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Energy values and metabolizability of lipid sources of plant and animal origin in the diet of Japanese quail

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ABSTRACT - The objective of this study was to determine the energy values and metabolizability of different lipid sources in the diet of Japanese quail at the laying phase. The quail were distributed in a completely randomized design with ten replications of seven poultry per treatment, totaling six treatments: basal feed (control) and basal feed containing 10% soybean oil, corn oil, canola oil, sunflower oil, and poultry fat. The values of nitrogen-corrected apparent metabolizable energy (AMEn) and the metabolizability coefficient (MC%) were evaluated. No significant difference was found between the different lipid sources for AMEn (kcal/kg) and MC (%). The value of metabolizable energy corrected for nitrogen for soybean oil was 8,790 kcal/kg; 8,773 kcal/kg for corn oil; 8,784 kcal/kg for canola oil; 8,788 kcal/kg for sunflower oil; and 8,681 kcal/kg for poultry fat in laying Japanese quail. The digestibility coefficients were 93.88% for soybean oil, 93.53% for corn oil, 93.32% for canola oil, 93.74% for sunflower oil, and 93.06% for poultry fat.

Keywords: digestibility, laying phase egg, metabolizable energy, oils, quail breeding

1. Introduction

Up-to-date nutritional values of foods are important for the accurate formulation of feeds for monogastric animals (Araujo et al., 2019). The energy level is involved in the various metabolic processes and linked to food intake, and commonly used as an initial parameter in feed formulations as a reference to establish the contents of all nutrients (Reda et al., 2020).

The energy provided by the feed is crucial for feed intake, weight gain, and feed conversion, and directly influences the production cost (Jahanian and Edriss, 2015). It consists of the sum of the caloric value released by all nutrients during metabolic oxidation inside the animal organism.

The metabolizable energy (ME) of feed is calculated by the difference between the gross energy of the ingredient and the gross energy (GE) lost in feces, urine, and gases produced during digestion. In poultry, the energy loss as gases is very low and has been neglected in the ME calculations (Sakomura and Rostagno, 2007; Brito et al., 2020; Yang et al., 2020). Thus, the ME values of ingredients include all metabolic losses during digestion, except for the caloric increase. It is a more accurate and reliable measure of expressing the amount of energy contained in feed considering its biological use by poultry (Vieira et al., 2020).

According to Wu et al. (2020), the energy contained in the animal diet is one of the most important factors to be considered in the formulation of poultry feed. This is due to its role in the maintenance of physiological functions, growth, and performance of animals, and for allowing greater deposition of protein in the carcass. In this regard, studies aimed at improving the process of formulating diets for quail and supporting other research are fundamental, especially under tropical conditions. Furthermore, the feed composition tables have no specific data for quail.

Due to the frequent genetic and physiological evolution of breeding animals, updates are necessary to efficiently meet their nutritional requirements. Therefore, this study determined the energy values and the metabolizability coefficients of lipid sources of soybean oil, corn oil, sunflower oil, canola oil, and poultry fat in the diet of Japanese quail in the laying phase.

2. Material and Methods

2.1. Animals and treatments

Research on animals was conducted according to the institutional committee on animal use (no. 16/2020). The experiment was conducted in Dourados, Mato Grosso do Sul, Brazil (latitude: 22°13'16"S and the longitude is 54°48'20" W). According to the Köppen classification, the climate is Cwa (humid mesothermic) with rainy summers and dry winters, average annual rainfalls of 1,500 mm, and average annual temperatures of 22 °C. The altitude ranges from 449 m to 477 m.

The experimental shed built with masonry was 6.0 m long, 2.5 m wide, and 3.5 m high, with a concrete floor and roof with fiber cement tiles, 0.60 m short walls, and 0.50 m eave in length. It had yellow polyethylene external curtains with manual activation and two evaporative air conditioners to control the shed temperature.

Temperatures and relative humidity (RH) were monitored at 08:00 and 16:00 h using Max-Min Thermometer and Hygrometer positioned at the center of the shed at the height of the poultry' back. The minimum temperature obtained was 20.1±0.25 °C, the maximum was 25.9±0.28 °C; the maximum RH was 78.9±1.8 (%), and the minimum was 59.8±1.7 (%). Sixteen hours of light were provided daily throughout the experimental period. This light supply was controlled by a timer. The activation of air conditioners and the control of curtains were carried out by assessing the current need according to the temperature of the day.

