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Original Article

Nutritional Composition, Metabolisable Energy and Total Use of Sunflower Seed Cake for Meat Quail

■Author(s)

Cordeiro CN[I] https://orcid.org/0000-0001-6125-2461
Freitas ER[I] https://orcid.org/0000-0001-7226-9517
Nepomuceno RC[I] https://orcid.org/0000-0003-0674-1662
Pinheiro SG[I] https://orcid.org/0000-0002-8577-3576
Souza DH[I] https://orcid.org/0000-0003-1345-1639
Watanabe GCA[I] https://orcid.org/0000-0002-8140-5119
Freitas CA[I] https://orcid.org/0000-0002-1321-2876
Watanabe PH[I] https://orcid.org/0000-0002-1010-2305

[I] Department of Animal Science, Federal University of Ceará, Campus Pici, Fortaleza, Ceará, Brazil.

■Mail Address

Corresponding author e-mail address
Carla Nágila Cordeiro
Animal Science Department, Federal University of Ceará, Fortaleza, CE 60356-001, Brazil.
Phone: +55 (88) 997128524
Email: carlinha_nagila@hotmail.com

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ABSTRACT

We determined the nutritional and energy compositions of sunflower seed cake (SC) and examined the effects of its inclusion in the diet of meat quail. A metabolism trial was performed employing the total excreta collection method, with 144 quails that were assigned to three treatments (control diet and two test diets in which SC replaced 20 and 40% of the control diet) in a completely randomised design (CRD) with six replicates of eight birds. The values determined of dry matter, crude protein and metabolisable energy were 94.72%, 24.29% and 2,629 kcal/kg, respectively. For the performance trial, 432 quails were assigned to six treatments (dietary inclusion of 0, 5, 10, 15, 20 and 25% SC) in a CRD with six replicates of 12 birds. The metabolic coefficients of dry matter (MCDM) and gross energy (MCGE) of the diet decreased linearly with increasing SC levels. Compared with the control group, SC inclusion at levels greater than 10% resulted in lower MCDM and MCGE values, whereas SC inclusion at 20 and 25% reduced AMEn. Weight gain, feed conversion and economic viability parameters showed a quadratic response, with the best values obtained at the respective SC levels of 15.5, 14.0, and 15.4%. Gizzard weight increased linearly with the inclusion of SC, whereas bone quality was not affected. Sunflower cake can be used up to 25% in diets of meat quails without compromising their performance. However, the best feed conversion and economic viability are obtained with an SC inclusion level of 15%.

INTRODUCTION

The recent years have seen a significant increase in quail production, mainly after the introduction of the European quail and breeding programs for this bird, which is mostly used for meat production. This development may be related to the nutritional and gastronomic characteristics of quail meat, which can be used in various dishes, and the stimulus to commercial production provided by numerous advantages of quail production, such as relatively small investments, no need for large areas, elevated production indices, short generation intervals and high growth rates (Massuda & Murakami, 2008).

In this scenario, viable strategies have been sought to optimize animal performance, reducing production costs, such as the use of alternative foods that can meet the nutritional requirements of animals, replacing conventional ingredients in the diet of these animals.

The growing production of biofuel in Brazil, which requires an increased production of vegetable oils extracted from oilseeds, generates a large number of by-products. This waste, which is often discarded, has the potential to be used in animal feeding.

A noteworthy example of such by-products is sunflower cake, which is obtained from the mechanical pressing of sunflower seeds (*Helianthus annuus L.*) for oil extraction in the biodiesel, food and cosmetic industries. Sunflower cake can be used in animal feeding because of its favourable composition of 26.06% of crude protein, 20.51% of ether extract and 5,249 kcal/kg of gross energy (Oliveira *et al*. 2012). However, its use in the feeding of monogastrics is still limited due to anti-nutritional factors such as elevated fibre contents and the presence of phytate, complicating the digestion and absorption of dietary nutrients and, consequently, influencing the production performance of these animals.

Oliveira *et al*. (2012) and Costa Júnior *et al*. (2015) reported that sunflower cake can be included with up to 18 and 15% in the diets of broilers and free-range chickens, respectively, without negatively affecting their production performance. However, information on the level of sunflower cake to be used in feed of meat quails for better productive performance is scarce. The inclusion of by-products in animal nutrition requires knowledge of their chemical composition, since they vary more widely than conventional feedstuffs in terms of nutrient digestibility, energy values and their influence on animal performance. In this way, by determining their chemical composition, their benefits can be better exploited, increasing the viability of such an approach (Pereira *et al.* 2011).

In this context, given the scarcity of information on the use of sunflower cake in quail diets, this study determined the nutritional and energy compositions of this ingredient and investigated the effects of its inclusion in the diet of meat quails.

