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Metabolizable energy values and metabolizability coefficients of ether extracts of different types of corn oil for broilers

Valores de energia metabolizável e coeficientes de metabolizabilidade do extrato etéreo de diferentes tipos de óleo de milho para frangos de corte

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Abstract: This study aims to determine and compare the metabolizable energy values and metabolizability coefficients of three types of corn oil (crude, semi-refined, and acid) for broiler chickens. 240 Cobb500™ chickens were randomly allocated into metabolic cages, resulting in four treatments, ten replicates, and six birds per experimental unit. The birds fed on diets specific to each treatment. Total excreta was collected from the day 23rd to the 27th. Gross energy (GE), apparent metabolizable energy (AME), and nitrogen-corrected apparent metabolizable energy (AMEn) were calculated for each oil type. The metabolizability coefficient values of ether extracts (MCEE) were also determined. Statistical analysis was performed using Tukey test at a 5% probability. There was a significant difference in AME and MCEE values (P<0.05). Crude corn oil showed higher AME and MCEE values than acid corn oil. The findings are crude corn oil - GE: 9,330 kcal/kg, AME: 8,916.84 kcal/kg, AMEn: 8,905.60 kcal/kg, MCEE: 97.14%; semi-refined corn oil - GE: 9,480 kcal/kg, AME: 8,547.99 kcal/kg, AMEn: 8,303.46 kcal/kg, MCEE: 96.64%; acid corn oil - GE: 9,114 kcal/kg, AME: 7,197.73 kcal/kg, AMEn: 7,515.68 kcal/kg, MCEE: 96.17%.

Keywords: Corn byproducts; Metabolism; Corn oil; Energy value.

Resumo: Este estudo teve como objetivo determinar e comparar os valores de energia metabolizável e os coeficientes de metabolizabilidade de três tipos de óleo de milho (bruto, semi-refinado e ácido) em frangos de corte. Foram usados 240 frangos da linhagem Cobb500™, distribuídos aleatoriamente em gaiolas metabólicas com quatro tratamentos, 10 repetições e 6 aves por unidade experimental. As aves foram alimentadas com rações específicas para cada tratamento, e a coleta total de excretas foi realizada dos dias 23 a 27. Os valores de energia bruta (EB), energia metabolizável aparente (EMA) e energia metabolizável aparente corrigida pelo balanço de nitrogênio (EMAn) foram calculados para cada tipo de óleo. Os coeficientes de metabolizabilidade do extrato etéreo (CMEE) também foram determinados. A análise estatística dos resultados foi realizada por meio do teste de Tukey ao nível de 5% de probabilidade. Houve diferença significativa para os valores de EMA e CMEE (P<0,05). O óleo de milho bruto apresentou maiores valores EMA quando comparado ao óleo de milho ácido. O mesmo

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comportamento foi verificado para o CMEE (P<0,05). Os valores encontrados para os óleos foram: óleo de milho bruto - EB: 9330 kcal/kg, EMA: 8916,84 kcal/kg, EMAn: 8905,60 kcal/kg, CMEE: 97,14%; óleo de milho semi refinado - EB: 9480 kcal/kg, EMA: 8547,99 kcal/kg, EMAn: 8303,46 kcal/kg, CMEE: 96,64%; óleo de milho ácido - EB: 9114 kcal/kg, EMA: 7197,73 kcal/kg, EMAn: 7515,68 kcal/kg, CMEE: 96,17%.

Palavras-chave: Coprodutos do milho; Metabolismo; Óleo de milho; Valor energético.

1. Introduction

Oils, particularly corn oil, play a crucial role in animal nutrition as essential sources of energy [1]. Their significance lies in enriching the energy value of feed for non-ruminant animals, often replacing soybean oil. Crude corn oil, which is extracted by pressing corn grains, usually contains impurities that are eliminated through refining processes [2]. In pursuit of cleaner energy sources, there is a growing global interest in ethanol as an alternative fuel. Brazil is a leading producer and annually yields about 32.5 billion liters of ethanol from sugarcane [3].

Brazil produces approximately 12 million liters of ethanol from 30,000 tons of corn, highlighting a preference for corn in ethanol production due to various advantages, including ease of storage, abundant production, and low costs [4]. However, the significant variability in the nutritional composition of corn poses great challenges [5].

