DOI: 10.5216/cab.v14i1.17697

CHEMICAL COMPOSITION AND METABOLIZABLE ENERGY VALUES OF ALTERNATIVE INGREDIENTS FOR BROILERS

MARCOS JOSÉ BATISTA DOS SANTOS[1], MARIA CARMO MOHAUPT MARQUES LUDKE[2], JORGE VITOR LUDKE[3], THAYSA RODRIGUES TORRES[4], LETÍCIA DOS SANTOS LOPES[5], MARIANY SOUZA BRITO[6]

[1]Postgraduation student, Universidade Federal Rural de Pernambuco, Recife, PE, Brazil - marcoszootecnista@gmail.com
[2]Professors, PhD, Universidade Federal Rural de Pernambuco, Recife. PE, Brazil
[3]Researcher, PhD, EMBRAPA-Swine and birds, Concórdia, SC, Brazil.
[4] Postgraduation student, Universidade Federal Rural de Pernambuco, Recife. PE, Brazil.
[5]Analyst at EMBRAPA-Swine and birds, Concórdia, SC, Brazil.
[6]Postgraduation student, Universidade Federal de Paraíba, Bananeiras, PB, Brazil.

ABSTRACT

An experiment was conducted to determine the chemical composition and apparent metabolizable energy (AME) and AME corrected for nitrogen (AMEn) of three types of cottonseed meal (CM): extruded CM, CM by solvent extraction with husk and CM with 40% crude protein (CP), two varieties of sorghum and hominy feed. AMEn values of CM and sorghum from the existing literature were used to create prediction equations using chemical composition. Male Ross broilers at 14 days of age (n=210) were used in a metabolism assay and housed in metabolism cages in groups of five animals with six replicates per treatment. A reference diet (RD) and six test diets containing the ingredients under evaluation replacing 40% of RD constituted the set of established treatments. The chemical composition of the ingredients was as follows: 92.92, 91.80, 89.08, 86.44, 87.19 and 88.50% for dry matter, 32.96, 35.11, 40.50, 9.83, 8.17 and 10.80% for CP, 17.81, 1.03, 3.59, 2.27, 2.67 and 12.90% for ether extract (EE) and the values of AMEn were 2977, 2793, 2827, 2766, 3117 and 3017 kcal/kg, respectively, for extruded CM, CM with hulls, CM with 40% CP, IPA sorghum, Dow sorghum and hominy feed. The established AMEn equation for CM was -9,158.67 + 1,106.94*CP - 12.05*CP*CP - 1,866.99*Ash + 100.16*Ash*Ash - 834.01*Crude Fiber (CF) + 30.43*CF*CF and for sorghum was 4,365.59 + 175.41*CP - 10.35*CP*CP - 99.55*EE + 525.34*Ash - 85.06*Ash*Ash - 1,310.47*CF + 251.61*CF*CF. AMEn values of one sorghum and one CM type did not adjust to the prediction equations established.

KEYWORDS: cotton seed meal; hominy feed; metabolism; prediction equations; sorghum.

COMPOSIÇÃO QUÍMICA E VALORES DE ENERGIA METABOLIZÁVEL DE INGREDIENTES ALTERNATIVOS PARA FRANGOS DE CORTE

RESUMO

Um experimento foi realizado para determinar a composição química e os valores de energia metabolizável aparente (EMA) e EMA corrigida para nitrogênio (EMAn) de três tipos de farelo de algodão (FA): FA extrusado, FA com extração por solvente com casca e FA com 40% de proteína bruta (PB); duas variedades de sorgo e farelo residual de milho (FRM). Valores de EMAn do FA e do sorgo da literatura foram usados para estabelecer equações de predição através da composição nutricional. Pintos de corte machos Ross (n=210) foram alojados com seis repetições por tratamento e cinco aves por gaiola. Foi utilizada uma ração-referência (RR) e seis rações-teste contendo os ingredientes a avaliar em substituição de 40 % da RR. A composição química dos ingredientes foi: 92,92; 91,80; 89,08; 86,44; 87,19; 88,50% de matéria seca; 32,96; 35,11; 40,50; 9,83; 8,17 e 10,80% de PB, 17,81; 1,03; 3,59; 2,27; 2,67 e 12,90% de extrato etéreo (EE) e os valores de EMAn foram 2977, 2793, 2827, 2766, 3117 e 3017 kcal/kg para o FA extrusado, FA com casca, FA com 40% PB, sorgo IPA, sorgo Dow e FRM, respectivamente. A equação de EMAn para o FA foi -9158,67 + 1106,94*PB - 12,05*PB*PB - 1866,99*Cinzas (CZ) + 100,16*CZ*CZ - 834,01*Fibra Bruta (FB) + 30,43*FB*FB e para o sorgo foi 4365,59 + 175,41*PB - 10,35*PB*PB - 99,55*EE + 525,34*CZ - 85,06*CZ*CZ - 1310,47*FB + 251,61*FB*FB. Os valores de EMAn de uma variedade de sorgo e um tipo de FA não se ajustaram às equações de predição estabelecidas.

