Inclusion of milled canola grain in the diet of broilers

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Abstract

The effect of milled canola grain (MCG) in the diet of broiler chickens, from 1 to 42 days old, on performance, organ weight, biochemical profile, and carcass yield was evaluated. A total of 660 one-day-old male Cobb® broilers were distributed in a completely randomized design with six levels of inclusion of MCG in the diet (0; 5; 10; 15; 20, and 25%), totaling six treatments with five replicates of 22 birds. The canola used for the experiment was ground using a hammer mill with a 4.5 mm sieve to obtain a DGM of 955 µm. Performance data, organ index, blood biochemical profile, carcass yields, and cut up weights were evaluated. The data were analyzed by analysis of variance (ANOVA), and when there was significance Dunnett' test was used to compare the inclusion levels the control diet. An effect was seen on mean weights and on feed conversion based on the inclusion level of MCG in the diets. The birds that received 20 and 25% inclusion of canola in the diet presented a worse performance in relation to that of the control. For the other variables analyzed, no effect of the treatments was observed when compared with the control ($p > 0.05$). It was concluded that the inclusion level of MCG in the diet of up to 15% can be used without losses to the performance of birds and without influencing the metabolism of the birds.

Introduction

The use of oilseeds in animal nutrition provide potential sources of protein and energy for diet formulations. Additionally oilseeds have been shown to have high levels of polyunsaturated fatty acids (Meng et al. 2006; Jia et al. 2008). Among these seeds, canola is an excellent source of energy, protein, and polyunsaturated fatty acids (PUFAs) for broiler diets (Agah et al. 2010; Kakani et al. 2012).

Due to its high fat content, between 40 and 45%, (Barbour and Sim 1991; Szczurek 2009), the canola seed can present crude energy values around 6,000 kcal kg^{-1} (Brand et al. 2000; Montoya and Leterme 2010) and 20–25% crude protein (Brand et al. 2000; Szczurek 2009, 2010; Montoya and Leterme 2010). These characteristics allow canola to be a substitute for corn and soybean meal, which are commonly used as the energy source and protein in broiler diets, respectively.

The use of the canola grain in the diet, allows a greater resistance to oxidation during storage and handling in feed mills when compared to the other sources of fat, like oils (Meng et al. 2006). Grinding is used to break the cell wall of the seed and increase the exposure of nutrients to the digestive enzymes of birds (Meng et al. 2006). Chickens do not have enzymes to digest the polysaccharides in the cell wall (Jia et al. 2008), which limits the use of encapsulated nutrients from the whole canola seed. Incomplete breakage during processing may reduce the utilization and nutritional value of canola (Toghyani et al. 2014).

According to Rutkowski et al. (2012), grain grinding improves performance, apparent metabolizable energy level, and ileal and total digestibility of canola for broiler chickens. These benefits are seen as a result of increased availability of protein and oil for digestion. Although previous studies have reported that whole grain utilization is feasible, the maximum level of inclusion of canola in poultry diets without negative effects on performance, organ weight, blood biochemical profile, and carcass yield has yet to be shown.

Therefore, the objective of this work was to evaluate effects of the inclusion of ground canola in the diet of broilers, from 1 to 42 days old, on the performance, organ weight, biochemical profile, and carcass yield.

Material And Methods

The experiment was conducted in Lages, SC Brazil (27°47'30.4" south latitude and 50°18'17.5" west longitude), and elevation 930 m, approved by the Committee of Ethics in Animal Experimentation - CETEA of UDESC, under protocol

#27262701162.

660 one-day-old male Cobb® broilers were distributed in a completely randomized design with 6 levels of inclusion of ground canola in the diet (0, 5, 10, 15, 20, and 25%) totaling six treatments with five replicates of 22 birds each. The granulometry of the canola used for the experiment was obtained by using a hammer-type mill with a 4.5 mm sieve to achieve a geometric mean diameter (GDM) of 955 µm. The reference value of the canola used in the formulation of the diets was 95% dry matter (DM), 4.6% ash, 23.76% crude protein, 29.5% ethereal extract, 6,385.3 kcal kg^{-1} of crude energy, and 3,863.5 kcal/kg of metabolizable energy. The canola used did not undergo any thermal treatment to deactivate the possible antinutritional factors.

The birds were housed in a climate-controlled shed with access to water and food being ad libitum. The food program was divided into four phases: pre-initial (1 to 7 days), initial (8 to 21 days), growth (22 to 33 days), and final (34 to 42 days). The rations were formulated using the values of chemical composition and nutritional requirements for broilers recommended by Rostagno et al. (2011) for all ingredients except for canola grain, whose values were determined by bromatological analysis. The rations and their calculated composition for each phase are presented in Tables 1, 2, 3 and 4.