MATERIAL AND METHODS

The experimental procedures were approved by the Ethics Committee on Animal Use (CEUA-UFC) of the Federal University of Ceará (UFC), Brazil.

Two trials were conducted in the Poultry Farming Unit at UFC. The sunflower cake was obtained from sunflower seeds with hull after mechanical pressing for oil extraction.

Nutritional Compositions and Determination of Metabolisable Energy in Sunflower Cake for Meat Quail Production

A metabolism trial was initially carried out with meat quail, using the traditional excreta collection method. A total of 144 meat quails (*Coturnix coturnix coturnix*) at 21 days of age non-sexed were used over a period of 8 days, with 4 days of acclimatisation and 4 days of sample collection. The quails were housed in metabolic battery cages equipped with feeder and drinker troughs and aluminium trays lined with plastic for excreta collection. The birds were assigned to three treatments in a completely randomised design with six replicates and eight quails per experimental unit. The initial weight per plot was 1,190 ± 4 g.

Treatments consisted of a corn- and soybean meal-based control diet (Table 1), considering the nutritional levels recommended by the NRC (1994), and two test diets in which 20 and 40% of the control diet were replaced with sunflower cake.

Table 1 – Percentages and calculated nutritional levels of the control diet in the 21-day-old quail meet metabolism trial.

Ingredient	%
Corn	51.19
Soybean meal	43.95
Soybean oil	1.94
Calcitic limestone	1.20
Dicalcium phosphate	0.93
Salt	0.33
Mineral-vitamin supplement[1]	0.20
DL-methionine	0.16
Choline chloride	0.05
Coxistac (salinomycin)	0.05
Calculated nutritional and energy composition	
Metabolisable energy [kcal/kg]	2,900
Crude protein [%]	24.00
Neutral detergent fibre [%]	12.16
Acid detergent fibre [%]	5.27
Calcium [%]	0.80
Digestible phosphorus [%]	0.28
Sodium [%]	0.15
Chloride [%]	0.24
Digestible lysine [%]	1.23
Digestible methionine [%]	0.47
Digestible methionine + cystine [%]	0.79
Digestible threonine [%]	0.83
Digestible tryptophan [%]	0.28

[1]Composition per kilogram of product: iron - 50.00 g; copper - 12.00 g; manganese - 60.00 g; zinc - 50.00 g; iodine - 1,000.00 mg; selenium - 400.00 mg; vit. A - 20,000,000.00 IU; vit. D3 - 5,000,000.00 IU; vit. E - 100,000.00 IU; vit. K3 - 6,000.00 mg; vit. B1 - 7,000.00 mg; vit. B2 - 15.00 g; niacin - 80.00 g; pantothenic acid - 30.00 g; vit. B6 - 8,000.00 mg; folic acid - 4,000.00 mg; biotin - 200.00 mg; vit. B12 - 36,000.00 mg

Water and the diets were supplied *ad libitum* throughout the experimental period. A lighting regimen of 24 h of light daily (natural + artificial) was adopted using 40-W fluorescent light bulbs.

During the collection period, all produced excreta were harvested twice daily (8 a.m. and 16 a.m.), packed in labelled plastic bags, weighed and frozen at –20ºC. To determine the start and end of the collection period, 1% ferric oxide was added to the diets as a marker.

For the analysis, the excreta were thawed at room temperature and homogenised. A sample was then taken and pre-dried in a forced-air oven at 55ºC for 72 h. Subsequently, the samples were ground through a knife mill with a 16-mesh sieve with 1-mm pores. Samples of excreta, diets and sunflower cake were analysed for DM and nitrogen concentrations, following the method described by Silva & Queiroz (2002); gross energy was determined using a bomb calorimeter (PARR, model 1241EA). The sunflower cake sample was also analysed for ether extract and ash contents, following the methodology described by Silva & Queiroz (2002), and for acid and neutral detergent fibre as described by Van Soest *et al*. (1991).

For the calculation of the nitrogen-corrected apparent metabolisable energy (AMEn), laboratory data were used in equations proposed by Matterson *et al*. (1965). The data were subjected to statistical analysis using SAS software (2000), and means were compared by the SNK test at the 5% significance level.

Levels of Sunflower Cake in Meat Quail Diets

The second trial consisted of an evaluation of the metabolisation of dietary nutrients, production performance, carcass characteristics, bone quality and the economic viability of producing meat quail fed diets containing increasing levels of sunflower cake. For this, a total of 432 meat quails (7 to 42 days of age) non-sexed were housed in 36 cages (dimensions: 0.60 × 0.60 m) equipped with a trough feeder and a bell drinker.