Six diets were provided in a completely randomized design with ten replications per treatment and seven quail per experimental unit (cage), totaling 420 birds at laying-peak phase, i.e., about eight weeks of age. The poultry were housed in galvanized wire cages measuring 50 × 50 × 16.5 cm (length × width × height) and containing two 25 × 50 cm partitions, totaling 1,250 cm^2. The animal density per experimental unit was 178 cm^2/bird.

The basal feed was composed of corn and soybean meal without the inclusion of lipid sources and formulated according to the feed composition and nutritional requirements established by Rostagno et al. (2011) (Table 1).

The test diets were formulated by replacing 10% of the basal ration for a lipid source. This replacement levels were chosen according to those Sakomura and Rostagno (2016) proposed considering the type of digestibility test and total excreta collection. The experimental diets consisted of basal feed (Table 1), basal feed + 10% soybean oil, basal feed + 10% corn oil, basal feed + 10% canola oil, basal feed + 10% sunflower oil, and 10% poultry fat. Vegetable oils were used in refined form and poultry fat in crude form.

The experimental diets were offered *ad libitum* three times a day in a trough-type galvanized sheet metal feeder that covered the entire length of the cages. The feeder was divided according to each treatment and replication. Water was also provided *ad libitum* in a nipple drinker. As it is an oil that has well-known digestibility and ME values and a regular quality standard, the determination of the ME of soybean oil in this experiment also served as an indicator of the experimental quality of the present work.

Table 1 - Percentage and calculated composition of experimental feed

Ingredient	Quantity (%)
Corn bran	54.610
Soybean meal	29.968
Limestone	7.463
Sugar	5.400
DL-Methionine	0.800
Inert	0.500
L-Lysine	0.400
Salt	0.339
Dicalcium phosphate	0.217
Mineral supplement (poultry)	0.100
Vitamin supplement (poultry)	0.100
Choline chloride	0.100
Calculated nutritional composition	
Metabolizable energy (kcal/kg)	2,800
Crude protein (%)	19.460
Digestible lysine (%)	1.080
Methionine + digestible cystine (%)	0.940
Digestible tryptophan (%)	0.230
Digestible threonine (%)	0.680
Calcium (%)	3.070
Available phosphorus (%)	0.300
Sodium (%)	0.160
Crude fiber (%)	2.740

[1] Vitamin supplement/kg: vitamin A, 13,440,000 IU; vitamin D, 3,200,000 IU; vitamin E, 28,000 mg/kg; vitamin K, 2,880 mg/kg; thiamine, 3,500 mg/kg; riboflavina, 9,600 mg/kg; pyridoxine, 5,000 mg/kg; cyanocobalamin, 19,200 mcg/kg; folic acid, 1,600 mg/kg; pantothenic acid, 25,000 mg/kg; niacina, 67,200 mg/kg; biotin, 80,000 mcg/kg; selenium, 600 ppm; antioxidante, 0.40 g/kg.
[2] Mineral supplement/kg: Mg, 150,000 ppm; Zn, 140,000 ppm; Fe, 100,000 ppm; Cu, 16,000 ppm; I, 1,500 ppm.

2.2. Energy metabolism assay

The evaluation of nitrogen-corrected apparent metabolizable energy (AMEn) of lipid sources was carried out using the method of total excreta collection and an iron oxide marker when the poultry reached nine weeks of age. The metabolic assay began five days after the provision of experimental diets, followed by five days, when excreta was collected. All cages were equipped with a tray previously prepared for the collection of excreta, which was cleaned out twice a day at 08:00 am and 17:00 h.

The excreta were placed in plastic bags identified by replication and stored in a freezer at −16 °C. At the end of the collection period, the amount of feed consumed, and the total amount of excreta produced were determined. At the time of analysis, the samples were defrosted and homogenized.

An aliquot of about 200 g of excreta from each replication was removed and weighed and then placed in an oven with forced air ventilation at 55 °C for 72 h to proceed with pre-drying. Subsequently, the samples were exposed to air to equilibrate with ambient temperature and humidity. Then, they were weighed, ground in 1-mm knife mill, and placed in containers for laboratory analysis.

The moisture and nitrogen contents of excreta and rations were determined according to the methodology described by Silva and Queiroz (2002). The GE of diets, lipid sources, and excreta was obtained using a calorimetric bomb (IKA® model PARR 6200). The ME and AMEn values were calculated using the equations proposed by Matterson et al. (1965):

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

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

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

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

in which TD = test diet, BF = basal feed, and NB = nitrogen balance (N ingested – N excreted).