Table 1
Nutritional and calculated composition of experimental diets from 1 to 7 days of age

Levels of inclusion of canola [%]						
Ingredients [%]	0	5	10	15	20	25
Corn	56.40	53.85	52.10	48.13	44.07	40.80
Soybean meal (46%)	35.60	35.05	32.60	30.00	27.42	25.00
Dicalcium phosphate	2.18	3.50	3.53	3.56	3.59	3.60
Soy oil	2.00	0.96	0.03	0.00	0.00	0.00
Wheat bran	1.20	0.00	0.00	1.46	2.97	3.60
Limestone	0.82	0.00	0.00	0.00	0.00	0.00
Salt	0.50	0.50	0.50	0.50	0.50	0.50
L-Lysine (99%)	0.40	0.42	0.50	0.59	0.67	0.75
DL-Methionine (99%)	0.40	0.22	0.24	0.26	0.28	0.30
Milled Canola grain	0.00	5.00	10.00	15.00	20.00	25.00
Mineral and vitamin premix[a]	0.50	0.50	0.50	0.50	0.50	0.50
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutritional composition [%]						
ME [MJ kg^{-1}]	12.42	12.39	12.39	12.39	12.39	12.51
Crude protein	22.40	22.40	22.40	22.41	22.40	22.40
Calcium	0.99	1.00	1.00	1.00	0.99	0.99
Available phosphorus	0.52	0.76	0.76	0.76	0.76	0.75
Digestible lysine	1.33	1.32	1.32	1.32	1.32	1.32
Digestible methionine	0.69	0.52	0.52	0.52	0.52	0.51

[a]Levels minimums per kg of product: Vitamin B12 3,000 mcg, Vitamin B6 622 mg, Pantothenic Acid 2,934.9 mg, Niacin 7,500 mg, Biotin 19 mg, Vitamin B2 1,125 mg, Manganese 16,800 mg, Zinc 13,000 mg, Iron 12,600 mg, iodine 250 mg, Copper 2,100 mg, Vitamin E 3,650 IU / kg, Vitamin K3 450 mg, Vitamin B1 502 mg, Folic Acid 189 mg, Colistin 2.500 mg, BHT 0.80 g, Choline 86.67 g

Table 2
Nutritional and calculated composition of experimental diets from 8 to 21 days of age

Levels of inclusion of canola [%]						
Ingredients [%]	0	5	10	15	20	25
Corn	56.11	51.51	51.00	44.90	44.00	45.00
Soybean meal (46%)	34.30	32.00	29.40	29.00	25.40	23.00
Dicalcium phosphate	3.00	3.00	2.99	2.99	3.00	3.00
Soy oil	3.50	3.80	2.30	3.00	2.00	0.00
Wheat bran	1.60	3.00	2.30	3.00	4.00	2.30
Limestone	0.00	0.00	0.30	0.50	0.00	0.00
Salt	0.40	0.45	0.40	0.40	0.40	0.40
L-Lysine (99%)	0.28	0.40	0.45	0.43	0.50	0.50
DL-Methionine (99%)	0.31	0.34	0.37	0.40	0.30	0.40
Milled Canola grain	0.00	5.00	10.00	15.00	20.00	25.00
Mineral and vitamin premix[a]	0.50	0.50	0.50	0.50	0.50	0.50
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutritional composition [%]						
ME [MJ kg^{-1}]	12.77	12.83	12.78	12.93	12.89	12.90
Crude protein	21.20	21.35	21.29	21.84	21.49	21.45
Calcium	0.88	0.87	0.97	1.05	0.85	0.84
Available phosphorus	0.67	0.67	0.66	0.66	0.65	0.64
Digestible lysine	1.22	1.24	1.21	1.18	1.14	1.08
Digestible methionine	0.60	0.62	0.63	0.64	0.52	0.61

[a]Levels minimums per kg of product: Iodine 333.00 mg, Vitamin B12 2,133.00 mcg, Manganese 22,400.00 mg, Vitamin K3 320.00 mg, Zinc 17.300,00 mg, Vitamin B6 442.00 mg, BHT0.80 g, Copper 2,800.00 mg, Vitamin E 2,830.00 IU / kg, Niacin 5,330.00 mg, Vitamin D3 454,000.00 IU/kg, Choline 58.07 g, Iron 17,000.00 mg, Vitamin B1 357.00 mg, Selenium 100,00 mg, Vitamin A 1,880,000.00 IU/kg, Vitamin B2 800.00 mg, Panthenic Acid 2,086.70 mg