PALAVRAS-CHAVE: equações de predição; farelo de algodão; farelo residual de milho; metabolismo; sorgo.

INTRODUCTION

In the Brazilian poultry industry, feeding expenses account for about 60-75% of total costs, being most of it represented by corn and soybean meal. The lack of technical information limits or even prevents the use of alternative food sources (MURAKAMI et al., 2009), thus further studies to allow the partial or complete replacement of the most expensive ingredients contribute to the viability of production.

Cottonseed meal (CM) is a potential ingredient and it can be used as a protein source in diets for broilers under low (OJEWOLA et al., 2006), medium (PIMENTEL et al., 2007) and high (SANTOS et al., 2008) performance conditions. The use of CM for poultry is restricted by the lysine limitation (AZMAN & YILMAZ, 2005), high crude fiber content and the presence of gossypol, but it becomes viable when combined with other protein ingredients to enhance the protein value of feed and substitute protein sources of animal origin. The by-products resulting from the cotton seed processing for oil extraction represent, with a relative availability of 6%, the third most important source of oilseed protein for animal feed in the world (NAGALAKSHMI et al., 2007; USDA, 2011). In Brazil, the estimated current production is 3.2 million tons of cottonseed (CONAB, 2011). The processing form applied to cottonseed provides various types of meal that differ from each other in the protein, fiber and residual oil content (WALDROUP & KERSEY, 2002).

Sorghum is an important grass in semi-arid regions because of its xerophilous characteristics and greater adaptability than corn to harsh conditions of lower water availability and high daytime temperature (SANCHEZ et al., 2002). The estimated sorghum grain production (CONAB, 2011) is 2.3 million tons, representing approximately 4.4% of the annual corn production in Brazil. The grain presents similar nutritional characteristics as corn regarding metabolizable energy (SEDGHI et al., 2011), and higher crude protein content depending on the environment and soil fertility (DOUGLAS et al., 1990; ANTUNES et al. 2006). As a disadvantage, it has lower levels of some amino acids (arginine, glycine and histidine) and fewer pigments than corn (GARCIA et al., 2005) and presents phenolic compounds, phytate and kafirin. Kafirin has a negative correlation with amino acid digestibility and the true metabolizable energy corrected for nitrogen (TMEn) (BYRDEN et al., 2009). Additionally, the digestibility of amino acids and carbohydrates in the digestive tract of birds is smaller and slower than the digestibility of corn because of the protein:carbohydrate complex in the endosperm, impairing the feed conversion of broilers (BYRDEN et al., 2009).

The residual corn (RCM) is a byproduct of industrialization of corn for human consumption. This ingredient generated in the dry processing corresponds to one third of the industrial corn and comprises bark, germ and starch portions extracted from the grain, and presents a minimum of 4% of oil (BRUM et al. 2000). According to statistical estimates (ABIMILHO, 2011), the estimated annual RCM availability in the country is 1.1 million tons, being traditionally used as feed for dairy cattle. However, with the widespread use of enzymes in diets for broilers (ADEOLA et al., 2010), there is also an expectation for the partial replacement of corn by RCM (KACZMAREK et al., 2009).

These alternative ingredients show potential use in poultry production, but producers still considered their inclusion in rations unsafe due to uncertainties about their nutritional value. Therefore, this experiment was conducted with the following objectives: a) to determine the chemical composition and apparent metabolizable energy (AME) and AME corrected for nitrogen balance (AMEn) of RCM, of two varieties of sorghum and three types of CM from different processing methods, and b) to establish prediction equations for AME of sorghum and CM by using the results obtained and literature data.

MATERIAL E MÉTODOS

The experiment was conducted at the research laboratory of metabolism of non-ruminant animals of the department of Animal Sciences, Federal Rural University of Pernambuco (DZ/UFRPE). We collected the ingredients – sorghum grain of two varieties, residual corn meal (RCM), cottonseed meal (CM) submitted to different processing methods (extruded CM, CM with bark and CM with 40% crude protein) – and analyzed them at the laboratory of Animal Nutrition of the DZ/UFRPE for dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF), ash (A), calcium, phosphorus and gross energy using the methodologies described by SILVA & QUEIROZ (2002). The calculation of non-nitrogenous extractive (NNE), expressed on natural matter basis, was performed using the formula:

NNE = 100 - [(DM-100) - A - CF - CP - EE].

Subsequently, we developed a metabolism trial, using male Ross broiler chicks, to determine the apparent metabolizable energy (AME) and AME corrected for nitrogen balance (AMEn) of ingredients. We used the method of total excreta collection, as described by HILL & ANDERSON (1958), using the correction factor of 8.22 kcal / g for nitrogen retention. We determined the AME and AMEn of the ingredients using the equations proposed by MATTERSON et al. (1965).

