis.

It is important to consider the variation in the digestibility of amino acids within each type of corn. Sauer and Ozimek (1986) reported that the digestibility of lysine ranges from 71% to 82% in corn common. A large part of this variation may be related to the relatively low content of amino acids in the cereal grains (Fontes et al., 2007). Small changes in the levels of endogenous amino acids could explain large variations in the values of apparent digestibility of amino acids, since this is expressed as percentages, especially for those amino acids which occur in small levels in grains such as lysine and tryptophan and to those which are found in relatively high concentrations in the endogenous secretions such as threonine, glycine and proline.

Moreover, the differences in the amino acid composition and digestibility may be due to several other factors such as variety of the grain, application of fertilizer and environmental conditions (Mosenthin et al., 2000). These factors alter the total and relative amounts of the major proteins in the seed (albumins, globulins, prolamins and glutelins), resulting in changes in the digestibility of amino acids.

Experiment III: Performance test using corns with different nutritional profiles

In growing and finishing phases the variables DFI, DWG, FGR, BT and LD were similar between the

treatments (Table 8). Similarly, in the finishing phase, the carcass variables (Table 9) were similar ($p>0.05$). This was expected as the fed diets were isonutrient (isocaloric, isophosphoric, isocalcium, isoaminoacidic for lysine, methionine+cystine and threonine). For the formulation of the diets the exact chemical composition and energy values as well as the SID digestible amino acids of the different corns were used. This has permitted the formulation of a diet which complied properly with the nutritional requirements proposed by NRC (1998). Thus, the pigs in the growing and finishing phases showed quite similar performance and carcass characteristics.

These results are consistent with those found by Spurlock et al. (1997), Lima et al. (2003) and Silva et al. (2006) who found no differences in the DFI and DWG of pigs in growing and finishing phases fed with diets containing total replacement of common corn by higher oil content corn.

Most studies evaluating high-oil level corn have been in animals for growing and finishing phases because of its higher energy content (Spurlock et al., 1997; Snow et al., 1998). Normally, pigs over 50 kg of body weight have got a good capacity to use supplemental dietary fat (Adeola and Bajjalieh, 1997; O'Quinn et al., 2000). Besides the age factor, Adeola and Bajjalieh (1997) highlighted the suitability of other dietary nutrients and the nutrient:calorie ratio in order to justify the different responses in performance with the addition of dietary fat.

Table 8. Daily feed intake (DFI), daily weight gain (DWG), feed: gain rate (FGR), backfat thickness at P2 (BT-P2), loin depth (LD) of pigs during the growing and finishing phases and the maximum price of the corn with different nutritional profile (MPC)

Items	Common corn ¹	High-lysine corn ¹	High-oil corn ¹	AV ²
Growing phase				
DFI, kg	1.912±0.080	1.827±0.059	1.942±0.049	NS
DWG, kg	0.784±0.031	0.772±0.029	0.797±0.018	NS
FGR	2.44±0.039	2.38±0.057	2.44±0.051	NS
BT-P2, mm	8.41±0.690	8.58±0.416	8.67±0.512	NS
LD, mm	45.3±1.647	45.8±1.537	44.7±1.644	NS
MPC, R\$	0.41	0.43	0.46	-
Finishing phase				
DFI, kg	2.645±0.112	2.510±0.081	2.630±0.093	NS
DWG, kg	0.956±0.040	0.922±0.317	0.969±0.408	NS
FGR	2.77±0.034	2.73±0.484	2.73±0.060	NS
BT-P2, mm	10.9±0.809	10.4±0.900	10.6±0.514	NS
LD, mm	54.0±0.843	53.5±1.998	53.8±1.548	NS
MPC, R\$	³	⁴	0.48	-

¹ Mean±standard error. ² AV = Analysis of variance. ³ Price of the corn = R\$ 0,41/kg.

⁴ It is economically unviable its replacement for CC; NS = Not significant (p>0.05).

Table 9. Carcass evaluation of finishing pigs fed on diets containing corns with different nutritional profiles

Items ¹	Common corn ²	High-lysine corn ²	High-oil corn ²	AV ³
FW, kg	92.9±1.528	90.3±1.253	92.0±1.331	NS
SW, kg	89.8±1.525	87.8±1.244	89.3±1.312	NS
CL, cm	90.5±0.761	90.4±0.528	89.8±0.771	NS
BT, mm	29.7±0.979	29.4±0.108	28.6±0.106	NS
FL, %	3.33±0.184	2.79±0.275	2.92±0.225	NS
HCW, kg	73.8±1.332	72.6±1.013	73.2±1.224	NS
HCY, %	82.2±0.710	82.7±0.248	82.0±0.331	NS
YL, %	2.60±0.178	2.66±0.733	2.61±0.528	NS
CCW, kg	71.9±1.295	70.7±0.994	71.3±1.193	NS
CCY, %	80.0±0.583	80.5±0.248	79.8±0.329	NS
HW, kg	11.2±0.226	11.1±0.177	11.2±0.163	NS
HY, %	31.2±0.375	31.5±0.219	31.5±0.387	NS
LEA, cm ²	41.5±1.516	42.1±1.082	42.8±1.358	NS
Fat, cm ²	21.7±1.804	21.4±0.881	21.9±1.616	NS
LMC, kg	57.6±1.423	57.3±0.989	58.6±1.287	NS
LMPC, %	78.4±2.429	79.1±1.347	80.1±1.341	NS
M:F	0.53±0.522	0.51±0.247	0.51±0.359	NS
DL, %	2.45±0.386	2.42±0.210	2.71±0.237	NS
MARB	2.20±0.170	1.92±0.193	1.75±0.131	NS

¹ Final weight (FW), slaughter weight (SW), carcass length (CL), backfat thickness (BT), fasting loss (FL), hot carcass weight (HCW), hot carcass yield (HCY), yield loss (YL), chilled carcass weight (CCW), chilled carcass yield (CCY), ham weight (HW), ham yield (HY), loin eye area (LEA), lean meat in the carcass (LMC), lean meat percentage of the carcass (LMPC), meat:fat ratio (M:F), drip loss (DL), marbling of *M. longissimus dorsi* (MARB).

