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Original Article

Metabolizable Energy for Chickens of High and Low Density Corn Fractions Segregated in Densimetric Table

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ABSTRACT

Corn is the main energy feed used in broiler chickens rations in most countries. In the literature, there are indications that high density corn segregated in densimetric table contains higher value of metabolizable energy than the corresponding fraction of low density, but the reasons are not clear. This study was conducted to determine the metabolizable energy of different types of corn, segregated in densimetric table, for poultry. The corn types were selected by the texture of grain (flint, semi-dent and dent) and were planted in the same area. Semi-dent grain corn was used as standard, and the flint and dent grains were segregated in a densimetric table to separate 25% of the total as high density and 25% as low density. The flint, semi-dent and dent corn and the high and low density fractions of flint and dent corn were used in a metabolism assay with broiler chickens from 20 to 29 days of age, with 9 replicates, to determine the Nitrogen-corrected apparent metabolizable energy (MEn). The density of the different types of corn, measured as hectoliter weight, varied from 683 to 768 g/L for dent corn and from 778 to 802 g/L for the flint corn; the density of the unsegregated semi-dent corn was intermediate. MEn ranged from 3.109 to 3.194 kcal/g for dent corn and from 3.141 to 3.211 kcal/g for flint corn. MEn of the high density dent corn, 3.194 kcal/g, was higher ($p<0.05$) than that of the low density fraction, 3.109 kcal/g. Segregation of flint corn did not result in fractions with contrasting MEn values. For dent corn, segregation in densimetric table was effective, resulting in a fraction with improved MEn for chickens.

INTRODUCTION

Energy is recognized as the most expensive component of poultry diets and corn is the main source of dietary energy in many production systems in the world. Metabolizable energy is widely used as the energy currency to formulate poultry diets and the use of accurate metabolizable energy values of corn, as well as other feed ingredients, is crucial for economic feed formulation and results of chicken production.

In a previous study (Silva *et al.*, 2011), it was observed that when corn was segregated in densimetric table, the high density fraction resulted in significantly increased nitrogen-corrected metabolizable energy (MEn) for chickens of different ages compared to the low density fraction. The densimetric table segregates the individual grains based on the specific density, but the usual unit to evaluate this property of grains in the industry is the apparent density, known as "test weight", or, more appropriately, "hectoliter weight". The corn used in the above study had a hectoliter weight of 794 g/L and high and low density fractions had hectoliter weight of 818 and 749 g/L, respectively. The densimetric table has also been used in order to segregate corn to provide a fraction with lower mold contamination and, thus, less risk of presence of mycotoxin (Silva *et al.*, 2008). Application of this tool can be useful and cost-effective for specific purposes in feed and poultry industries.

The corn kernel is composed of about 83% endosperm, 11% germ and 6% pericarp plus tip (Paterniani & Viegas, 1987), but these proportions can vary due to endosperm texture, form and size of the grain, relative size of endosperm and germ, etc. The composition of each constituent is distinct, the endosperm is rich in starch, but also contains protein, the germ is rich in lipids and protein, and the pericarp and tip concentrate the fibrous components cellulose and hemicellulose.

The texture of the endosperm is a characteristic that defines the hardness of the grain, which can be classified as popcorn, hard (or flint), dent and farinaceous (Paes *et al.*, 2011) in order of decreasing hardness. The cultivated corn hybrids used in the feed industry may have different proportions of vitreous and amorphous endosperm; the dent corn has a higher proportion of amorphous endosperm and the flint type has a higher proportion of vitreous endosperm, contributing to the higher density of the latter. In corn, the starch is present as about 25% in the form of amylose and 75% in the form of amylopectin. The vitreous region is rich in amylopectin and the amorphous portion is rich in amylose (McAllister *et al.*, 2006).

Based on the above considerations, it was hypothesized that corn segregation in densimetric table may separate grains according to certain characteristics resulting in contrasting MEn for chickens. The improvement in MEn for the high-density corn determined by Silva *et al.* (2011) was based on only one corn hybrid, which was produced especially for the study, but the reason for the difference in MEn values has not been pointed out. The efficacy of densimetric table in segregating grains of different types or textures has not been compared. The present study was carried out to determine the MEn for poultry of corn types contrasting in endosperm texture (flint and dent) and segregated in densimetric table.

MATERIAL AND METHODS

Production of corn grain for the experiment

Three commercial hybrids of corn were planted in adjacent plots of 0,22 ha each in a uniform area and subjected to the same management, in Piracicaba – SP (latitude 22° 50'11" S and longitude 48° 00'57" W). One of the hybrids represented the standard semi-dent corn for the region (DKB 390 Pro2), the other two were chosen for their contrasting characteristics, one with flint grain (Ag 8088 Pro2) and the other with dent grain (Ag 4051 Pro).