We housed 210 day-old chicks in battery cages, each consisting of six cages, in a climatized metabolism room, under continuous lighting (24 hours / day) and average temperature of 23.5 ± 2.8 °C. The cages were provided with feeders and drinkers with trays covered with plastic, arranged to collect the excreta per experimental unit. We divided the birds at 14 days of age and with an average weight of 396 ± 10g into seven treatments with six replications in randomized blocks and five birds per experimental unit. The seven treatments consisted of a reference diet based on corn and soybean meal as shown in Table 1, and the six test diets contained 60% of the reference diet and 40% of the ingredient under evaluation. The nutritional composition of the reference diet was obtained from a standard table (ROSTAGNO et al., 2011).

We provided water and mash feeds *ad libitum*. The adaptation period of the birds to the diets lasted five days, followed by five more days for total collection. We used ferric oxide powder as fecal marker, homogenized into the experimental diets at a ratio of 0.1%, to determine the beginning and end of the excreta collection. We collected the excreta twice a day, at 8:00 a.m. and at 4:00 p.m. During data collection, we packed the material in plastic bags, then properly identified and stored the bags in a freezer at a temperature of -20 ºC until the end of the experiment, when the samples were homogenized per experimental unit. We sent representative samples of feed and excreta to the laboratory for analyses of dry matter, crude protein and gross energy.

Table 1. Basal diet composition[1]

Ingredients	%
Ground Corn Grain (2 mm sieve)	59.34
Soybean meal	34.36
Soybean oil	2.29
Dicalcium phosphate	1.8
Limestone	0.89
Iodized salt	0.49
DL-methionine 99%	0.24
L-lysine (78.8%)	0.19
Vitamin premix[2] and micro-mineral[3]	0.40
Total	100.00

[1]Energy and nutritional composition: 3000 kcal ME / kg; 20.79% crude protein; 0.88% calcium; 0.45% available phosphorus; 0.81% methionine + cystine; 0.56% methionine; 1.24% lysine, and 0.21% sodium. [2]Concentration levels per kg of diet: vit. A - 15,000 IU; vit. D_3 – 1,500 IU; vit. E -15 IU; vit. B_1 – 2.0 mg; vit. B_2 – 4.0 mg; vit. B_6 – 3.0 mg; pantothenic acid – 10.0 mg; vit. K_3 – 3.0 mg; folic acid – 1.0 mg; nicotinic acid – 25.0 mg; vit. B_{12} – 15 µg; biotin - 120 µg; cholin - 500 mg and selenium - 250 µg. [3]Concentration levels per kg of diet: Mn - 24.0 mg; Fe - 24.0 mg; Zn - 15.0 mg; Cu - 3.0 mg; Co - 0.60 mg; and I - 0.30 mg .

We established the prediction equations of sorghum and CM apparent metabolizable energy using data published in national and international food composition tables. To perform the multiple linear regression analyses of prediction, we used the linear and quadratic components of the values of the chemical composition (EE, CF, CP, A) expressed on dry matter basis. Regression analyses were performed using Stepwise indirect elimination method (Backward) and SAS (2008). In each equation, the variables were maintained with significant effects at 5% probability by T test, and when the mean quadratic component was significant, the linear component was also kept in the equation. The use of NNE values in equations was restricted to reduce collinearity effects. After the establishment of the initial equations with the selection of the predictor variables for the initial data set that generated the equation, we compared the predicted value with the value determined in the metabolism trial or the tabulated value. After defining the equation by the criteria of adjusted R^2 and of t test for the estimated coefficients, we also adopted additional restriction criteria based on the extent of the difference between actual and predicted values. As a criterion, we established that the difference between these values for the ingredients could not be greater than 1% of the AMEn of the diets (28-32 kcal) when the level of inclusion is optimum, in case of energy ingredient, and 0.5% (14-16 kcal) in case of proteic ingredient. Thus, to include a particular data source to the final prediction analysis we adopted restriction criteria of maximum deviation between predicted and actual values of 50 kcal for sorghum (considering 56% of inclusion to the diet for broilers) and 75 kcal for CM (18% of inclusion to the diet).

RESULTS AND DISCUSSÃO

The types of cottonseed meal we evaluated present particular nutritional characteristics, which are the result of the processing methods. Extruded CM presents low relative CF content (7.56%), due to the withdrawal of the bark, and high EE content (17.81%), due to the loss of a small fraction of oil during extrusion, so the CP content (32.96%) is intermediate between the content present in the unprocessed cottonseed and the one present in the high-protein meal (Table 2). The CM bark obtained via solvent extraction has an EE concentration of only 1.03% and CF content of 15.94% due to the partial addition of the bark. The high protein CM (40.5%) presents a CF content of 11.9% resulting from the partial addition of bark after oil extraction by screw-press. In the process, residual oil content remains and the EE concentration is 3.59%. This CM presents similar CF and CP concentration to the findings by EMBRAPA (1991), but the EE content is twice higher. The CM with bark presents close CF and EE concentrations to the results reported by ROSTAGNO et al. (2005; 2011), but in this case, the CP concentration is lower.

