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Metabolizable energy values of soybean meals and soybean oil for broilers at different ages

Antônio Gilberto Bertechini[1*], Reinaldo Kanji Kato[1], Luís Filipe Villas-Bôas de Freitas[1], Robert Talles da Costa Castro[1] and Helenice Mazzuco[2]

[1]Departamento de Zootecnia, Universidade Federal de Lavras, s/n, 37200-000, Lavras, Minas Gerais, Brazil. [2]Empresa Brasileira de Pesquisa Agropecuária, Embrapa Suínos e Aves, Concórdia, Santa Catarina, Brazil. *Author for correspondence. E-mail: bertechini@dzo.ufla.br

ABSTRACT. One trial with six analyses of different diets at different ages was carried out to determine the values of apparent (AME), corrected (AMEn), true (TME) and true corrected (TMEn) metabolizable energy of SBM and SBO for broiler chickens from 1 to 42 days of age. Three Brazilian SBM samples and one SBO were evaluated by replacing part of the basal diet with the test ingredient (300 g kg^{-1} for SBM and 100 g kg^{-1} for SBO). A total of 1.368 one-day-old male Ross 308 birds were assigned into 36 metabolic cages according to weight in a completely randomized experimental design with six replicates for each test ingredient and basal diet. Six more replicates of fasted birds were used for the determination of metabolic energy and N losses at each age. Four days of adaptation followed by three days of excreta collection for energy measurement. The birds were reared until each age, in solid floor pens with a corn/soybean basal diet. The total excreta collection method was used. The AME, AMEn, TME and TMEn of SBM and SBO increased ($p < 0.05$) until 28 days and after this time no difference ($p > 0.05$) was observed.

Keywords: broiler feed; corrected metabolizable energy; soy products; true metabolizable energy.

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Introduction

In general, the energy values used for poultry feed formulation are obtained from ingredient composition tables (National Research Council [NRC], 1994; Rostagno et al., 2017), and these data were obtained from studies on adult cockerels and may not be appropriate, particularly for young birds. The digestive capacity of birds, especially for SBM (Krás et al., 2013), increases with age, development of accessory organs and the digestive system itself (Thomas, Ravindran, & Ravindran, 2008).

The modern broiler presents better energetic efficiency than the commercial broiler from previous decades. The broiler feed conversion ratio is affected mainly by energy diet content (Willems, Miller, & Wood, 2013) and dietary energy definition affects the technical and economic broiler performance (Basurco et al., 2015; Martins et al., 2016).

The average of total no starch polysaccharide (NSP) content in SBM is 22% (Choct, Dersjant-Li, McLeish, & Peisker, 2010) and it presents low digestibility, which affects the energetic use of this ingredient, especially by young birds (Saki, Matin, Zamani, & Mirzaaghatabar, 2011). Studies by Tancharoenrat, Ravindran, Zaefarian, and Ravindran (2013) that used soybean oil (SBO) showed increases in energy values for birds until 21 days of age but the basal diets contained dextrose as an energy source.

The use of reference diets based on corn/SBM can result in ME values that are closest to the true nutritional need of the bird. Regarding fat, low digestion and absorption in young birds is well documented (Saki et al., 2011; Tancharoenrat et al., 2013) and it is attributed to low lipase activity (Krogdahl & Sell, 1989) and low bile salt production (Tancharoenrat, Ravindran, Zaefarian, & Ravindran, 2014). However, the ME values listed in the tables of ingredient composition were also determined in adult cockerels.

Considering the physiological development of birds throughout the production cycle, the formulation of diets using ME values weekly determined could be a better adjustment to the nutrient/calorie requirements and performance of broiler chickens (Firman, Leigh, & Kamyab, 2010; Tancharoenrat et al., 2014).

The objective of this study was to verify the influence of age on SBM and SBO energy values, using weekly determinations, in order to reduce the differences between the formulated energy values and the actual energy values of the diets in the practice.

Material and methods

All the experimental procedures in this research were approved by Animal Ethics Committee of the Federal University of Lavras under number 021/10.

Animals and experimental design

Six experiments were carried out to determine AME, AMEn, TME and TMEn, of commercial SBM and soybean oil (SBO) samples in weekly determinations.