In the first week of age, from 1 to 7 days, the quails were housed in a protection circle containing tray feeders, pressure-cup drinkers and heat brooders. At 7 days of age, the birds were selected based on the average body weight of the lot and distributed into the plots as suggested by Sakomura & Rostagno (2007), with an average weight of 429 ± 4.78 g per plot.

The trial was set up as a completely randomised experimental design with six treatments and six replicates, with 12 birds per experimental unit. Treatments consisted of a control diet and five diets in which sunflower cake replaced 5, 10, 15, 20 and 25% of the control diet.

The experimental diets (Table 2) were formulated to contain equal amounts of nutrients and calories, following the requirements proposed by Silva & Costa (2009). The chemical composition of the ingredients was adopted from Rostagno *et al*. (2011), except for the sunflower cake, for which the AMEn was determined considering a dietary inclusion (substitution) level of 20%. Using the tables of FEDNA (2016), the chemical composition of sunflower cake was estimated (as-is basis) as 23.00% crude protein, 16.10% ether extract, 47.33% neutral detergent fibre, 31.20% acid detergent fibre, 2.87% ash (obtained in the previous trial), 0.30% calcium, 0.10% available phosphorus, 0.03% sodium, 0.09% chloride, 1.28% potassium, 0.70% digestible lysine, 0.49% digestible methionine, 0.80% digestible methionine + cystine, 0.73% digestible threonine and 0.27% digestible tryptophan.

The lighting regime adopted was 24 h of light daily (natural + artificial) throughout the experimental period. Temperature and air relative humidity inside the shed were measured daily during the entire experimental period, using three thermo-hygrometers that were placed in the main points of the shed. Readings were taken twice daily (8 a.m. and 16 p.m.). Average minimum and maximum room temperatures and air relative humidity recorded in the shed during the performance trial were 28.5ºC, 33.3ºC and 58%, respectively.

For the evaluation of the performance, the quails and the diets were weighed at the start (7 days) and at the end of the experiment (42 days) to determine feed intake (g/bird), weight gain (g/bird) and feed conversion. The variables were corrected based on the observed mortality.

To evaluate the effect of sunflower cake inclusion on the metabolisation of the dietary nutrients, the traditional total excreta collection method was employed from 21 to 28 days of age. Six birds from each experimental plot were transferred and housed in metabolic battery cages equipped with a tray for excreta collection, feeders and drinkers, following the same experimental design as that adopted in the experiment.

For carcass evaluation, at 42 days of age, two birds from each experimental unit (one male and one female) were selected based on the average weight of the plot. After a feed-deprivation period of 6 h, the birds were weighed, euthanised by electronarcosis followed by bleeding, and subsequently scalded, plucked and eviscerated.

After the removal of the head, the neck and the feet, the carcass was weighed to determine carcass yield using the weight of the feed-deprived bird. Subsequently, the full breast, drumstick + thigh as well as abdominal fat were separated and weighed for the calculation of cut yields. Drumsticks + thighs

Table 2 – Percentages and calculated nutritional levels of the experimental diets for meat quail.

Ingredient	Price[1] [BRL/kg]	Sunflower cake inclusion level					
		0%	5%	10%	15%	20%	25%
Corn	1.10	56.81	53.28	49.75	46.22	42.68	39.15
Soybean meal	1.96	40.31	38.67	36.68	34.7	32.72	30.74
Sunflower cake	0.80	0.00	5.00	10.00	15.00	20.00	25.00
Soybean oil	2.80	0.00	0.21	0.72	1.24	1.75	2.26
Limestone	0.19	1.06	1.01	0.98	0.95	0.93	0.90
Dicalcium phosphate	3.70	0.90	0.91	0.92	0.92	0.93	0.94
Salt	0.60	0.35	0.35	0.35	0.35	0.35	0.35
DL-methionine	18.83	0.27	0.26	0.26	0.25	0.24	0.23
L-lysine	11.18	0.00	0.01	0.04	0.07	0.10	0.13
Vitamin supplement[2]	15.29	0.15	0.15	0.15	0.15	0.15	0.15
Mineral supplement[3]	6.84	0.05	0.05	0.05	0.05	0.05	0.05
Anti-coccidial	22.00	0.05	0.05	0.05	0.05	0.05	0.05
Choline chloride	20.00	0.05	0.05	0.05	0.05	0.05	0.05
Total		100.00	100.00	100.00	100.00	100.00	100.00
Cost [BRL/kg]		1.55	1.53	1.51	1.48	1.46	1.47
Calculated nutritional and energy composition							
Metabolisable energy [Kcal/kg]		2,950	2,950	2,950	2,950	2,950	2,950
Crude protein [%]		23.00	23.00	23.00	23.00	23.00	23.00
Neutral detergent fibre [%]		12.29	14.05	15.73	17.40	19.07	20.75
Acid detergent fibre [%]		5.18	6.48	7.76	9.04	10.32	11.60
Calcium [%]		0.75	0.75	0.75	0.75	0.75	0.75
Available phosphorus [%]		0.29	0.29	0.29	0.29	0.29	0.29
Sodium [%]		0.16	0.16	0.16	0.16	0.16	0.16
Chloride [%]		0.27	0.27	0.27	0.27	0.27	0.27
Digestible lysine [%]		1.14	1.14	1.14	1.14	1.14	1.14
Digestible methionine + cystine [%]		0.89	0.89	0.89	0.89	0.89	0.89
Digestible methionine [%]		0.58	0.58	0.58	0.58	0.58	0.58
Digestible threonine [%]		0.77	0.77	0.77	0.77	0.77	0.77
Digestible tryptophan [%]		0.26	0.26	0.26	0.26	0.26	0.26