As a general rule, the EE concentration in cottonseed cake, resulting from mechanical extraction via hydraulic press, is between 4% and 8%. However, when it results from screw-press processing, cottonseed cake maintains EE content between 3% and 5%. By solvent extraction, the meal has less than 3% of residual oil, and the content is usually close to 1%. WALDROUP & KERSEY (2002) reported the nutritional composition of cottonseed meal or cake obtained by solvent or mechanical extraction from 16 U.S. factories and specified that, due to different kinds of management, the highest variability occurs in CF and EE concentrations. The CM evaluated in this study presented 0.12% of maximum total gossypol.

Table 2. Chemical composition of extruded cottonseed meal (CM), CM by solvent extraction and with bark and CM with 40% crude protein (CP), IPA sorghum, Dow sorghum and residual corn meal with the values of dry matter (DM), crude protein (CP), ether extract (EE), crude fiber (CF), ash (A), calcium (Ca) and phosphorus (P), expressed in percentage, and gross energy (GE) expressed in kcal / kg on fresh matter basis

Ingredient	DM	CP	EE	CF	A	GE	Ca	P
Extruded CM	92.92	32.96	17.81	7.56	4.80	5365	0.11	0.78
CM with bark	91.80	35.11	1.03	15.94	5.02	4287	0.10	0.76
CM with 40% CP	89.08	40.50	3.59	11.90	5.54	4655	0.12	0.94
IPA Sorghum	86.44	9.83	2.27	1.76	1.07	3903	0.02	0.20
Dow Sorghum	87.19	8.17	2.67	1.79	0.72	3829	0.01	0.23
Residual corn meal	88.50	10.80	12.90	5.04	3.90	4638	0.01	0.85

The sorghum grains evaluated belong to the genetic group I (tannin-free): IPA 7301011®, which is white and presents tannin below 0.10%, and Dow Agroscience® 822, which is red. Both varieties present testa layer (sublayer below pericarp) without pigmentation. Dow sorghum presented lower CP content than IPA sorghum and lower than the values tabulated by ROSTAGNO et al. (2005, 2011) and NRC (1994). The concentration of CF, EE and A in both Dow and IPA sorghum was lower than the values tabulated by NRC (1994) and ROSTAGNO et al. (2011). The amount of GE of IPA sorghum is similar to the value tabulated by ROSTAGNO et al. (2011), while Dow sorghum has a concentration of about 100 kcal/kg lower than the tabulated value.

The RCM presented a nutrient composition similar to the one described for the corn germ meal (ROSTAGNO et al., 2011). The CP and CF values were similar to the ones described by NRC

(1994); however, EE was much higher than the values published by NRC (1994) and BRUM et al (2000).

The AMEn values calculated were, on average, 4.84% lower than the AME values (Table 3). This difference characterizes the extent of nitrogen retention by birds. A correction by nitrogen balance aims to standardize and reduce the variation in AME of ingredients measured and applied in different conditions (LOPEZ & LEESON, 2008). According to these authors, the AME and AMEn values for corn are little affected by the age of the chickens and the correction for nitrogen retention was consistent at 3%. The sorghum cultivars evaluated showed a high difference between them, which is potentially related to differences in CP content. The coefficients of energy metabolism (CEM = 100* AMEn/GE) were influenced by the type of processing applied in different CM and the calculated values were higher than those reported by ROSTAGNO et al. (2011), ranging from 40.3 to 46.7% for CM derived by solvent extraction with high (24.93%) and low (13.97%) concentration of CF. However, the values were close to the value of 58.8% for CM with 12.96% CF established by BRUMANO et al. (2006) for broilers with an average age of 45 days. The CEM for the CM extracted by solvent with low content of CF (11.98%), calculated from EMBRAPA (1991), is 52.5%.

The CEM value of Dow sorghum is similar to the ones calculated by NAGATA et al. (2004), with 80% for ground grain and 81% for whole grain; by NUNES et al. (2008) with 81.1%; and by ROSTAGNO et al. (2011) with 81.5%. These CEM values contrast with the one calculated for IPA sorghum, which was closer to the values (74.8%) calculated from the data by BRUM et al. (2000). For RCM, CEM value was close to the one reported (69.0%) by BRUM et al. (2000); however, it is lower than the calculated values presented in NAGATA et al. (2004), 72.7%, and in ROSTAGNO et al. (2011), 74.0%, for corn germ.

The value of 2977 kcal AMEn/kg determined for extruded CM was higher than the values established by the national (ROSTAGNO et al., 2011) and international tables (NRC, 1994), which are 1947 and 1657 kcal/kg, respectively. However, the EE concentration of extruded CM was much higher than the EE values of the CM presented in the tables, and the removal of the bark allowed a lower value of CF than at the tables.