The calculation of the AMEn metabolizability coefficient (MC) was obtained by the ratio between AMEn and GE ingested and excreted and expressed as a percentage:

$$\text{MC (\%)} = \frac{\text{AMEn diet} - \text{AMEn excreta}}{\text{AMEn diet}} \times 100$$

2.3. Statistical analysis

Data were tested for homogeneity of variances and for normality of residues (PROC UNIVARIATE). The ME and AMEn values from the different lipid sources were tested by analysis of variance (PROC MIXED), and means were compared by Tukey's test at a 5% significance. The statistical model used is represented below:

$$Y_{ij} = m + t_i + e_{ij},$$

in which Y_{ij} = response variable of poultry, referring to the values of AMEn or MC (%) of the different lipid sources; m = overall mean effect; t_i = fixed effect of treatments (lipid sources); and e_{ij} = residual error.

3. Results

3.1. Energy metabolism assay

The AMEn value with soybean oil was 8,790 kcal/kg; for corn oil, 8,773 kcal/kg; for canola oil, 8,784 kcal/kg; for sunflower oil, 8,788 kcal/kg; and for poultry fat, 8,681 kcal/kg for laying Japanese quail. The digestibility coefficients were 93.88% for soybean oil, 93.53% for corn oil, 93.32% for canola oil, 93.74% for sunflower oil, and 93.06% for poultry fat (Table 2).

Table 2 - Dry matter (DM), gross energy (GE), metabolizable energy corrected for nitrogen (AMEn; kcal/kg), and metabolizability coefficient (MC%) of different lipid sources in the diet of Japanese quails at peak laying phase

Variable	Lipid source					MSE	P-value
	Soybean	Corn	Canola	Sunflower	Poultry fat		
DM (%)	99.76	99.75	99.67	99.18	99.38	-	-
GE (kcal/kg)	9,363	9,379	9,412	9,374	9,328	-	-
AMEn (kcal/kg)	8,790	8,773	8,784	8,788	8,681	285.300	0.9373
MC (%)	93.88	93.53	93.32	93.74	93.06	2.808	0.7425

MSE - mean standard error.

4. Discussion

4.1. Energy metabolism assay

The DM values of the lipid sources were similar as those found in the literature (Rostagno et al., 2005; Silva et al., 2009; Rostagno et al., 2011), i.e., ranging from 99.18 to 99.79%; the GE values (kcal/kg) were also similar, ranging from 9,328 to 9,412 kcal/kg. These values were mainly related to the lipid source of soybean origin, which was the control parameter used in the present research because they were available to a greater extent in the literature.

The GE found for soybean oil (9,363 kcal/kg) was lower in relation to the findings of Rostagno et al. (2011), who found GE values for soybean oil of 9,851 kcal/kg, Junqueira et al. (2005), who found 9,866 kcal/kg, and Silva et al. (2009), who found 9,851 kcal/kg. These differences may be related to factors such as processing, type of extraction, and temperature.

Poultry fat was the source that presented the lowest AMEn value (8,681 kcal/kg) and the lowest MC, however without significant differences when compared with the other oils analyzed. This difference may be explained by the chemical composition, physical structure, and passage rate in the digestive tract, which may interfere with the use of the energy value of a feed (Oliveira et al., 2007).

The nutritional assessment of ingredients is important to understand their structure to maximize digestive aspects. Oils and fats are energy-rich ingredients because they contain long chains with bonds between carbons and between carbons and hydrogen. These long hydrocarbon molecules, bound to the carboxyl group, are called fatty acids (Silva et al., 2018). Fatty acids are found in nature mainly in the form of triglycerides, which are molecules composed of three fatty acids bound to a glycerol molecule through ester bonds (Paula et al., 2021).

Among the edible vegetable oils produced on a large scale, those from soybean and canola have an α-linolenic acid content that, depending on the variety, climate, soil, and other factors, may vary between 5 and 10% of their total compositions in fatty acids (Carvalho, 2017). Poultry fat has about 17% of linoleic acid. The different types of oils have different percentages of fatty acids.

The length of the carbon chain, number of double bonds, configuration of the double bonds (*cis* and *trans*), presence of free fatty acid or fatty acids grouped in triglycerides, position of the fatty acid in the glycerol molecule, and unsaturated and saturated fatty acids in the lipid are chemical characteristics that affect digestibility and energy use by poultry (Fonseca et al., 2018), as well as the nutritional effects of lipid sources (Lara et al., 2005).