[1]Prices of ingredients as of July/2017 in the municipality of Fortaleza - CE, Brazil; [2]Composition per kilogram of product: vit. A - 9,000,000.00 IU; vit. D3 - 2,500,000.00 IU; vit. E - 20,000.00 mg; vit. K3 - 2,500.00 mg; vit. B1 - 2,000.00 mg; vit. B2 - 6,000.00 mg; vit. B12 - 15.00 mg; Niacin - 35,000.00 mg; pantothenic acid - 12,000.00 mg; vit. B6 - 8,000.00 mg; folic acid - 1,500.00 mg; selenium - 250.00 mg; biotin - 100.00 mg; [3]Composition per kilogram of product: iron - 100,000.00 mg; copper - 20.00 g; manganese - 130,000.00 mg; zinc - 130,000.10 mg; iodine - 2,000.00 mg.

were labelled and frozen at –20ºC for later analysis. Liver and gizzard were also weighed to determine their respective relative weights.

For the evaluation of bone quality, the drumsticks + thighs were thawed in a domestic refrigerator (4ºC for 12 h) and placed on countertops to reach room temperature. Subsequently, they were immersed in boiling water for 5 min, and all tissues surrounding the bones were then removed with a scalpel.

Femur and tibia length were measured using a digital calliper, and weight was determined using an electronic scale with a precision of 0.01 g. Bone density was determined as the "Seedor index", which was calculated by dividing the weight value (mg) by the length (mm) of the evaluated bone (Seedor *et al*. 1991).

The left femur and the tibia were subjected to analyses of bone resistance and deformity, using a mechanical press. Bones were placed in the horizontal position, and a compression force was exerted by a piston (at a descent speed of 0.4064 mm/min) on their centre. The breaking strength was considered the maximum amount of force applied to the bone until it broke (kgf/cm2), which was measured with a digital extensometer. Deformity (mm) was measured using an analogical extensometer until the bone broke by the action of the applied force.

To determine bone composition, the left and right bones were pre-dried in a forced-air oven at 55ºC for 72 h and ground in a mortar with a pestle; subsequently, mineral matter was determined, following the method described by Silva & Queiroz (2002).

The economic viability of SC inclusion in the diets was determined by calculating the cost of the diet per kilogram of body weight gain, using the equation proposed by Bellaver *et al*. (1985). The economic efficiency index (EEI) and the cost index (CI) were calculated by using the equations proposed by Fialho *et al*. (1992).

To determine the feeding costs, we considered the composition of each diet and the prices of the ingredients purchased in July 2017 in Fortaleza, CE, Brazil.

The data were analysed by the ANOVA procedure of the SAS software (2000) as a completely randomised model, and the means of the treatments with sunflower seed cake were compared with those of the control treatment by Dunnett's test (5%). To determine the best level of inclusion of sunflower seed cake, the data were subjected to regression analysis.

RESULTS

Nutritional Compositions and Determination of Metabolisable Energy in Sunflower Cake for Meat Quail Production

The chemical analysis of sunflower cake (Table 3) revealed 94.72% dry matter, 24.29% crude protein, 5,297 kcal/kg gross energy, 50.00% neutral detergent fibre, 32.94% acid detergent fibre, 17.00% ether extract and 3.03% ash.

Table 3 – Chemical and energy composition of sunflower cake, expressed on a dry matter basis[1].

Parameter	Sunflower cake
Dry matter [%]	94.72
Crude protein [%]	24.29
Gross energy [kcal/kg]	5.297
Neutral detergent fibre [%]	50.00
Acid detergent fibre [%]	32.94
Ether extract [%]	17.00
Ash [%]	3.03

[1]Analyses performed at the Laboratory of Animal Nutrition at DZ/UFC.