BRUMANO et al. (2006) conducted a metabolism trial using broilers aged between 41 and 50 days, and established the value of 2461 kcal AMEn/kg for CM, which is significantly different from the value determined for the age between 21 and 30 days (1963 kcal/kg). SHARMA et al. (1978) determined a value of 2601 kcal AMEn/kg for CM with 89% DM, 12.5% CF and 7.4% EE, originated by the controlled extraction via press. The CM with 40% CP with AMEn of 3173 kcal/kg of DM did not show the expected adjustment to the equation presented in Table 4. The factors that contribute to variation on energy values in metabolism trials are related to the food: physico-chemical composition, processing, digestibility and antinutritional factors; to the animals: genetics, age and sex; to methodology: trial duration, level of inclusion of the food, reference diet composition, consumption rate; and to the environment (SOARES et al., 2005; LOPEZ & LEESON, 2008; ADEOLA & ILELEJI, 2009).

Table 3. Average values for dry matter (DM), coefficient of energy metabolism (CEM), apparent metabolizable energy (AME) and AME corrected for nitrogen (AMEn) of three kinds of cottonseed meal (CM), two sorghum cultivars and residual corn meal (RCM)

Ingredient	DM (%)	CEM (%)	AME (kcal/kg)	AMEn (kcal/kg)	Difference (%) AME and EMAn
Extruded CM	92.92	55.5	3131±58.2	2977±60.4	4.92
CM with bark	91.80	65.2	2944±27.7	2793±22.1	5.13
CM with 40% CP	89.08	60.7	3016±59.2	2827±72.2	6.27
IPA Sorghum	86.44	70.9	2908±44.1	2766±45.3	4.88
Dow Sorghum	87.19	81.4	3206±15.3	3117±64.3	2.78
Residual corn meal	88.50	65.0	3178±42.3	3017±32.2	5.07

Regarding IPA sorghum, AMEn was below the expected value, disagreeing with ROSTAGNO et al. (2011) and NRC (1994), which presented values of 3189 and 3288 kcal / kg, respectively. The result for the variety of AMEn is close to what is displayed at the tables. NAGATA et al. (2004) determined the values of 3137 and 3177 kcal AMEn/kg, respectively, for ground sorghum and whole grain sorghum, showing 88.90% of DM. However, BRUM et al. (2000) showed the value of 2954 kcal AMEn/kg for low tannin sorghum. IPA sorghum with AME of 3200 kcal/kg of DM showed lack of adjustment to the equation presented in Table 4. There are intrinsic factors to the grains of different types of sorghum, regarding especially the endosperm texture (ANTUNES et al., 2006), which interfere with the digestibility of starch (BENMOUSSA et al., 2006) and protein (DUODU et al., 2003), affecting their actual nutritional value for broilers (KRIEGSHAUSER et al., 2006; SALINAS et al., 2006). Environmental factors, such as water deficit during grain filling, can affect their nutritional value, which invalidates the comparison between different varieties produced in different climatic conditions.

Table 4. Equations for estimating the amount of apparent metabolizable energy corrected for nitrogen retention (AMEn) expressed based on dry matter for sorghum and cottonseed meal

Ingredient		Sorghum (n=19)		Cottonseed meal (n=13)	
Component	Parameter*	Coefficient	Prob	Coeficiente	Prob
	Constant	4365.59	<0.0001	-9158.67	0.0013
Crude Protein	L	175.41	0.0744	1106.94	<0.0001
	Q	-10.35	0.0182	-12.05	<0.0001
Ether Extract	L	-99.55	0.0008	-	-
	Q	-	-	-	-
Ashes	L	525.34	0.0002	-1866.99	<0.0001
	Q	-85.06	0.0036	100.16	<0.0001
Crude Fiber	L	-1310.47	<0.0001	-834.01	<0.0001
	Q	251.61	<0.0001	30.43	<0.0001
Prob. of the regression model		p<0.0001		p<0.0001	
Coefficient of determination		0.9619		0.9908	
Mean prediction error (kcal)		19.63		22.41	
Maximun prediction error (kcal)		44.8		75.5	
Difference between estimated and determined**		31 kcal		5 kcal (1) and 13 kcal (2)	

* L = Linear, Q = Quadratic. The parameters that multiply the coefficients present values expressed on dry matter basis. The probability presented refers to each of the significant parameters. ** Dow sorghum with AMEn value of 3575 kcal/kg DM and CM with determined AMEn values of (1) 3204 kca/kg DM (extruded CM) and (2) 3042 kcal/kg DM (CM with bark).

The calculated value of AMEn for RCM was close to the one (3040 kcal/kg) reported by BRUM et al. (2000), but it was lower than the value (3144 kcal/kg) presented by ROSTAGNO et al. (2011) for corn germ and higher than the value (2896 kcal/kg) presented by NRC (1994) for hominy feed. By adopting the equation AMEn = 3839.5 + 53.80 x EE - 264.46 x MM, proposed by NASCIMENTO et al. (2009), to estimate the AMEn values of energy concentrate feed for birds, the estimated value for RCM is 3060 kcal/kg (on natural matter basis), with a difference of 43 kcal/kg, representing 1.4%. ROCHELL et al. (2011) argues that the use of GE, CP and neutral detergent fiber as parameters to estimate corn byproducts produce more accurate estimates.