Six experiments were carried out to determine the apparent metabolizable energy (AME), apparent metabolizable energy with nitrogen (N) corrected (AMEn), true metabolizable energy (TME) and true metabolizable energy N corrected (TMEn) of three commercial soybean meal (SBM) and one soybean oil (SBO) collected from commercial feed mill in Brazil.

A total of 1,368 one-day-old male Ross 308 broilers chickens, obtained from a commercial hatchery, Marek´s disease vaccinated, with initial body weight (BW) of 46 ± 3 g were used in the current experiment according to the ages, being 360 birds at 1 - 7 d, 288 birds (BW of 159 g) at 8 - 14 d, 216 birds (BW of 437 g) at 15 - 21 d, 180 birds (BW of 892 g) at 22 - 28 d, 180 birds (BW of 1,483 g) at 29 - 35 d and 144 birds (BW of 2,242 g) at 36 - 42 d of age.

The birds were randomly allocated according to phases to 36 metabolic cages (50 x 50 x 45 cm) with wire flooring and equipped with individual feeders, water drinkers, and excreta collecting system. For the phases from 1 to 14 d, birds were reared directly in the cages in an environmentally controlled building (32°C, 60% relative humidity (RH) and 23L:1Dh day^{-1} light program (10 lux). The other birds, before the experimental study, were raised in a conventional system (floor) and fed with a conventional corn/SBM diet following nutritional recommendation by Rostagno et al. (2017).

The broiler room temperature and RH were kept on a 24°C and 65%, respectively (from 15 – 42 d), 23L:1Dh day^{-1} light program (10 lux) and feed and water *ad libitum* throughout the trial.

The analyzed composition of the feedstuffs is presented in Table 1, and the corn/SBM basal diets are presented in Table 2.

Experimental design and diets

The energy values of SBM and SBO were determined by the difference method. A corn-soy basal diet was formulated (Table 2) to each phase and the test diets with different SBM samples and SBO were formulated by replacement (w/w) 300 g kg^{-1} and 100 g kg^{-1} of the basal diet with SBM and SBO, respectively. The energy values are reported in MJ kg^{-1} dry matter (DM) and adjusted for nitrogen (N) retention according to Hill and Anderson (1958). The TME methodology used in this study was modified by replacing adult cockerels (Sibbald, 1976) with broiler chickens with *ad libitum* feed intake. Endogenous and metabolic energy losses were determined during two days in each age group using six replicates of the same number of birds from each experimental unit of age per 48h post 24h fasting. The total energy endogenous and N losses were corrected to 72h to match the same number of days of excreta collection (3 days). The excreta collections were made in the last 3 days of each phase.

Table 1. Analyzed composition of the SBM and SBO (as feed basis)

Item[1]	SBM 1	SBM 2	SBM 3	SBO
Dry matter, g kg^{-1}	892.1	901.1	899.2	987.1
Crude protein, g kg^{-1}	482.1	477.3	470.5	-
Gross energy (kcal kg^{-1})	17.447	17.736	17.351	39.371
Ether extract, g kg^{-1}	15.0	21.5	18.7	985.0
Crude fiber, g kg^{-1}	47.7	50.0	41.6	-
Neutral detergent fiber, g kg^{-1}	102.0	105.1	93.3	-
Acid detergent fiber, g kg^{-1}	87.2	80.0	61.5	-
Ash, g kg^{-1}	56.5	57.8	49.4	-
Calcium, g kg^{-1}	3.19	3.78	3.49	-
Phosphorus, g kg^{-1}	4.90	5.70	5.70	-
Magnesium, g kg^{-1}	1.95	1.99	2.03	-
Zinc, mg kg^{-1}	53.82	50.87	50.93	-
Iron, mg kg^{-1}	180.50	172.01	168.40	
KOH protein solubility[2]	82.5	83.2	81.8	-
Urease activity[3]	0.045	0.038	0.041	-

[1]Analyzed in triplicate according Association Official Analytical Chemist (AOAC, 2005). [2]Protein solubility in KOH was determined using the procedures of Araba and Dale (1990). [3]According to the methodology indicated by Coca-Sinova, Valencia, Jiménez-Moreno, Lázaro, and Mateos (2008).