The research of biofuels results in the production of “distiller’s dried grains with soluble” (DDGS) as a primary byproduct of the corn starch fermentation process. Oil is a secondary byproduct of the ethanol production from corn [6]. Corn, the second-largest crop in Brazil, yields valuable co-products, such as gluten, germ, and oil, which account for 3.1 to 5.7% of the total grain weight.

Understanding the energy values of feed is crucial for a precise formulation of diets for livestock, directly affecting metabolic processes and production costs [7, 8]. The objective of this study is to determine gross energy (GE), apparent metabolizable energy (AME), nitrogen-corrected apparent metabolizable energy (AMEn), and metabolizability coefficients of the ether extract (MCEE) of three varieties of corn oil: crude, semi-refined, and acidic.

2. Materials and methods

2.1 Ethics Committee

The Ethics Committee on the Use of Production Animals (CEUAP-UFV) (protocol number 034/2021) approved all protocols adopted in this research according to the standards of the National Council for Animal Experimentation Control [9].

2.2 Experimental design and protocol for total collection

240 male Cobb500™ broiler chickens, 18 days old, with an average initial weight of 929 grams, were used in the study. The birds were randomly allocated into metabolic cages, resulting in four treatments, ten replicates, and six birds per experimental unit.

From day 1 to 18 of age, the birds were reared in a masonry shed, fed on a starter diet formulated with corn and soybean meal, meeting the requirements of Rostagno et al. [(10)]. Birds were managed according to the lineage's manual.

For the determination of AME and AMEn values of corn oils, a reference diet (RD) was prepared to meet the nutritional requirements of birds according to Rostagno et al. [(10)]. It was Treatment 1 (Table 1). Treatments 2, 3, and 4 included 94% RD + 6% crude corn oil, semi-refined corn oil, and acid corn oil, respectively. From days 18 to 22, the birds underwent an adaptation phase to the diets and cages. Total excreta were collected twice a day from day 23 to 27 for analysis.

Table 1 Nutritional composition of the reference diet (RD).

Ingredients (%)	**Reference Diet**
Corn	52.926
Soybean meal	41.422
Soybean oil	1.500
Dicalcium phosphate	1.786
Limestone	0.924
Salt	0.515
DL-Methionine (99%)	0.318
BioLis (60.0%)	0.136
L-Threonine (98%)	0.048
Vitamin supplement [2]	0.130
Mineral supplement [1]	0.130
Choline chloride (60%)	0.100
Salinomycin (12%)	0.055
Antioxidant (BHT) [3]	0.001
Total	**100.00**
Composition (%)	
Metabolizable Energy, kcal/kg	2850
Crude Protein, %	24.00
Calcium, %	0.937
Available Phosphorus, %	0.440
Sodium, %	0.218
Digestible Arginine, %	1.460
Digestible Glycine + Serine, %	1.871
Digestible Lysine, %	1.256
Digestible Methionine + Cysteine, %	0.929
Digestible Threonine, %	0.829
Digestible Tryptophan, %	0.267
Digestible Valine, %	0.967

[1]Guaranteed levels per kg of product (Minimum): Cobalt 2 mg, copper 10 mg, iron 50 mg, iodine 0.7 mg, manganese 78 mg, selenium 0.18 mg, zinc 55 mg. [2]Guaranteed levels per kg of product (Minimum): Folic Acid 0.3 mg, Pantothenic Acid 12 mg, Nicotinic Acid 50 mg, Biotin 0.05 mg, Niacin 30 mg, Vitamin A 10,000,000 IU, Vitamin B1 1.5 mg, Vitamin B12 0.015 mg, Vitamin B2 6 mg, Vitamin B6 4 mg, Vitamin D3 2,000,000 IU, Vitamin E 36,100 IU, and Vitamin K3 3 mg. [3]BHT: Butylated hydroxytoluene.

The provided diets were weighed at the beginning and the end of the excreta collection period to quantify the consumption per experimental unit. Feed and water were provided *ad libitum*. Feeders were replenished multiple times a day in small portions to minimize waste.

For the collection of excreta, aluminum trays lined with plastic were placed under the cages. Collections occurred twice a day at 8:00 a.m. and 3:00 p.m. to avoid fermentation and nutrient loss. After collection, the excreta were placed in plastic bags, identified according to the experimental unit, and stored in a freezer at -30°C.