Table 3
Nutritional and calculated composition of experimental diets from 22 to 33 days of age

	Levels of inclusion of canola [%]					
Ingredients [%]	0	5	10	15	20	25
Corn	58.65	59.65	58.55	56.63	54.00	50.20
Soybean meal (46%)	30.66	28.20	25.80	23.50	21.15	18.25
Dicalcium phosphate	1.99	1.99	1.99	1.99	1.99	1.99
Soy oil	4.28	2.66	1.44	0.54	0.00	0.00
Wheat bran	1.57	0.49	0.00	0.00	0.50	2.20
Limestone	0.48	0.50	0.53	0.55	0.57	0.59
Salt	0.40	0.40	0.40	0.40	0.40	0.40
L-Lysine (99%)	0.29	0.37	0.50	0.55	0.60	0.65
DL-Methionine (99%)	1.18	0.19	0.25	0.30	0.24	0.27
L-Tryptophan	0.00	0.05	0.04	0.04	0.05	0.07
Milled Canola grain	0.00	5.00	10.00	15.00	20.00	25.00
Mineral and vitamin premix[a]	0.50	0.50	0.50	0.50	0.50	0.50
TOTAL	100	100	100	100	100	100
Calculated nutritional composition [%]						
ME [MJ kg^{-1}]	13.19	13.19	13.20	13.20	13.20	13.20
Crude protein	19.80	19.83	19.88	19.93	19.98	19.82
Calcium	0.800	0.799	0.799	0.799	0.799	0.80
Available phosphorus	0.481	0.473	0.466	0.460	0.455	0.451
Digestible lysine	1.131	1.131	1.163	1.139	1.118	1.083
Digestible methionine	0.452	0.452	0.492	0.524	0.451	0.453

[a]Levels minimums per kg of product: Iodine 333.00 mg, Vitamin B12 2,133.00 mcg, Manganese 22,400.00 mg, Vitamin K3 320.00 mg, Zinc 17.300,00 mg, Vitamin B6 442.00 mg, BHT0.80 g, Copper 2,800.00 mg, Vitamin E 2,830.00 IU / kg, Niacin 5,330.00 mg, Vitamin D3 454,000.00 IU/kg, Choline 58.07 g, Iron 17,000.00 mg, Vitamin B1 357.00 mg, Selenium 100,00 mg, Vitamin A 1,880,000.00 IU/kg, Vitamin B2 800.00 mg, Panthenic Acid 2,086.70 mg

Table 4
Nutritional and calculated composition of experimental diets from 34 to 42 days of age

Levels of inclusion of canola [%]						
Ingredients [%]	0	5	10	15	20	25
Corn	66.80	65.10	63.41	61.72	58.30	54.22
Soybean meal (46%)	26.77	24.26	21.74	19.22	16.60	13.99
Dicalcium phosphate	1.98	2.02	2.05	2.08	2.12	2.15
Soy oil	3.08	2.14	1.19	0.25	0.00	0.00
Wheat bran	0.00	0.00	0.00	0.00	1.13	2.66
Salt	0.40	0.40	0.40	0.40	0.40	0.40
L-Lysine (99%)	0.31	0.40	0.49	0.57	0.66	0.75
DL-Methionine (99%)	0.16	0.17	0.19	0.21	0.23	0.25
L-Tryptophan	0.00	0.01	0.03	0.05	0.06	0.08
Milled Canola grain	0.00	5.00	10.00	15.00	20.00	25.00
Mineral and vitamin premix[a]	0.50	0.50	0.50	0.50	0.50	0.50
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Calculated nutritional composition [%]						
ME [MJ kg^{-1}]	13.40	13.40	13.40	13.40	13.40	13.40
Crude protein	18.40	18.40	18.40	18.40	18.41	18.41
Calcium	0.60	0.60	0.60	0.60	0.60	0.60
Available phosphorus	0.47	0.47	0.47	0.47	0.48	0.48
Digestible lysine	1.06	1.06	1.06	1.06	1.06	1.06
Digestible methionine	0.42	0.42	0.42	0.42	0.42	0.42

[a]Levels minimums per kg of product: Iodine 333.00 mg, Vitamin B12 2,133.00 mcg, Manganese 22,400.00 mg, Vitamin K3 320.00 mg, Zinc 17.300,00 mg, Vitamin B6 442.00 mg, BHT0.80 g, Copper 2,800.00 mg, Vitamin E 2,830.00 IU / kg, Niacin 5,330.00 mg, Vitamin D3 454,000.00 IU/kg, Choline 58.07 g, Iron 17,000.00 mg, Vitamin B1 357.00 mg, Selenium 100,00 mg, Vitamin A 1,880,000.00 IU/kg, Vitamin B2 800.00 mg, Panthenic Acid 2,086.70 mg

The body weight and feed intake were recorded weekly, using the consumption and body weight data feed conversion ratio were calculated. At 42 days of age, two birds per replicate were randomly selected to collect 5 mL of blood from the jugular vein to obtain serum (Nunes et al. 2018). With blood collection, serum levels of uric acid, total proteins, serum calcium, chlorides, cholesterol, alkaline phosphatase, total serum phosphorus, triglycerides were determined using a spectrophotometer and the calorimetric enzymatic method.