The total excreta collection method was used in this study. Feed intake during each experimental period was recorded. The excreta collections were conducted twice a day, at 08:00 and 16:30, and the samples were stored in a freezer (-50°C). At the end of the collection, the samples were weighed and homogenized, and 200 g of each homogenized sample was taken for analysis.

Chemical analysis and calculations

Feed and excreta were analyzed for dry matter (method 930.15) according to AOAC (2005), N content by the combustion method using a CNS-2000 carbon, nitrogen and sulphur analyzer (LECO® Corporation, St. Joseph, MI, USA), ether extract (method 945.39), crude fiber (ISO 5498:1981), ash (method 942.05), and gross energy (GE) by using an adiabatic bomb calorimeter (Parr Instruments Co., Moline, IL) benzoic acid standardized. Acid detergent fiber (ADF) and neutral detergent fiber (NDF) were determined with a Foss Fibertec System (Foss Tecator, Höganäs, Sweden).

The AME of SBM and SBO were calculated using the following formulas:

$$AME_{diet}(MJ\ kg^{-1}) = \frac{[(Feed\ intake * GE_{diet}) - (Excreta\ output * GE_{excreta})]}{Feed\ intake}$$

$$AME_{SBM}(MJ\ kg^{-1}) = \frac{[AME_{of\ SBM\ diet} - (AME_{of\ basaldiet} * 0.70)]}{0.30}$$

$$AME_{SBO}(MJ\ kg^{-1}) = \frac{[AME_{of\ SBO\ diet} - (AME_{of\ basaldiet} * 0.90)]}{0.10}$$

AMEn of SBM and SBO was determined by correction for zero N retention by simple multiplication with 34.39 kj per gram N retained in the body (Hill and Anderson, 1958). The TME and TMEn of ingredients were calculated using the following formulas:

$$TME_{diet} = \frac{\left[\left(GE_{intakediet} - \left(GE_{excreta} - GE_{endogenous}\right)\right)\right]}{DM_{intake}}$$

$$TME_{SBM\ or\ SBO} = \frac{[(TME_{diet} + (TME_{SBM\ or\ SBO} - TME_{diet}))]}{g}\ \text{per g inclusion;}$$

$$TMEn_{diet} = \frac{[\left(GE_{intakediet} - \left(GE_{excreta} - GE_{endogenous} + 36.54 * NB\right)\right)]}{DM_{intake}}$$

$$TEMn_{SBM\ or\ SBO} = \frac{[(TMEn_{diet} + (TMEn_{SBM\ or\ SBO} - TMEn_{diet}))]}{g}\ \text{per g inclusion,}$$

where GE=gross energy, NB= nitrogen balance (N_{intake}-$N_{excreted}$).

Statistical analysis

Data were statistically analyzed by ANOVA using GLM procedure from Statistical Analysis System (SAS, 2001) version 8.2, according to statistical models: $Y_{ijkl} = \mu + S_i + A_j + SA_k + e_{ijk}$, for SBM and $Y = \mu + A_i + e_{ij}$, for SBO where: Y_{ijkl} and Y_{ij}= variable response, μ=general mean, S_i=effect of SBM samples (i= 1 to 3), A_j=effect of birds ages (j=1 to 6), SA_k= interaction S and ages; and e_{ijk} and eij = effect of random error. Each cage was considered an experimental unit. The energy means of the different SBM and broiler ages were compared using the Tukey test ($p < 0.05$).

Results and discussion

The SBM composition values obtained in this study (Table 1) showed good quality, which has normal protein solubility and urease index (Rostagno et al., 2017). There was no interaction ($p > 0.05$) between SBM sources and ages of birds and no differences ($p > 0.05$) were observed between the three batches of SBM determined within each age. The proximate analysis observed that CP, EE, CF and ash were similar between SBM sources, but different from Frikha et al. (2012) and Ravindran, Abdollahi, and Bootwalla (2014) studies with Brazilian SBM, which found higher averages of protein content and ash than this study. On the other hand, the SBM analysis showed higher values of urease and NDF than those observed by Frikha et al. (2012) and Ravindran et al. (2014) with Brazilian SBM.

Table 2. Composition (g kg^{-1} as-fed basis) of the basal diets[1].