Corn cobs were harvested manually with the shells when the moisture reached around 16% and sun dried to avoid interfering effects of high temperatures on the nutritional quality of the grain. It was then mechanically shelled. The yield of dried grain was equivalent to 4.2 ton/ha for the semi-dent, 4.7 ton/ha for the flint and 3.5 ton/ha for the dent corn. The low yield obtained may be considered normal given the soil characteristics and environmental conditions of the location prevalent during the growing period; the cobs and kernels were well formed and very little affected by insects and diseases.

Segregation in densimetric table

A portion of the original non-segregated grain of the three hybrids was kept for the chicken experiment and the remainder flint and dent corn were passed through the densimetric table. The semi-dent corn was not segregated and served as a standard for comparisons. The densimetric table was set to segregate 25% of the corn in the high density and 25% in the low density fraction, which were stored for the metabolizable energy assay.

Chemical composition of samples of the flint high density (FlintHi), flint low density (FlintLo), dent high density (DentHi), dent low density (DentLo), and the original semi-dent (Semi) corn was determined according to the AOAC (1990) methods; specific density of samples was determined using Helium gas pycnometer and hectoliter weight using a hectoliter weight apparatus.

Metabolizable energy assay

The procedures for the animal trial were approved by the Institutional Animal Care and Use Committee. The experiment was conducted in three repetitions over time to determine the apparent metabolizable energy (ME) and the apparent nitrogen-corrected metabolizable energy (MEn) of the different corn types, according to Sakomura & Rostagno (2016). For each repetition, a group of Ross AP95 day-old male chicks was raised in a chicken house under controlled environmental conditions and rice hulls as litter material. Corn-soybean meal feed and water were provided *ad libitum* until 20 days of age. On day 20, 120 chickens were selected and uniform groups of 5 chickens were allotted to 24 cages in metallic batteries in a metabolism room. The cages dimension was 0.70 m long, 0.66 m wide and 0.34 m height, with mesh floor under which there was a collection tray and equipped with stainless steel through feeder and waterer. The experimental period was 9 days, with 5 days of adaptation period to the environment and feed followed by a 4-day collection period. The treatments included a reference diet (Table 1) and 7 test diets in which the reference diet was substituted with 40% of the original or segregated corn: 1. Flint; 2. FlintHi; 3. FlintLo; 4. Dent; 5. DentHi; 6. DentLo and 7. Semi. The chickens had free access to feed and water. Feed consumption was measured, and the corresponding excreta was collected twice a day. The excreta were kept frozen and, at the end of the trial, it was homogenized, sampled, and dried at 65 °C for 72 h. Feed samples and the excreta were ground and analysed for gross energy (calorimeter Parr 1261) and nitrogen. ME and MEn of the corn samples were calculated according to Sakomura & Rostagno (2016).

Table 1 – Ingredients and nutrient composition of the reference diet.

Ingredients (%)	
Corn	60.937
Soybean meal	32.483
Soybean oil	3.277
Dicalcium phosphate	1.298
Limestone	0.878
Salt	0.457
DL–Methionine	0.248
L-Lysine.HCl	0.165
L-Treonina	0.027
Choline chloride (60%)	0.060
Vitamin supplement[1]	0.120
Mineral supplement[2]	0.050
TOTAL	100.00
Calculated composition	
Crude protein (%)	19.821
Metabolizable energy (kcal/kg)	3,100
Calcium (%)	0.732
Available Phosphorus (%)	0.342
Potassium (%)	0.771
Sodium (%)	0.200
Chloride (%)	0.325
Digestible lysine (%)	1.078
Digestible methionine (%)	0.513
Digestible meth+cysteine (%)	0.787
Digestible threonine (%)	0.701

[1]DSM Nutricional Products, Composition per kg of feed: Vit. A – 10,800 UI; Vit. D3 – 3,000 UI; Vit. E – 24 UI; Vit. K3 – 3.0 mg; Vit. B1 – 2.4 mg; Vit. B2 – 7.2 mg; Vit. B6 – 3.6 mg; Vit. B12 – 18 µg; Nicotinic acid – 42 mg; Pantothenic acid – 14.4 mg; Biotin – 0.10 mg; Folic acid – 1.8 mg; Selenium – 0.3 mg.

[2]DSM Nutritional Products, Composition per kg of feed: Manganese – 80 mg; Iron – 50 mg; Zinc – 50 mg; Copper – 10 mg; Cobalt – 1.0 mg; Iodine – 1.0 mg.