Pearson’s correlation coefficient between CP concentration and AMEn of sorghum was significant, indicating that as the level of CP increased, the value of AMEn decreased (Table 5). This result corroborates those obtained by BRYDEN et al. (2009), who characterized a negative correlation between TMEn and CP levels in sorghum, which is conditioned by the formation of low digestibility complexes between kafirin and carbohydrates. For CM, significant Pearson’s correlation coefficients for AME were the EE, positively correlated, and the A, negatively correlated.

Table 5. Pearson's correlation coefficient and significance levels among the components of the nutritional composition and AMEn for sorghum and cottonseed meal

Ingredient	Sorghum (n=19)		Cottonseed meal (n=13)	
	AMEn	p =	AMEn	p =
Crude Protain	-0.5621	0.0123	-0.1561	0.6105
Ether Extract	0.0859	0.7266	0.609	0.0272
Ashes	0.2109	0.3862	-0.5449	0.0542
Crude Fiber	0.3879	0.1008	-0.3888	0.1892

The results presented in Tables 4 and 5 taken together enable us to interpret CP, CF and A in association with their linear and quadratic components in the prediction equation of AMEn for CM, and to explain the isolated effect EE would have.

CONCLUSIONS

AMEn values determined for the types of cottonseed meal evaluated are different from the values reported in the literature, reflecting differences in the adopted processing technology, which alters the nutritional composition. Regarding sorghum, IPA variety presented lower AMEn value than expected, which characterizes that the grain was produced under water stress condition. The AMEn equation established for the CM was -9158.67 + 1106.94*CP - 12.05*CP*CP - 1866.99*A + 100.16*A*A - 834.01*CF + 30.43*CF*CF, and for sorghum, 4365.59 + 175,41*CP – 10.35*CP*CP – 99.55*EE + 525.34*A – 85.06*A*A – 1310.47*FB + 251.61*CF*CF. The use of prediction equations based on the nutritional composition and on the imposed restrictions does not allow the estimation of AMEn for one variety of sorghum and one type of CM evaluated.

REFERENCES

ABIMILHO – ASSOCIAÇÃO BRASILEIRA DAS INDÚSTRIAS DE MILHO. **Estatística** – Consumo por processo. Disponível em: www.abimilho.com.br. Acesso: 12 de outubro de 2011.

ADEOLA, O.; ILELEJI, K. E. Comparision of two diet types in the determination of metabolizable energy content of corn distillers dried grains with solubles for broiler chickens by the regression method. **Poultry Science**, v.88, n. 3, p. 579-585, 2009.

ADEOLA, O.; JENDZA, J. A.; SOUTHERN, L. L.; POWELL, S.; OWUSU-ASIEDU, A. Contribuition of exogenous dietary carbohidrases to the metabolizable energy value of corn distillers grains for broiler chickens. **Poultry Science**, v. 89, n. 7, p. 1947-1954, 2010.

ANTUNES, R. C.; RODRIGUEZ, N. M.; GONÇALVES, L. C.; RODRIGUES, J. A. S.; BAIÃO, N. C.; PEREIRA, L. G. R.; LARA, L. J. Valor nutritivo de grãos de sorgo com diferentes texturas do endosperma para frangos de corte. **Arquivos Brasileiros de Medicina Veterinária e Zootecnia**, v. 58, n. 5, p. 877-883, 2006.

AZMAN, M. A.; YILMAZ, M. The growth performance of broiler chicks fed diets containing cottonseed meal supplemented with lysine. **Revue Medecine Veterinaire**, v. 156, n. 2, p. 104-106, 2005.

BENMOUSSA, M.; SUHENDRA, B.; ABOUBACAR, A.; HAMAKER, B. R. Distinctive sorghum starch granule morphologies appear to improve raw starch digestibility. **Starch-Stärke**, v. 58, n. 2, p. 92-99, 2006.

BRUM, P. A. R.; ZANOTTO, D. L.; LIMA, G. J. M. M.; VIOLA, E. S. Composição química e energia metabolizável de ingredientes para aves. **Pesquisa Agropecuária Brasileira**, v. 35, n. 5, p. 995-1002, 2000.

BRUMANO, G.; GOMES, P. C.; ALBINO, L. F. T.; ROSTAGNO, H. S.; GENEROSO, R. A. R.; SCHMIDT, M. C. Composição química e valores de energia metabolizável de alguns alimentos protéicos determinados com frangos de corte em diferentes idades. **Revista Brasileira de Zootecnia**, v. 35, n. 6, p. 2297-2302, 2006.