Item	1-7 d	8-14 d	15-21 d	22-28 d	29-35 d	36-42 d
Corn	569.74	576.87	584.68	594.20	604.08	615.56
Soybean meal, 46% CP	370.36	358.14	345.18	331.29	316.71	301.24
Limestone	9.98	9.82	9.64	9.48	9.29	9.09
Dicalcium phosphate	18.92	18.31	17.66	16.95	16.24	15.49
Salt	4.57	4.39	4.41	4.10	4.11	3.86
Soybean oil	19.50	25.68	31.79	37.49	43.24	48.60
DL-methionine, 99%	2.48	2.36	2.25	2.12	1.98	1.84
L-Lysine-HCl, 78%	1.70	1.68	1.64	1.62	1.60	1.57
Anticoccidial[2]	0.50	0.50	0.50	0.50	0.50	0.50
Growth promoter[3]	0.25	0.25	0.25	0.25	0.25	0.25
Vitamin supplement[4]	1.00	1.00	1.00	1.00	1.00	1.00
Mineral supplement[5]	1.00	1.00	1.00	1.00	1.00	1.00
Calculated nutrient composition, g kg^{-1}						
ME, MJ kg^{-1}	12.33	12.54	12.75	12.96	13.17	13.38
Crude protein	219.1	213.9	208.3	202.6	196.3	189.9
Calcium	9.88	9.63	9.36	9.08	8.79	8.48
Av. phosphorus	4.66	4.53	4.39	4.24	4.09	3.93
Sodium	2.24	2.16	2.16	2.03	2.03	1.92
Lysine	1.305	1.271	1.234	1.196	1.156	1.114
Methionine	5.08	4.95	4.82	4.68	4.54	4.39
Methionine + cystine	9.27	9.02	8.77	8.50	8.22	7.92
AMEn, MJ kg^{-1}*	11.3±0.22	12.2±0.23	12.6±0.18	12.9±0.14	13.1±0.14	13.2±0.12

[1]Test diets were obtained by replacing (w/w) 300 g kg^{-1} of the basal diet by SBM and 100 g kg^{-1} by FFSB. [2]Salinomicin 12%; [3]Zinc bacitracin 10%; [4]Provided per kilogram of diet: vit. A = 12,000 IU; vit. D3 = 2,200 IU; vit. E = 30 mg; vit. K3 = 2.5 mg; vit. B_1 = 2.2 mg; vit. B_2 = 6 mg; vit. B_6 = 3.3 mg; vit. B_{12} = 0.016 mg; Niacin = 53 mg; pantothenic acid = 13 mg; biotin = 0.11 mg; folic acid = 1 mg; selenium = 0.25 mg. [5]Provided per kilogram of diet: manganese = 75 mg; zinc = 70 mg; copper = 8.5 mg; iron = 50 mg; iodine = 1.5 mg; cobalt = 0.2 mg. *Determined values ± SEM (standard error of the mean).

The energy values (AME, AMEn, TME and TMEn) of SBM (Table 3) and SBO (Table 4) determined to each stage, show differences ($p < 0.05$), as the birds grew older. The AME and AMEn values for SBM and SBO were similar to those listed in the literature (NRC, 1994; Rostagno et al., 2017) but only after the birds were 28 days old for SBM, and birds 21 days old for SBO.

The development of the digestive tract of chickens influences the metabolizable energy values of the ingredients, and the data tends to be similar (Tancharoenrat et al., 2013) subsequently to the maturation of the digestive system of birds.

In the NRC (1994), energy values of 44% and 48% for SBM crude protein are reported with an average AMEn of 10.905 MJ kg^{-1} DM. The average value determined in this study of 28 to 42 days was 11.014 MJ kg^{-1} DM.

Furthermore, using this value for diet formulation for young birds overestimates the metabolizable energy of the diets. At the first, second and third weeks of age, the SBM energy values were different from the NRC (1994), with differences of 1.379, 0.765 and 0.247 MJ kg^{-1} DM lower, respectively. These differences can be explained by the absence of non-starch polysaccharide (Saki et al., 2011), lipase (Krogdahl & Sell, 1989) and bile salt (Tancharoenrat et al., 2014), which result in the efficiency reduction of fat utilization. The results of this study indicate the energy values of SBM were 9.514, 10.141, 10.659 and 11.132 MJ kg^{-1} AMEn DM basis for ages 1 – 7, 8 – 14, 15 – 21 and 22 – 42 days, respectively, for better practical energy diet adjustment. Ravindran et al. (2014) founded an average of AMEn for Brazil SBM at 21 to 28 days was 9.685 MJ/kg, using the same method with replacing (w/w) 300 g kg^{-1} of the basal diet with SBM.