The nitrogen-corrected apparent metabolisable energy (Table 4), determined at 20% of substitution of the control diet (2,629 kcal/kg), was significantly higher than that observed when 40% of the control diet were replaced with SC (2,402 kcal/kg).

Table 4 – Mean values of nitrogen-corrected apparent metabolisable energy (AMEn) of sunflower cake determined for meat quail, on a dry-matter basis.

Sunflower cake inclusion level	AMEn [Kcal/kg]
20%	2.629a
40%	2.402b
Mean	2.515
Analysis of variance (*p*-value)	0.0152
SEM[1]	0.05

[1]Std Error of mead; Means followed by different letters significantly differ from each other according to the SNK test ($p<0.05$).

Levels of SC in Meat Quail Diets

Digestibility of the experimental diets

The inclusion of SC significantly influenced the metabolisability coefficients of dry matter (MCDM), gross energy (MCGE) and AMEn (Table 5). However, no significant difference was observed for the metabolisability coefficient of nitrogen.

According to the results of the regression analysis, after the SC inclusion level of 5%, there was a linear decrease in MCDM, MCGE and AMEn, although MCN was not significantly affected.

Dunnett's test revealed that the diets containing 10% SC or more showed lower MCDM and MCGE values, and the inclusion of 20 and 25% SC led to a worse AMEn in the diets as compared with the control diet.

Table 5 – Metabolisability coefficients and metabolisable energy values of meat quail diets containing increasing levels of sunflower cake.

Inclusion level [%]	MC_{DM} [%]	MC_{N} [%]	MC_{GE} [%]	AMEn [kcal/kgDM]
0	72.41	40.68	77.76	3,166
5	70.83	45.45	76.66	3,219
10	69.04*	43.58	74.95*	3,182
15	67.15*	40.25	73.75*	3,180
20	64.98*	45.45	70.41*	3,048*
25	65.98*	44.56	71.25*	3,066*
Mean	68.40	43.33	74.13	3,1436
SEM[1]	0.54	1.45	0.55	0.02
Analysis of variance			*p*-value	
Level	< 0.0001	0.1118	< 0.0001	< 0.0001
Regression			*p*-value	
Linear	0.0043[1]	0.1272	0.0211[2]	< 0.0001[3]
Quadratic	0.0558	0.1197	0.2644	0.8357

[1]Std Error of mead; *Statistical effect significant according to Dunnett's test ($p<0.05$); [1]$y = 71.7260 – 0.2753x$, $R^2 = 0.85$; [2] $y = 78.009 – 0.3069x$, $R^2 = 0.87$; [3]$y = 3.271 – 8.8x$, $R^2 = 0.82$.

Production performance

Feed intake (FI), weight gain (WG) and feed conversion (FC) did not differ significantly between the birds fed diets with different levels of SC or the control diet (Table 6). However, regression analysis revealed a quadratic effect of SC inclusion after 5% on WG and FC, whose maximum and best values were estimated at the replacement levels of 15.5 and 14%, respectively.

Table 6 – Performance of meat quail fed sunflower cake in the period of 7 to 42 days of age.

Inclusion level [%]	Intake [g/bird]	Weight gain [g/bird]	Feed conversion
0	1050.74	228.48	4.60
5	1102.35	225.38	4.89
10	1095.01	236.72	4.62
15	1064.27	238.06	4.47
20	1111.49	236.86	4.69
25	1153.49	226.18	5.10
Mean	1096.22	231.95	4.73
SEM[1]	13.79	1.34	0.07
Analysis of variance		*p-value*	
Level	0.3257	0.0502	0.0594
Regression		*p-value*	
Linear	0.2516	0.8751	0.3243
Quadratic	0.1441	<0.0001[2]	0.0017[3]

[1]Std Error of mead; [2]$Y = 208.83 + 4.03X – 0.13X^2$, $R^2 = 0.98$; [3]$Y = 5.47 – 0.14X + 0.005X^2$, $R^2 = 0.99$. Statistical effect insignificant according to Dunnett's test ($p>0.05$).

Carcass characteristics

The yields of carcass, breast, drumstick + thigh, abdominal fat and liver did not differ between the birds fed the diets containing SC and those fed the control diet (Table 7). However, the SC inclusion levels of 20 and 25% provided an increase in relative gizzard weight in relation to the control diet.

In the regression analysis, no significant effect was observed for the carcass characteristics, except for the gizzard percentage, which increased linearly with increasing SC levels.

Table 7 – Yields of carcass, breast, drumstick + thigh, abdominal fat, gizzard and liver of meat quail fed sunflower cake from 7 to 42 days of age.