BRYDEN, W. L.; SELLE, P. H.; CADOGAN, D. J.; LI, X.; MULLER, N. D.; JORDAN, D. R.; GIDLEY, M. J.; HAMILTON, W. D. **A review of the nutritive value of sorghum for broilers**. RIRDC Publication N° 9/007, 68 p., 2009.

CONAB – COMPANHIA NACIONAL DE ABASTECIMENTO. **Acompanhamento da safra brasileira**: Primeiro levantamento da produção de grãos safra 2011/2012. Outubro de 2011. CONAB, Brasília, 2011, 40 p. Disponível em www.conab.gov.br. Acesso: 12 de outubro de 2011.

DOUGLAS, J. H.; SULLIVAN, T. W.; BOND, P. L.; STRUWE, F. J. Nutrient composition and metabolizable energy values of selected grain sorghum varieties and yellow corn. **Poultry Science**, v. 69, n. 6, p. 1147-1155, 1990.

DUODU, K.; TAYLOR, J. R. N.; BELTON, P. S.; HAMAKER, B. R. Factors affecting sorghum protein digestibility. **Journal of Cereal Science**, v. 38, n. 2, p.117-131, 2003.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA. Centro Nacional de Pesquisa de Suínos e Aves. **Tabela de composição química e valores energéticos de alimentos para suínos e aves**. 3 ed. Concórdia, SC: EMBRAPA – CNPSA, Série Documentos, n. 19, 97 p., 1991.

GARCIA, R. G.; MENDES, A. A.; COSTA, C.; PAZ, I. C. L. A.; TAKAHASHI, S. E.; PECÍLIA, K. P.; KOMIYAMA, C. M.; QUINTEIRO, R. R. Desempenho e qualidade da carne de frangos de corte alimentados com diferentes níveis de sorgo em substituição ao milho. **Arquivo Brasileiro de Medicina Veterinária e Zootecnia**, v. 57, n. 5, p. 634-643, 2005.

HILL, F. W.; ANDERSON, D. L. Comparation of metabolizable energy and productive energy determination with growing chicks. **The Journal of Nutrition**, v. 64, n. 4, p. 587-608, 1958.

KACZMAREK, S.; BOCHENEK, M.; JÓZEFIAK, D.; RUTKOWSKI, A. Effect of enzyme supplementation of diets based on maize or hominy feed on performance and nutrient digestibility in broilers. **Journal of Animal and Feed Sciences**, v. 18, n. 2, p. 113-123, 2009.

KRIEGSHAUSER, T. D.; TUINSTRA, M. R.; HANCOCK, J. D. Variation in nutritional value of sorghum hybrids with contrasting seed weight characteristics and comparisions with maize in broiler chicks. **Crop Science**, v. 46, n. 2, p. 695-699, 2006.

LOPEZ, G.; LEESON, S. Assessment of the nitrogen correction factor in evaluating metabolizable energy of corn and soybean meal in diets for broilers. **Poultry Science**, v. 87, n. 2, p. 298-306, 2008.

MATTERSON, L. D.; POTTER, L. M.; STUTS, M. W.; SINGSEN, E. P. **The metabolizable energy of feed ingredients for chickens**. Storrs: Connecticut, the University of Connecticut. Agricultural Experiment Station, Research Report, n. 7, 1965, 11p.

MURAKAMI, A. E.; SOUZA, L. M. G.; MASSUDA, E. M.; ALVES, F. V.; GUERRA, R. H.; GARCIA, A. F. Q. Avaliação econômica e desempenho de frangos de corte alimentados com diferentes níveis de milheto em substituição ao milho. **Acta Scientiarum. Animal Sciences**, v. 31, n. 1, p. 31-37, 2009.

NAGALAKSHMI, D.; RAO, S. V. R.; PANDA, A. K.; SASTRY, V. R. B. Cotton meal in poultry diets: A Review. **The Journal of Poultry Science**, v. 44, n. 2, p.119-134, 2007.

NAGATA, A. K.; RODRIGUES, P. B.; FREITAS, R. T. F.; BERTECHINI, A. G.; FIALHO, E. T. Energia metabolizável de alguns alimentos energéticos para frangos de corte, determinada por ensaios metabólicos e por equações de predição. **Ciência e Agrotecnologia**, v.8, n. 3, p. 668-677, 2004.

NASCIMENTO, G. A. J.; RODRIGUES, P. B.; FREITAS, R. T. F.; BERTECHINI, A. G.; LIMA, R. R.; PUCCI, L. E. A. Equações de predição para estimar valores da energia metabolizável de alimentos energéticos para aves utilizando meta-análise. **Revista Brasileira de Zootecnia**, v. 38, n. 7, p. 1265-1271, 2009.

NATIONAL RESEARCH COUNCIL. **Nutrient Requirements of Poultry**. Ninth Revised Edition, Washington D.C.: National Academy Press, 1994, 155 p.