Comparing the apparent metabolizable forms of energy without corrections with the corrected (AME and TME *vs.* AMEn and TMEn) values for all assessed ages, the corrected values were 5-6 % lower for SBM and 1-2% lower for SBO. These lower values for corrected forms of energy depend on a positive N balance because the birds were kept under ad libitum intake conditions, resulting in nitrogen retention greater than zero. Consequently, the metabolizable energy corrected for nitrogen balance, and endogenous losses were lower than the determined apparent values.

Usually the research papers indicate that TMEn value 5 to 10% higher than the AME value, and this difference was attributed to the feed intake level. In this study, this difference averaged 2% for SBM and 0.4% for SBO. Moreover, considering the first week of life, these differences were 5 % and 0.9 %, which declined over the course of the determinations.

Table 3. AME. AMEn. TME and TMEn of SBM (DM basis) according to chicken age.

Ingredient	AME[1] (MJ kg^{-1})	AMEn[1] (MJ kg^{-1})	TME[1] (MJ kg^{-1})	TMEn[1] (MJ kg^{-1})
		1-7 d		
SBM 1	10.186	9.501	10.617	9.902
SBM 2	10.136	9.705	10.621	10.116
SBM 3	9.710	9.372	10.391	9.978
Mean	10.011^{b}	9.514^{b}	10.542^{b}	9.998^{b}
SEM[2]	0.43	0.39	0.44	0.41
		8-14 d		
SBM 1	10.626	10.086	10.893	10.216
SBM 2	10.559	10.237	10.851	10.379
SBM 3	10.509	10.095	10.776	10.224
Mean	10.562^{b}	10.141^{b}	10.838^{b}	10.274^{b}
SEM	0.33	0.28	0.34	0.31
		15-21 d		
SBM 1	11.265	10.659	11.508	10.826
SBM 2	11.144	10.563	11.524	10.738
SBM 3	11.357	10.759	11.717	10.922
Mean	11.256^{b}	10.659^{b}	11.583^{b}	10.526^{b}
SEM	0.17	0.16	0.18	0.15
		22-28 d		
SBM 1	11.896	11.215	12.193	11.374
SBM 2	11.850	11.136	12.239	11.345
SBM 3	11.303	11.018	11.583	11.633
Mean	11.683^{a}	11.123^{a}	12.005^{a}	11.298^{a}
SEM	0.14	0.13	0.15	0.13
		29-35 d		
SBM 1	11.645	11.131	11.704	11.165
SBM 2	11.888	11.182	12.043	11.248
SBM 3	11.729	11.161	11.959	11.319
Mean	11.754^{a}	11.156^{a}	11.900^{a}	11.244^{a}
SEM	0.10	0.08	0.11	0.09
		36-42 d		
SBM 1	11.420	11.062	11.863	11.127
SBM 2	11.662	11.190	12.147	11.449
SBM 3	11.491	11.156	11.959	11.294
Mean	11.524^{a}	11.136^{a}	11.992^{a}	12.290^{a}
SEM	0.13	0.12	0.14	0.11

[1]Means within a column followed by different superscript differ significantly ($p < 0.05$) and compare ages. [2]Standard error of the mean.

Table 4. AME. AMEn. TME and TMEn values of SBO (DM basis) according to chicken age.