Statistical analyses

The metabolism assay was conducted in three repetitions; each repetition consisted of eight treatments and three replicates in a completely randomized experimental design; the treatments included the reference diet and seven test diets whose ME and MEn values were determined in order to calculate the energy values of the corn types. These variables were submitted to analysis of variance using PROC GLM of SAS (2001) and the means compared through the following orthogonal contrasts, with p value of 0.05:

a. Semi (standard) *vs.* all others;
b. All flint (Flint, FlintHi, FlintLo) *vs.* all dent (Dent, DentHi, DentLo);
c. FlintHi *vs.* FlintLo;
d. DentHi *vs.* DentLo.

RESULTS AND DISCUSSION

The efficacy of the process of segregation in the densimetric table was evaluated based on specific density and hectoliter weight. The flint corn had specific density of 1.338 g/cm^3, generating the fractions FlintHi and FlintLo with 1.341 and 1.335 g/cm^3, respectively. The corresponding hectoliter weights were 788, 802, and 778 g/L, respectively. For the dent corn, the specific density was 1.291 g/cm^3, and the values for DentHi and DentLo were 1.303 and 1.277 g/cm^3. The corresponding hectoliter weights were 698, 735, and 683 g/L, respectively. The Semi corn had intermediate values for specific density (1.313 g/cm^3) and hectoliter weight (768 g/L). The specific density of flint corn was higher than that of dent corn, and the range among the segregated fractions was greater for dent than for flint. This was an indication that the process of segregations was more effective for the dent corn type. Similarly to what was found for specific density, the measurement of hectoliter weight allowed a better discrimination of dent corn than flint corn, being a more practical tool for use in the industry.

Phillipeau *et al.* (1999) reported average values of specific density of 1.20 g/cm^3 for dent corn and 1.36 g/cm^3 for flint corn, values that were below and above, respectively, of the dent and flint corn used in this study. Evaluating a series of corn hybrids, Moore *et al.* (2008) found specific density ranging from 1.207 to 1.263 g/cm^3, values characteristic of dent corn. In the study of Silva *et al.* (2008), the high and low density corn fractions had hectoliter weights of 818 and 749 g/L, values above and below, respectively, the high and low density flint corn in the present study.

Table 2 – Dry matter (DM), gross energy (GE), crude protein (CP), ether extract (EE), mineral matter (MM), crude fiber (CF), nitrogen-free extract (NFE), neutral detergent fiber (NDF) and acid detergent fiber (ADF) of the different corn types used in the metabolism assay.

Corn	DM (%)	GE (kcal/g)	CP (%)	EE (%)	MM (%)	CF (%)	NFE (%)	NDF (%)	ADF (%)
Flint	90.36	4.46	7.08	5.71	1.43	3.34	82.44	11.17	3.15
FlintHi	90.16	4.44	7.28	4.83	1.10	2.99	83.80	10.67	3.04
FlintLo	90.17	4.43	6.96	5.44	1.47	3.61	82.53	10.59	3.01
Dent	90.32	4.37	7.27	4.85	1.20	4.16	83.51	11.39	2.40
DentHi	90.36	4.36	7.37	5.02	1.54	3.05	83.02	12.42	3.46
DentLo	90.52	4.64	7.08	4.92	1.32	4.16	82.53	13.48	3.09
Semi	90.62	4.51	7.03	6.23	1.62	3.75	81.37	11.67	3.18

The gross energy and chemical composition of the different corn types are shown in Table 2. The values are similar, but it can be noted that the DentLo corn had higher gross energy, crude fiber and NDF. Also, it seems that the segregation, for both types of corn, produces the low density fraction with lower crude protein level.

The average values of the components used in the calculations of ME and MEn are presented in Table 3. With these data and the inclusion rate of 40% of corn in the test diets, the energy values of the different corn types were estimated, which are presented in Table 4. The MEn values estimated for the different types of corn ranged from 3.109 to 3.211 kcal/g, which reached a P=0.10 level of significance. The average MEn value for the flint corn and their segregated fractions (Flint, FlintHi and FlintLo) was 3.181 kcal/g, with a maximal difference of 0.070 kcal/g between the samples. For the dent corn (Dent, DentHi, DentLo) the average value of MEn was 3.140 kcal/g; in this case, the maximal difference was 0.085 kcal/g. It is important to notice that the densimetric table was adjusted to separate 25% of each fraction, which are characterized in this study, and that more tight settings may produce fractions of more extreme densities. The MEn value of 3.165 kcal/g for the reference corn (Semi) was intermediate between the flint and dent materials.

Table 3 – Average daily values per chicken collected in the metabolism assay. Values are on as fed basis for the diets and on-air dried basis for the excreta.