The same birds used for blood collection and serum collection were then stunned by electroshock and sacrificed through cervical dislocation to obtain organ and digestive system weights, carcass weights, and piece cut-up weights. These weights were then used for calculation of the indices of organs, carcass yield, and piece cut-up yield. For analysis of carcass yield, the weight of the carcass without feet, head and abdominal fat was considered in relation to the live weight of the bird. For the calculation of yields of piece cut ups were considered using the breast, leg quarters, wing and back, with skin and bones, being calculated in relation to the weight of the eviscerated carcass.

The data were analyzed using analysis of variance (ANOVA), when there were significant ($p < 0.05$) observations the data were further analyzed by polynomial regression, in order to determine whether the effect of the treatments was linear or quadratic. Significant data that did not fit polynomial regression were analyzed using the Dunnet's test to compare treatment means. The analysis was performed using the statistical software SAS (2017) STUDENT version.

Results

There were linear trends ($p < 0.05$) based on the inclusion of MCG levels in the diet on the performance of birds. Regarding the mean weekly weight of the birds, there was a significant effect ($p < 0.05$) from the inclusion of canola on the average weight in all the evaluated weeks, where birds that consumed 20 and 25% of MCG in the diet had lower weights at 7, 14, 21, 28, 35, and 42 days when compared to the control. In addition, it was observed that in the first and second week of age the inclusion of 15% of canola in the diet reduced the mean weight, however this is not observed in subsequent weeks (Table 5).

Table 5
Performance of different aged of broilers fed diets containing milled canola

	Level of canola [%]							***p*-Values**	
	0	5	10	15	20	25	SEM#	ANOVA	Regression
Day 1 to 7									
Weight gain [g]	106	105	100	97*	97*	93*	1.15	0.0003	< 0.0001(L)
Feed intake [g]	136	144	134	137	138	142	1.7	0.4584	-
Feed conversion ratio	1.279	1.373	1.336	1.424*	1.430*	1.530*	0.02	0.0008	< 0.0001(L)
Day 1 to 14									
Weight gain [g]	308	308	293	281*	279*	274*	3.6	0.0043	< 0.0001(L)
Feed intake [g]	414	439	413	433	418	432	4.5	0.4364	-
Feed conversion ratio	1.347	1.426	1.408	1.543*	1.504	1.577*	0.023	0.0122	0.0005(L)
Day 1 to 21									
Weight gain [g]	701	707	670	664	628*	619*	8.5	0.0021	< 0.0001(L)
Feed intake [g]	894	911	873	926	889	915	9.5	0.6691	-
Feed conversion ratio	1.281	1.288	1.303	1.400	1.422	1.480*	0.024	0.0466	0.0017(L)
Day 1 to 28									
Weight gain [g]	1168	1170	1120	1120	1048*	1040*	14	0.0132	< 0.0001(L)
Feed intake [g]	1643	1655	1584	1688	1605	1648	20	0.7194	-
Feed conversion ratio	1.409	1.416	1.413	1.512	1.534	1.592		0.0593	-
Day 1 to 35									
Weight gain [g]	1814	1788	1749	1724	1661*	1530*	20	< 0.0001	< 0.0001(L)
Feed intake [g]	2628	2664	2585	2704	2589	2651	27	0.8373	-
Feed conversion ratio	1.450	1.491	1.478	1.572	1.561	1.730*	0.024	0.0022	0.0001(L)
Day 1 to 42									
Weight gain [g]	2461	2406	2379	2329	2273*	2020*	30	< 0.0001	< 0.0001(L)
Feed intake [g]	3793	3828	3808	3897	376	3880	34	0.8861	-
Feed conversion ratio	1.545	1.592	1.601	1.677	1.656	1.924*	0.03	0.0004	< 0.0001(L)

[a] *SEM* standard error of the mean

*Mean differs from the control (0% canola) by a Dunnett's test ($p < 0.05$)

The inclusion of MCG in the diet did not alter the feed intake of the birds in any of the evaluated time points (Table 5). For feed conversion, it was observed that in the first week of age, birds receiving 20 and 25% of canola in the diet presented greater feed conversion in relation to the birds that received the control diet. In the other weeks, there were no statistical differences for feed conversion of birds between treatments (Table 5).