NUNES, R. V.; ROSTAGNO, H. S.; GOMES, P. C.; NUNES, C. G. V.; POZZA, P. C.; ARAUJO, M. S. Coeficientes de metabolizabilidade da energia bruta de diferentes ingredientes para frangos de corte. **Revista Brasileira de Zootecnia**, v. 37, n. 1, p. 89-94, 2008.

OJEWOLA, G. S.; UKACHUKWU, S. N.; OKULONYE, E. I. Cottonseed meal as substitute for soyabean meal in broiler ration. **International Journal of Poultry Science**, v. 5, n. 4, p. 360-364, 2006.

PIMENTEL, A. C. S.; DUTRA JÚNIOR, W. M.; LUDKE, M. C. M. M.; LUDKE, J. V.; RABELLO, C. B. V., FREITAS, C. R. G. Substituição parcial do milho e farelo de soja por sorgo e farelo de caroço de algodão extrusado em rações de frangos de corte. **Acta Scientiarum. Animal Sciences**, v. 29, n. 2, p. 135-141, 2007.

ROCHELL, S. J.; KERR, B. J.; DOZIER III, W. A. Energy determination of corn co-products fed to broiler chicks from 15 to 24 days of age, and use of composition analysis to predict nitrogen-corrected apparent metabolizable energy. **Poultry Science**, v. 90, n. 10, p.1999-2007, 2011.

ROSTAGNO, H. S.; ALBINO, L. F. T.; DONZELE, J. L.; GOMES, P. C.; OLIVEIRA, R. F.; LOPES, D. C.; FERREIRA, A. S.; BARRETO, S. L. T. **Tabelas brasileiras para aves e suínos**: composição de alimentos e exigências nutricionais de aves e suínos. 2ª edição, Viçosa, MG: UFV, 186 p., 2005.

ROSTAGNO, H. S.; ALBINO, L. F. T.; DONZELE, J. L.; GOMES, P. C.; OLIVEIRA, R. F.; LOPES, D. C.; FERREIRA, A. S.; BARRETO, S. L. T.; EUCLIDES, R. F. **Tabelas brasileiras para aves e suínos**: composição de alimentos e exigências nutricionais de aves e suínos. 3ªedição, Viçosa, MG: UFV, 252 p., 2011.

SALINAS, I.; PRÓ, A.; SALINAS, Y.; SOSA, E.; BECERRIL, C. M.; CUCA, M.; CERVANTES, M.; GALEGOS, J. Compositional variation amongst sorghum hybrids: Effect of Kafirin concentration on metabolizable energy. **Journal of Cereal Science**, v. 44, n. 3, p. 342-346, 2006.

SANCHEZ, A. C.; SUBUDHI, P. K.; ROSENOW, D. T.; NGUYEN, H. T. Mapping QTLs associated with drought resistance in sorghum (*Sorghum bicolor* L. Moench). **Plant Molecular Biology**, v. 48, n. 5-6, p. 713-726, 2002.

SANTOS, A. P. S. F.; LUDKE, M. C. M. M.; LUDKE, J. V.; FRAIHA, M.; OLIVEIRA, E. L.; TORRES, T. R.; SANTOS, M. J. B.; VILELA, M. R. O. Carcass traits of broilers feed with cottonseed meal. **Archivos de**

Zootechnia, v. 57, n. 217, p. 15-24, 2008.

SAS INSTITUTE INC. System for Microsoft Windows, Release 9.2 - Standard Edition, Cary, NC, USA, 2002-2008. (CD-ROOM).

SEDGHI, M.; EBADI, M. R.; GOLIAN, A.; AHMADI, H. Estimation and modeling true metabolizable energy of sorghum grain for poultry. **Poultry Science**, v. 90, n. 5, p.1138-1143, 2010.

SHARMA, N. K.; LODHI, G. N.; ICHHPONANI, J.S. Comparative feeding value of expeller-processed undecorticated and decorticated cottonseed cakes for growing chicks. **Journal of Agricultural Science**, v. 91, n. 3, p. 531-541, 1978.

SILVA, D. J.; QUEIROZ, A. C. **Análise de alimentos**: métodos químicos e biológicos. 3.ed. Viçosa, MG: Editora UFV, 235 p., 2002.

SOARES, K. R.; BERTECHINI, A. G.; FASSANI, E. J.; RODRIGUES, P. B.; FIALHO, E. T.; GERALDO, A.; BRITO, J. A. G. Valores de energia metabolizável de alimentos para pintos de corte na fase pré-inicial. **Ciência e Agrotecnologia**, v. 29, n. 1, p. 238-244, 2005.

USDA - UNITED STATES DEPARTMENT OF AGRICULTURE. **Oilseeds**: World markets and trade. USDA Foreign Agricultural Service: Circular Series, FOP 10-11, 33 p., 2011.

WALDROUP, P. W.; KERSEY, J. H. Nutrient composition of cottonseed meal surveyed. **Feedstuffs**, v.74, n. 45, p. 11-12, 2002.

Protocolado em: 27 mar. 2012. Aceito em: 30 nov. 2012.