At the end of the experiment, after thawing, the excreta were homogenized. A sample from each experimental unit was collected. Excreta samples were pre-dried in a forced-air ventilation oven at 55°C for 72 hours to determine air-dried matter content (ADM). Subsequently, the dried samples were weighed, grounded in a ball mill, and placed in a forced air ventilation oven at 105°C for 24 hours to determine the final dry matter content (FDM), enabling the calculation of dry matter.

Samples of excreta and diets were sent to the laboratory for analysis of dry matter (DM), nitrogen (N), gross energy (GE), and ether extract (EE), following the procedures of the AOAC [(11)]. In addition, a sample of each oil was sent to the laboratory of the Department of Animal Science at the Federal University of Viçosa for GE analysis using a calorimeter or a bomb calorimeter.

Moisture and nitrogen contents in the excreta and diets were determined according to the methodology of Silva and Queiroz [(12)]. The gross energy of diets, oil sources, and excreta were obtained using a bomb calorimeter (IKA® PARR 6200). AME and AMEn were calculated using the equations proposed by Matterson et al. (13):

$$\text{AME of TD or RD (kcal/kg)} = \frac{(\text{GE ingested - GE excreted})}{\text{Feed intake}}$$

$$\text{AME of lipid source (kcal/kg)} = \text{AME RD} + \frac{(\text{AME TD} - \text{AME RD})}{\text{\% of replacement}}$$

$$\text{AMEn of TD or RD (kcal/kg)} = \frac{(\text{GE ingested} - (\text{GE excreted} + 8.22 \times \text{NB}))}{\text{Feed intake}}$$

$$\text{AMEn of lipid source (kcal/kg)} = \text{AMEn RD} + \frac{(\text{AMEn TD} - \text{AMEn RD})}{\text{\% of replacement}}$$

where TD = test diet, RD = reference diet, GE = gross energy, and NB = nitrogen balance = N ingested – N excreted.

The calculation of the metabolizability coefficient values of the ether extracts (MCEE) from the total collection of excreta was performed using the following equation:

$$MCEE(\%) = \frac{Amount\ of\ nutrients \in the\ feed - Amount\ of\ nutrients \in the\ excreta}{Amount\ of\ nutrients \in the\ feed}$$

2.3. Statistical analysis

Data were tested for homogeneity of variance and residual normality using PROC UNIVARIATE in the SAS system [14]. AME and AMEn derived from lipid sources were analyzed using analysis of variance (PROC MIXED). Next, the means of treatments were compared using Tukey test at a significance level of 5%. The statistical model adopted is represented as follows:

$yi = m + ti + ei. (a \times b)i$

Where:

- Yijk = response variable in broilers, which was the AMEn or MCEE (%) of the different lipid sources.

- μ = overall mean effect.

- ti = fixed effect of treatments (lipid sources).

- eij (a × b)i = residual error.

3. Results and discussion

The table 2 shows the values of AME, AMEn, and MCEE of three types of corn oil (crude, semi-refined, and acid) for broiler chickens.

Table 2 Apparent metabolizable energy (AME), apparent metabolizable energy corrected by nitrogen balance (AMEn), and metabolizability coefficient of corn oil ether extract (MCEE) of three corn oil types for broiler chickens.

Lipid Source	Crude Energy	Dry Matter	AME	AMEn	MCEE
Crude Corn Oil	9,330	88.92	8,916.84a	8,905.603	97,142a
Semi-refined Corn Oil	9,480	88.60	8,547.99ab	8,496.964	96,644ab
Acid Corn Oil	9,114	89.38	7,293.311b	7,601.443	96,1716b
P-value	---	----	0.0298	0.0922	0.0451
MSE	---	----	447.275	413.073	0.260

MSE: mean standard error.

There were significant differences for AME and MCEE (P < 0.05). The AME of crude corn oil was greater than that of acid corn oil. The same pattern occurred for MCEE (P < 0.05).