Among the sources tested, poultry fat has the highest percentage of saturated fatty acids, a characteristic related to the reduction in lipid digestibility, which reflects on the AMEn of the ingredient. However, there were no significant differences between the amounts of AMEn of the lipid sources in the present study.

In contrast, Araujo et al. (2019), working with the inclusion of fish oil for laying hen diets, found lower AMEn values (kcal/kg) compared with lipid sources of plant origin. The authors justify this fact precisely by the high amount of saturated fatty acids from animal sources and their lower digestibility.

Apparently, lipid sources of plant origin have a better composition for use in poultry because their fatty acid profile is rich in unsaturated forms (oleic, linoleic, and linolenic) (Aardsma et al., 2017), which present a better assimilation at the point of delivery. From a metabolic point of view, due to the sources of animal origin, they present a greater variation in terms of composition and a greater proportion of saturated fatty acids.

The sources of plant origin evaluated presented AMEn values higher than GE values, which is not common in digestibility tests with other feeds (Santos et al., 2013; Troni et al., 2016), but when it comes to vegetable oils, such a finding appears in studies (Araujo et al., 2019). Some researchers

reported that the extra caloric effect of some lipid sources may improve their energy values, that is, values that extrapolate their GE content (Junqueira et al., 2005; Araujo et al., 2019), which justifies metabolizability coefficients of plant sources above 100%.

According to Andreotti et al. (2004), the passage rate of feed through the digestive system helps in the digestibility of other feed ingredients. Thus, these values may have been influenced by the use of other diet components, such as corn and soybean, resulting in an apparent increase in use of the energy added in AMEn (Cullen et al., 1962; Araujo et al., 2019).

As Kerr et al. (2016) reported, values of MC (%) of lipids in poultry diets above 92% are suitable for inclusion in diets. The precise definition of the amount of energy in feed, especially from lipid sources that are major energy providers, is a fundamental factor to adequately meet the nutritional requirements of poultry (Yang et al., 2020).

Works such as the one proposed here, i.e., those which evaluate the metabolic use of feed, are necessary and periodically required due to differences in the environment and due to the genetic improvements of bird lineages. These works contribute to a better use of diets, specifically of AMEn in feed (Araujo et al., 2019), indicating evolution in feed efficiency.

In addition, with the exception of soybean oil, the lipid sources evaluated in the present study are not present in the latest publication of the "Brazilian tables for poultry and swine: composition of feedstuffs and nutritional requirements" (Rostagno et al., 2017). Such data are important to formulate diets for quail in a precise way to efficiently meet the energy needs of each animal category.

5. Conclusions

The values of apparent metabolizable energy corrected for nitrogen in laying Japanese quail are: 8,790 kcal/kg for soybean oil; 8,773 kcal/kg for corn oil; 8,784 kcal/kg for canola oil; 8,788 kcal/kg for sunflower oil; and 8,681 kcal/kg for poultry fat. The digestibility coefficients for laying Japanese quail are 93.88% for soybean oil, 93.53% for corn oil, 93.32% for canola oil, 93.74% for sunflower oil, and 93.06% for poultry fat.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization: J.K. Valentim, R.G. Garcia, M.F.C. Burbarelli and G.V. Polycarpo. Data curation: J.K. Valentim, R.G. Garcia, M.F.C. Burbarelli and J. Zanella. Formal analysis: J.K. Valentim, R.G. Garcia and M.F.C. Burbarelli. Funding acquisition: R.G. Garcia and M.F.C. Burbarelli. Investigation: J.K. Valentim, R.G. Garcia, M.F.C. Burbarelli, F.C. Serpa, J. Zanella and V.A.R. Castilho Heiss. Methodology: R.G. Garcia and F.C. Serpa. Project administration: R.G. Garcia and M.F.C. Burbarelli. Supervision: R.G. Garcia, F.R. Caldara and C.M. Komiyama. Validation: R.G. Garcia and C.M. Komiyama. Visualization: R.G. Garcia and F.R. Caldara. Writing – original draft: J.K. Valentim, R.G. Garcia and J. Zanella. Writing – review & editing: J.K. Valentim, R.G. Garcia, M.F.C. Burbarelli, F.R. Caldara, C.M. Komiyama, G.V. Polycarpo and L.F.T. Albino.

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