² Mean±standard error. ³ AV = Analysis of variance; NS = Not Significant (p>0.05).

Adeola and Bajjalieh (1997) observed an improvement of 8 to 10% in feed efficiency when studying a high-oil corn as a substitute of a common corn in diets for 25 kg-piglets. However, O'Quinn et al. (2000) found no difference in the performance of weaned piglets fed diets with total substitution of common corn by high-oil and high-protein corns. These authors suggested attention in diet formulation with high-oil and high-protein corn, because the level of lysine increases substantially, but the content of the other amino acids are not increased in proportion to lysine. Thus, tryptophan and threonine are more likely to be deficient when this corn is used and less soybean meal is included in the diet.

In this case a special care was taken when formulating the diets based on the concept of an ideal protein, observing the proportionality of amino acids on lysine as well as the use of true digestible amino acid values of corns with different nutritional profiles.

Results of the carcass evaluation (Table 9) are similar, in part, to those obtained by Lima et al. (2003) and Silva et al. (2006). They found no differences in carcass length, loin eye area, ham percentage, backfat thickness and meat:fat ratio between animals fed diets containing common corn or high-oil corn.

Equations 1, 2, 3 and 4 were developed by using the data of weight gain and feed intake for each type of corn (HLC and HOC) in the diets of growing (from 30 to 60 kg) and finishing (from 60 to 90 kg) pigs, respectively. The purpose of such equations is to estimate the maximum price to be paid for HLC and HOC, analyzing whether they are economically viable in relation to the CC (common corn).

Equation 1, maximum price of HLC in diets for pigs in growing phase: $MPHLC \leq -0.009290 \times PRP - 0.067351 \times PSM + 0.026539 \times PSO - 0.000138 \times PL - 0.000400 \times PDP - 0.000241 \times PSA - 0.000181 \times PMX + 0.000103 \times PLI + 0.001087 \times PM - 0.000003 \times PP$.

Equation 2, maximum price of HOC in diets for pigs in growing phase: $MPHOC \leq +0.007144 \times PRP + 0.032819 \times PSM - 0.007667 \times PSO - 0.000342 \times PL + 0.000420 \times PDP + 0.000090 \times PSA + 0.000068 \times PMX - 0.000123 \times PLI + 0.000703 \times PM + 0.000001 \times PP$.

Equation 3, maximum price of HLC in diets for pigs in finishing phase: $MPHLC \leq -0.011977 \times PRP - 0.020350 \times PSM - 0.000560 \times PSO - 0.000184 \times PL + 0.026883 \times PDP - 0.000195 \times PSA - 0.000073 \times PMX - 0.001283 \times PLI + 0.000750 \times PM - 0.000557 \times PT - 0.000557 \times PP$.

Equation 4, maximum price of HOC in diets for pigs in finishing phase: $MPHOC \leq +0.013287 \times PRP + 0.073030 \times PSM - 0.000267 \times PSO - 0.000402 \times PL - 0.007945 \times PFB + 0.000045 \times PSA + 0.000017 \times PMX - 0.001655 \times PLI + 0.000312 \times PM - 0.000557 \times PT - 0.000557 \times PP$.

Where: MPHLC or MPHOC, maximum price of HLC

or HOC to have the same economic efficiency of the reference diet (CC); PRP, price of the kg of live pigs; PSM, price of the kg of soybean meal; PSO, the price of the kg of soybean oil; PL, price of the kg of limestone; PDP, price of kg of dicalcium phosphate; PSA, price of the kg of salt; PMX, price of the kg of vitamin mineral premix for growing or finishing pigs; PLI, price of the kg of L-lysine; PM, price of the kg of DL-methionine; PT, price of the kg of L-threonine and PP, the price of the growth promoter.

By applying the equations to the current prices during the experiment, the maximum prices for HLC and HOC (Table 8) were obtained at the growing and finishing phases.

Bio economic studies demonstrated the maximum prices paid for the HLC and HOC at the different phases. HOC may have an increase in its price up to 12% for the growing phase and up to 17% for the finishing phase. HLC may have an increase in its price up to 5% for the growing phase; however, in the finishing phase it is economically unviable to substitute the CC.

HLC is a variety which is still under study and despite being rich in protein and amino acids (lysine and threonine), has shown low value for metabolizable energy, which reduces its nutritional and economic efficiency for growing and finishing pigs.

CONCLUSIONS

Values (as-fed basis) for digestible and metabolizable energy for common corn, high-lysine corn and high-oil corn are 3,396 and 3,275 kcal/kg, 3,249 and 3,139 kcal/kg for 3,445 and 3,308 kcal/kg, respectively.

All corns with different nutritional profiles may be used in diets for pigs from 30 to 90 kg of body weight without impairing the performance and carcass traits.

Our results highlighted the importance to segregate corns in their real chemical composition and energy value as well as the values of SID digestible amino acids for the formulation of diets for growing and finishing pigs.

High-oil corn may have an increase in its price up to 12 and 17% for the growing and finishing phase, respectively, while high-lysine corn may have an increase in its price up to 5% for the growing phase, and still remain feasibly.

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