Inclusion level [%]	Carcass [%]	Breast [%]	Drumstick + thigh [%]	Abdominal fat [%]	Gizzard [%]	Liver [%]
0	67.53	40.43	24.34	1.95	2.03	2.07
5	66.39	40.60	24.39	1.91	2.31	1.93
10	68.03	42.63	24.60	2.99	2.32	2.03
15	67.70	43.58	25.19	2.96	2.25	1.87
20	66.86	42.80	25.26	2.63	2.82*	1.86
25	66.86	43.59	24.49	2.69	2.66*	1.85
Mean	67.23	42.27	24.71	2.52	2.40	1.94
SEM[1]	0.33	0.81	0.15	0.15	0.06	0.03
Analysis of variance				*p*-value		
Level	0.7321	0.7983	0.3168	0.0933	<0.0001	0.1288
Regression				*p*-value		
Linear	0.9321	0.2486	0.5106	0.2627	0.0030[2]	0.1439
Quadratic	0.2517	0.5038	0.1002	0.0573	0.5031	0.7828

[1]Std Error of mead; [2]$Y = 2.11 + 0.02X$, $R^2 = 0.57$; *Differs statistically compared with the control treatment according to Dunnett's test ($p<0.05$).

Bone growth and quality

The bone parameters measured in the femur and tibia were not significantly influenced by the treatments (Table 8), which means that the inclusion of SC up to 25% did not affect the evaluated bone parameters.

Economic viability

Sunflower cake inclusion levels greater than 5% elicited a quadratic response from feeding cost per live-weight gain, EEI and CI. Minimum feeding cost per live-weight gain, maximum EEI and minimum CI were estimated for an SC inclusion level of 15.4% (Table 9).

Table 8 – Bone parameters measured in the femur and tibia of meat quails fed sunflower cake.

Inclusion level [%]	Variable[1]							
	BW [g]	BL [mm]	BDI [mm]	SI [mg/mm]	BR [kgf/cm²]	BDE [mm]	BDM [%]	BA [%]
FEMUR								
0	0.711	45.05	3.36	15.76	3.48	1.36	77.18	49.53
5	0.726	46.19	3.26	15.70	3.54	1.46	74.98	52.53
10	0.710	45.61	3.33	15.56	3.57	1.36	74.68	48.82
15	0.748	45.80	3.34	16.30	3.54	1.39	74.46	49.22
20	0.733	46.08	3.22	15.88	3.74	1.33	72.11	52.28
25	0.733	45.51	3.23	16.09	3.77	1.40	71.44	50.12
Mean	0.726	45.71	3.29	15.88	3.65	1.36	74.14	50.42
SEM[2]	9.45	0.17	0.02	0.17	0.08	0.03	0.87	0.55
Analysis of variance	p-value							
Level	0.8723	0.4259	0.3171	0.8653	0.9129	0.8297	0.4665	0.2214
Regression					*p*-value			
Linear	0.6170	0.4766	0.3691	0.4447	0.3427	0.5147	0.1239	0.7554
Quadratic	0.8253	0.9480	0.2609	0.7992	0.7738	0.3349	0.6961	0.2710
TIBIA								
0	0.795	55.96	3.11	14.19	1.86	1.59	79.30	51.27
5	0.823	57.31	3.17	14.38	2.23	1.66	77.48	54.08
10	0.837	56.47	3.17	14.82	1.73	1.47	76.63	50.87
15	0.845	57.01	3.05	14.75	1.80	1.48	76.05	52.00
20	0.851	57.04	3.22	14.91	1.79	1.44	75.57	53.07
25	0.832	56.42	3.11	14.73	1.94	1.61	73.93	52.00
Mean	0.831	56.71	3.14	14.63	1.89	1.54	76.49	52.22
SEM[2]	10.80	0.22	0.03	0.17	0.11	0.06	0.74	0.48
Analysis of variance	p-value							
Level	0.7572	0.5134	0.6149	0.8385	0.8154	0.9065	0.4298	0.4196
Regression					*p*-value			
Linear	0.6998	0.4861	0.7529	0.5418	0.5302	0.7952	0.0875	0.6061
Quadratic	0.4838	0.9137	0.7554	0.5155	0.2076	0.2820	0.7905	0.3508

[1] BW = bone weight, BL = bone length, BDI = bone diameter, SI = Seedor index, BR = bone resistance, BDE = bone deformity, BDM = bone dry matter, BA = bone ash; [2]Std Error of mead; Statistical effect insignificant according to Dunnett's test ($p>0.05$).

The comparison of means by Dunnett's test revealed that the economic viability variables did not differ significantly ($p>0.05$) across the SC inclusion levels.