The analysis determined the GE, AME, and AMEn of the crude, semi-refined, and acid corn oils. Crude corn oil had a GE of 9,330 kcal/kg, an AME of 8,916.84 kcal/kg, and an AMEn of 8,905.60 kcal/kg. Semi-refined corn oil had a GE of 9,480 kcal/kg, an AME of 8,547.99 kcal/kg, and an AMEn of 8,303.46 kcal/kg. Acid corn oil had a GE of 9,114 kcal/kg, an AME of 7,197.73 kcal/kg, and an EMAn of 7,515.68 kcal/kg (Table 2).

Such differences may be the result of processing characteristics inherent to each type of oil, which affect its composition and digestibility. Both crude and semi-refined corn oils showed higher MCEEs (97.14%, and 96.64%, respectively), while acid corn oil showed an MCEE of 96.17%. These findings suggest that the refining process, whether complete or partial, did not affect the digestibility of the ether extract. However, the acidity level appeared to affect this parameter.

The refinement process of corn oil requires taking into account several variations. Semi-refined corn oil is obtained from crude oil and undergoes a refining stage that removes certain impurities, such as gums and proteins, employing techniques such as centrifugation, filtration, and decantation to improve quality and stability.

On the other hand, acid corn oil is also obtained from crude oil, but it undergoes an acidification process to remove impurities and reduce product acidity. During this procedure, crude oil is mixed with an acidic solution, such as phosphoric acid or citric acid, to facilitate purification. Subsequently, the oil is neutralized with an alkaline solution to eliminate any residual acids, thereby ensuring the quality of the final product.

According to Paula et al. [(6)], using different types of corn oil in broiler nutrition can affect performance and nutrient utilization by birds. Therefore, the selection of oil types for incorporation into feed formulations should consider not only energy values, but also processing characteristics and nutritional composition.

Serpa et al. [(16)] reported that chemical characteristics such as carbon chain length, number of double bonds, and configuration of double bonds (cis and trans) may affect digestibility and energy use efficiency by birds. Additionally, factors such as the presence of free fatty acids or their arrangement in triglycerides, the position of fatty acids in the glycerol molecule, and the ratio between unsaturated and saturated fatty acids in lipids may affect the nutritional effects of lipid sources.

According to Shurson et al. [(17)], corn oil stands out for its exceptional stability in comparison with other sources of oil and dietary fats. Its high content of polyunsaturated fatty acids may be the reason for it (PUFAs). The fatty acid composition of corn oil is remarkable: predominance of linoleic acid (48.02%), oleic acid (34.68%), palmitic acid (12.5%), and stearic acid (2.11%). Considering its abundance, Sabchuk et al. [(18)] emphasized that corn oil is a viable alternative to soybean oil, which is traditionally used as a fat source in poultry diets in Brazil.

Studies such as the present one, which assess the metabolic utilization of feed, are essential and frequently demanded due to environmental variations and the continual genetic improvements of bird strains. This progress in turn improves diet use efficiency, including the determination of AMEn values for feeds, indicating improvement in feed efficiency. These findings are crucial for a precise formulation of poultry diets that meet the birds' energy requirements during various growth stages.

4. Conclusion

The oils evaluated yield the following energy values: crude corn oil: 9,330 kcal/kg of GE, 8,916.84 kcal/kg of AME, and 8,905.60 kcal/kg of AMEn; semi-refined corn oil: 9,480 kcal/kg GE, 8,547.99 kcal/kg AME, and 8,303.46 kcal/kg AMEn; and acid corn oil: 9,115 kcal/kg GE, 7,197.73 kcal/kg AME, and 7,515.68 kcal/kg AMEn. The MCEEs are 97.14%, 96.64%, and 96.17% for crude, semi-refined, and acid oils, respectively.

Conflict of interest statement

The authors declare that there are no conflicts of interest.

Author contributions

Conceptualization: E. D. da Silva; A. A. Calderano; L. F. T. Albino. Data Curation: E. D. da Silva; M. J. Vieira; J. K. Valentim. Investigation: E. D. da Silva; C. H. de Oliveira; M. J. Vieira; K. M. M. Dias; B. F. de Almeida. Project Management: L. F. T. Albino. Visualization: J. K. Valentim and L.F.T Albino. Supervision: L.F.T Albino. Writing (Original Draft): E. D. da Silva; A. A. Calderano; M. J. Vieira; J. K. Valentim; E. D. Silva. Writing (Review and Editing): E. D. da Silva; A. A. Calderano; L.F.T Albino; J. K. Valentim.

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