		Test diets						
	Ref	Flint	FlintHi	FlintLo	Dent	DentHi	DentLo	Semi
Diet								
Intake, g	159.3	169.22	163.14	164.29	159.71	159.10	157.19	165.88
GE, kcal/g	4.038	3.993	4.019	4.018	3.984	3.997	3.986	4.020
EI, kcal	643.4	675.72	655.61	660.07	636.36	636.00	626.58	666.79
N in diet, %	3.02	2.33	2.15	2.27	2.29	2.26	2.26	2.11
N intake, g	4.80	3.94	3.51	3.72	3.66	3.60	3.55	3.50
Excreta								
Output, g	41.98	38.32	36.41	36.28	35.32	34.85	35.19	37.30
GE, kcal/g	3.811	4.017	3.994	4.002	4.008	3.979	3.994	3.999
EE, kcal	160.0	153.92	145.45	145.21	141.54	138.68	140.56	149.19
N in excreta, %	4.09	3.37	3.47	3.43	3.41	3.45	3.40	3.40
N excreted, g	1.72	1.29	1.26	1.24	1.20	1.20	1.19	1.27
N balance NB, g	3.09	2.65	2.24	2.48	2.45	2.39	2.36	2.23
NB x 8.22, kcal	25.36	21.79	18.44	20.36	20.17	19.68	19.38	19.35

Ref: reference diet; GE: gross energy; EI: energy intake; EE: energy excreted.

Table 4 – Metabolizable energy (ME) and nitrogen-corrected metabolizable energy of the flint, dent and semi dent corn and the fractions of high and low density segregated in densimetric table.

Corn	ME, kcal/g	MEn, kcal/g
Flint	3.226	3.141
Flint high density (FlintHi)	3.235	3.192
Flint low density (FlintLo)	3.281	3.211
Dent	3.194	3.118
Dent high density (DentHi)	3.263	3.194
Dent low density (DentLo)	3.178	3.109
Semi-dent (Semi)	3.198	3.165
p-value	0.1896	0.1024
SEM	0.030	0.029
Contrasts		
1 (Semi vs. Others)	0.4955	0.7975
2 (All flint vs. All dent)	0.1727	0.1049
3 (FlintHi vs. FlintLo)	0.3525	0.7428
4 (DentHi vs. DentLo)	0.0504	0.0487

The contrast analysis indicated that (a) the semi-dent hybrid, used as representative of corn production, had MEn value that did not differ from the flint or dent corn ($p>0.05$); (b) MEn of the flint corn did not differ of the dent corn ($p>0.05$); (c) there was no difference in MEn for the segregated fractions of flint corn; (d) the dent corn segregated for high density had greater MEn than the low density counterpart (DentHi = 3.194 kcal/g *vs.* DentLo = 3.109 kcal/g, $p<0.05$).

In previous studies (Silva *et al.*, 2008; Silva *et al.*, 2011) the magnitude of the difference favoring the MEn of the corn segregated for high density was greater than reported here and the reason for that is not clear. One possible reason is that the difference in hectoliter weight, as mentioned above, was greater than in this study. The degree of environmental damage to the grain before and after harvesting or the time between harvesting and the segregation may also be implied. In any instance, a difference of 0.085 kcal/g (85 kcal/kg) is significant for the economic result of feed formulation and poultry operation.

Some associations concerning the process of corn segregation in densimetric table and the fractions produced must be highlighted. The specific density of the fractions FlintHi and FlintLo was 1.341 and 1.335, respectively, a difference of only 0.45%. On the other hand, the specific density of the fractions DentHi and DentLo was 1.303 and 1.277, respectively, a difference of 2.04%. The hectoliter weight, which is a more practical measure of grain density for the feed industry, provided wider values for both types of corn, having a good discrimination capacity; hectoliter weight for FlintHi and Flint Lo was 802 and 778 g/L, respectively (difference of 3.1%), while hectoliter weight for DentHi and DentLo was 735 and 683 g/L, respectively (difference of 7.6%).

The efficacy of the process of segregation of corn in densimetric table may be dependent on the type or quality of corn, as indicated by the results of this study. Here, the efficacy was greater for the dent corn than for the flint corn; also, the MEn of the dent corn segregated for high density was equivalent of that of the flint corn. The possible implication of these findings is that the segregation could be more advantageous when the corn has lost part of its quality due to harvest, storage, mold or insect damage. As a result, the fraction of corn with improved quality can be separated and directed to meet specific needs of animals such as birds in the initial phase of growth and the fraction with lower quality may have more adequate use in feeds for chickens in the finisher phase, for example.

CONCLUSION

The efficacy of the process of corn segregation in densimetric table may be dependent on the type of corn, with better results for dent than flint hybrids, and the high density fraction of dent corn may have a metabolizable energy value similar to that of flint corn.

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