Table 9 – Economic assessment of sunflower cake inclusion in the diet of meat quails.

Inclusion level [%]	Feeding cost [BRL/kg of gain]	Economic efficiency index [%]	Cost index [%]
0	7.14	94	108
5	7.46	89	112
10	6.96	96	105
15	6.64	100	100
20	6.86	97	104
25	7.35	91	111
Mean	7.07	95	107
SEM[1]	0.10	1.27	1.44
Analysis of variance		*p-value*	
Level	0.1134	0.0737	0.1052
Regression		*p-value*	
Linear	0.6617	0.7250	0.6838
Quadratic	0.0019[1]	0.0012[2]	0.0017[3]

[1]Std Error of mead; Statistical effect insignificant according to Dunnett's test ($p>0.05$); [1]$Y = 8.4133 - 0.223X + 0.00722X^2$, $R^2 = 0.99$; [2]$Y = 76.10 + 3.08428X - 0.10047X^2$, $R^2 = 0.97$; [2]$Y = 126.633 - 3.361428X + 0.1090476X^2$, $R^2 = 0.98$.

DISCUSSION

Nutritional composition and determination of the metabolisable energy of SC for meat quail

In the present study, the composition of SC differs from that reported by Oliveira *et al*. (2012), who reported 28.44% CP, 5,729 kcal/kg GE, 34.37% NDF, 30.26% ADF, 23.39% EE and 4.40% ash. Berwanger *et al*. (2014) also reported different CP, GE, NDF, ADF, EE and ash values in SC (26.44%, 5,228 kcal/kg, 38.32%, 24.19%, 25.80%, and 4.44%, respectively).

In the literature, the composition of SC widely varies, mainly as a result of the different degrees of seed hulling, influencing its nutritional components (Costa *et al*. 2015). The present results can be explained by the characteristics of the seeds used and the oil extraction process, which increased the fibre contents and reduced the EE contents, respectively. Moreover, the seeds were not hulled and were crushed by mechanical pressing.

Levels of SC in the meat quail diets

Digestibility of the experimental diets

High fibre contents in a feedstuff may reduce the digestibility of its nutrients. According to Rostagno *et al*. (2017), the fibre present in the sunflower seed by-product, after its processing for oil extraction, is characterised mainly by the insoluble fraction. The presence of insoluble fibre in the diet may increase the rate of passage and reduce the residence time of the feed in the gastrointestinal tract (Cumming *et al*. 2004), reducing the time of access of the enzymes to the nutrients. This effect may explain the difference found in the AMEn values when the level of substitution of the feedstuff was elevated, since SC is rich in fibre, given the observed ADF and NDF values.

Based on the present results, we recommend considering an AMEn value of 2,629 kcal/kg of DM for SC in the formulation of diets for meat quail, since the 40% level reduced the EMAn of the sunflower cake. This assertion corroborates the observations made by Sakomura & Rostagno (2007), who stated that the recommended level for the determination of energy values of fibrous feedstuffs by the traditional total excreta collection method is 20% substitution.

Our AMEn values of the SC for meat quail are higher than the 2,150 kcal/kg obtained for broilers by Berwanger *et al*. (2014) and lower than the 2,800 kcal/kg reported by Oliveira *et al*. (2012), also for broilers. However, in addition to the differences in the use of dietary nutrients between species, the sunflower cakes used by those authors and that used in the present experiment had different compositions, especially in terms of gross energy and fibre, which explains the variations in metabolisable energy.

The reduction in the MC_{DM} and MC_{GE} of the experimental diets observed as SC may be associated with the effects of the anti-nutritional factors present in SC. Most importantly because the increase in the fibre contents of the diets may reduce the time of passage of the feed through the gastrointestinal tract, minimise the access of enzymes to the feed and affect nutrient use (Khajali & Slominskr 2012; Sakomura *et al*. 2014).

Although the MC_{GE} worsened after an SC inclusion of 5%, AMEn was not compromised up to the inclusion level of 15%. This indicates that the birds could adjust their metabolism, despite the difference between these energy coefficients. This can be proved by the lack of differences in MC_N between the treatments, with similar values found for the control diet and the diet with the highest inclusion level.

The present results for meat quail differ from those observed for broilers by Kalmendal *et al*. (2011), who described a positive linear effect of including up to 30% SC on the ileal digestibility of proteins, despite the significant linear decrease in the ileal digestibility of energy and dry matter.

The nitrogen-corrected apparent metabolisable energy was not expected to be influenced by the inclusion of SC in the meat quail diets, since the fat content of the diets with higher concentrations of SC had to be increased to obtain the same amount of energy. However, despite the addition of soybean oil to the diets, the birds could not efficiently use the energy. This result is attributed to the fibrous fraction of the feedstuff, which negatively influences the metabolisable energy from the diet (Arruda & Fernandes, 2014). Nutrient digestion was compromised when the SC inclusion levels were increased to 20 and 25%, reducing the AMEn.