Ingredient	AME[1] (MJ kg^{-1})	AMEn (MJ kg^{-1})	TME[1] (MJ kg^{-1})	TMEn (MJ kg^{-1})
		1-7 days		
SBO	34.431^{c}	33.699^{c}	34.773^{c}	34.004^{c}
SEM[2]	0.45	0.37	0.39	0.31
		8-14 days		
SBO	36.253^{b}	35.530^{b}	36.349^{b}	35.580^{b}
SEM	0.36	0.31	0.36	0.32
		15-21 days		
SBO	36.416^{b}	35.923^{b}	36.529^{b}	35.977^{b}
SEM	0.23	0.16	0.25	0.22
		22-28 d		
SBO	36.734^{a}	36.429^{a}	39.963^{a}	36.554^{a}
SEM	0.21	0.18	0.18	0.16
		29-35 d		
SBO	36.663^{a}	36.533^{a}	37.344^{a}	36.521^{a}
SEM	0.20	0.18	0.21	0.19
		36-42 d		
SBO	36.918^{a}	36.692^{a}	36.922^{a}	36.278^{a}
SEM	0.18	0.14	0.16	0.13

[1]Values within a column and followed by a different superscript differ significantly ($p < 0.05$). [2]Mean standard error.

The values of TME and TMEn were similar to those established for AME and AMEn. On the other hand, they were higher because this study assumes that metabolic fecal energy and endogenous urinary losses are constant and independent of the level of feed intake. With the increase of bird's age, there was an increase in the SBO energy values, regardless of the form of assessment, and these SBO data were affected by increasing food intake (Nitsan, Dvorin, Zoref, & Mokady, 1997). In this work, the endogenous and metabolic energy losses were determined weekly, so that at least the age of the birds was similar. This probably explains the small differences between TMEn and AMEn observed in this study when compared with the literature.

The energy values for SBO (Table 4) indicate that birds up to 21 days of age undergo significant increases ($p < 0.05$), and after 21 days of age, the birds can make good use of this ingredient, probably because of their developed systems for the digestion of fats, which results in the similar energy levels after that age. This work suggests that the SBO energy values from 33.699, 35.530 and 36.923 MJ kg^{-1} DM can be used for birds of 1 – 7, 8 – 14 d, and 15 – 21 days of age, respectively. But the values found in the literature have great variation. Using 200 g kg^{-1} (w/w) replacement in the basal diet, Shires, Robblee, Hardin, and Clandinin (1980) found the feed had an AME value of 34.499 MJ kg^{-1}. Tancharoenrat et al. (2013) found the AME value is 16.760 MJ kg^{-1} at first week by using 40 g kg^{-1} (w/w) in the basal diet. In contrast, values from 40.492 – 42.686 MJ kg^{-1} were found with 20 - 60 g kg^{-1} (w/w) in the basal diet (Wiseman et al., 1986). Thus, depending on the age of bird and the replacement percentage of the basal diet, energy values can vary. In the practice, the inclusion of oil in the diet should not exceed 6 – 8 % which can compromise the results. The experimental period may also influence the energy values, and the use of high levels of oil substitution, coupled with increased collection time, can create a physiological situation in the bird that impairs the digestion and absorption of fats, resulting in non-applicable energy values.

The differences observed between energy determination values with and without correction of retained N indicate the importance of taking into account the use of the nitrogen compounds that can be retained or excreted as uric acid (Liu, Meng, Liu, Kan, & Jin, 2017). In the case of broiler chickens, increased body N retention occurs mainly in the initial and growing phases, and the correction can be more significant for those birds in relation to adults. Likewise, specific energy values applied to adult birds are not adapted for use in birds in the initial and growth phases. Therefore, the proposed correction (Hill & Anderson, 1958) for retained or excreted N, 34.39 KJ g^{-1}, contributes to improving the energy evaluation of the feedstuffs. The differences between AME and AMEn found in this work were 0.530 and 0.574 MJ for SBM and SBO, respectively, considering all the energy determination phases of feedstuffs.

The differences obtained between AMEn calculated and determined (Table 1) for basal diets indicate reductions with advancing age, thereby confirming the results obtained for the ingredients studied, with the use of practical basal diets.

Conclusion

The soybean meal and soybean oil energy values increase with the age of broiler chickens. Increases in the energy values of soybean meal and soybean oil occur from 1 to 28 days of bird age.

AMEn values for SBM at 1 – 7 d, 8 – 14 d, 15 – 21 d, and 22 – 42 d of 9.514, 10.141, 10.659 and 11.132 MJ kg^{-1} DM, respectively, and for SBO of 33.699, 35.530, 35.923 and 36.551 MJ kg^{-1} DM, respectively, are suggested to provide optimal energy levels for broiler diets.

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