Production performance

Voluntary feed intake is mainly governed by the amount of energy from the diet that is destined for metabolic processes. Because there was a reduction in the dietary metabolisable energy, the increasing FI was expected as an attempt to meet the nutritional requirements. Although intake increased numerically, this effect was not significant.

These results differ from those presented by Oliveira *et al*. (2012) and Berwanger *et al*. (2017), who observed a quadratic and a linear response of FI, respectively, after SC was included in the diet of broilers. However, those authors did not observe differences in FI between the SC-containing and the control treatments, similar to our findings.

A quadratic regression model was fitted for WG when increasing levels of SC were added to the quail diets. The AMEn of the diets was influenced by the treatments, and the lowest values for this variable were obtained at the inclusion levels greater than 15%. This led to a decline in WG after an SC inclusion of 15.5%, despite the lack of differences between the treatment without SC inclusion (control) and the other treatments.

Contrasting results for the inclusion of up to 40% SC in the diet of broilers were reported by Kalmendal *et al*. (2011), who observed a linear increase in WG with SC inclusion. Similar results were reported by Costa Júnior *et al*. (2015), who included up to 15% SC in diets for semi-free-range hens and observed that the WG of the birds fed SC did not differ from that of the hens fed the control diet.

Considering the results for FI and WG, feed conversion was also influenced by SC inclusion, since this variable is obtained as the ratio between FI and WG. In this way, the lack of effects on FI and the quadratic response shown by WG resulted in a quadratic effect on FC.

A distinct result was obtained by Oliveira *et al*. (2012), who used increasing levels of SC up to 18% in the diet of broilers from 20 days of age and observed a linear decrease in FC. Our results corroborate those obtained by Costa Júnior *et al*. (2015) and Berwanger *et al*. (2017), who also did not observe a significant difference between birds fed diets containing SC and those fed the control treatment. Kalmendal *et al*. (2011), however, reported that SC inclusion levels negatively affected the FC of broilers and recommended its inclusion up to 20%.

Carcass characteristics

Considering that changes in the dietary energy: protein ratio or amino acids can influence muscle and fat deposition in the carcass, the carcass characteristics were expected to be influenced by the addition of higher SC levels to the diets, since the AMEn of the diets was affected. However, it can be inferred that the reduction in the AMEn of the diets was not sufficient to have a significant effect on the carcass characteristics of the meat quail. By contrast, Berwanger *et al*. (2017) reported significant effects of SC on the carcass yield and fat percentage of broilers as the inclusion levels were increased. In their study, SC levels greater than 10% reduced carcass and abdominal fat percentages.

The greater development of the gizzard is associated with the maceration performed to crush the feed particles to the adequate size, enabling their passage towards the duodenum for subsequent digestion and absorption processes (Ribeiro *et al*. 2002). The increased percentage of gizzard observed at the SC levels of 20 and 25% is due to the high fibre content present in those diets, which required greater work by that organ to degrade the feed.

Bone growth and quality

There are literature data about the impossibility of using the phosphorus complexed to the phytate molecule present in plant-derived feedstuffs. These feedstuffs are unavailable to birds due to the absent or minimal production of endogenous enzymes. Additionally, the ability of phytate to bind to those minerals reduces the availability of other minerals (Angel *et al*. 2002). The bone quality of the meat quail was expected to be influenced by SC inclusion. Nevertheless, no such effect was observed, because the diets were formulated to contained equal amounts of available calcium and phosphorus.

Economic viability

The SC used had a lower cost than corn and soybean meal, only accounting for 72 and 40.8% of their prices, respectively. However, the feeding cost per live-weight gain did not differ from that of the corn- and soybean meal-based treatments without SC addition, despite the performance results obtained in this study. This finding is related to the cost of soybean oil, which was included in larger amounts in the SC-containing diets so that the energy requirements of the quail would be met, rendering the costs of similar diets.

In view of the present results, it can be inferred that it is viable to include 25% SC in the diet of meat quail. However, the best FC and economic viability were obtained with dietary SC inclusions of 14 and 15.4% SC, respectively.

In conclusion, the nutritional composition of sunflower cake varied within the values reported in the literature, and the AMEn of sunflower cake determined for meat quail was 2.629 Kcal/kg DM.

Sunflower cake can be included up to a level of 25% in diets for meat quail from 7 to 42 days of age without compromising their production performance. However, the best results for feed conversion and economic viability were obtained with an inclusion level of 15%.

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