The carcass yields, and piece cut evaluation showed no effect of treatments ($p > 0.05$) for carcass yield, breast, leg quarters, wing and back (Table 6). No effects of canola in the diet were observed on uric acid, total protein, calcium, chloride, cholesterol, alkaline phosphatase, total phosphorus and triglycerides serum levels (Table 7).

Table 6
Carcass yield and cuts of broilers at 42 days old fed diets containing milled canola

Level of canola [%]	Carcass [%]	Breast [%]	Leg quarters [%]	Wings [%]	Back [%]
0	74.2	33.5	30.5	11.3	24.1
5	74.6	34.2	29.5	10.9	24.4
10	74.9	34.7	29.9	11.3	23.5
15	75.5	35.3	29.5	11.2	23.0
20	73.9	34.2	29.1	11.6	24.3
25	73.0	33.5	30.1	11.7	24.1
SEM[a]	1.96	1.27	0.67	0.39	0.74
ANOVA					
p-Values	0.4745	0.2075	0.3074	0.3021	0.0525

[a] *SEM* standard error of the mean

Table 7
Blood profile of broilers fed diets containing milled canola

Level of canola [%]	Uric acid [mg/dL]	Total proteins [g/dL]	Calcium [mg/dL]	Chlorides [mEq/L]	Cholesterol [mg/dL]	Alkaline phosphatase [U/L]	Phosphorus [mg/dL]	Triglycerides [mg/dL]
0	2.36	2.86	4.51	104.5	149.6	576.3	5.67	56.3
5	2.21	2.85	4.89	105.2	152.2	634.3	6.18	59.2
10	1.91	2.79	4.82	104.7	148.9	1085.9	5.73	50.8
15	1.85	2.76	4.98	104.5	154.4	1082.9	5.89	52.1
20	2.62	2.82	4.75	105.6	158.6	947.5	5.90	48.0
25	1.86	2.72	4.32	105.9	149.2	1023.7	6.10	52.0
SEM[a]	0.49	0.22	0.56	2.17	19.43	445.1	0.58	11.12
ANOVA								
p-Values	0.1058	0.9275	0.4574	0.8651	0.9602	0.2255	0.7245	0.6678

[a] *SEM* standard error of the mean

The evaluation of the index of organs, data presented in Table 8, did not present significant difference ($p > 0.05$) based on the levels of inclusion of canola in the diet on the indexes of gizzard, liver, spleen, heart and intestine.

Table 8
Index of organs of broilers fed diets containing milled canola

Level of canola [%]	Gizzard [%]	Liver [%]	Spleen [%]	Heart [%]	Intestine [%]
0	1.80	2.01	0.10	0.57	4.58
5	1.83	1.96	0.08	0.58	4.18
10	1.82	2.08	0.10	0.58	4.46
15	1.80	1.97	0.09	0.57	3.96
20	1.94	2.05	0.07	0.55	4.48
25	2.14	2.07	0.09	0.59	4.52
SEM[a]	0.22	0.16	0.02	0.08	0.42
ANOVA					
p-Values	0.1475	0.7915	0.1952	0.9903	0.2075

[a] *SEM* standard error of the mean

Discussion

The use of canola grain in the diet of broiler chickens is of great interest to researchers and animal nutritionists. Canola (Canadian Oil Low Acid) is a result of the genetic improvement of rapeseed (*Brassica napus* L.) and is intended to reduce erucic acid content in oil (< 2%) and glucosinolates in grain (3 μg g^{-1}), improving palatability and digestibility of nutrients (Chavarria et al. 2011; Canola Council of Canada 2014).

However, current studies still do not use the canola grain in the diet in its integral form without thermal or enzymatic treatments as seen in the works of Assadi et al. (2011) and Barekatain et al. (2015, 2017). It is possible that the grain presents the presence of residual isothiocyanate from the breakdown of glycosinolates by the enzyme myrosinase, isothiocyanate can alter the palatability of the diets making them taste bitter (Tripathi and Mishra 2007). Thus, diets with canola beans tend to have less palatability, which reduces feed consumption by birds and consequently their performance (Barekatain et al. 2017).

However, in this work it was demonstrated that there was no effect of the inclusion of canola in up to 25% in the diet on the feed consumption, even using it without thermal or enzymatic treatments. It is known that the composition and content of glucosinolates in the grain vary due to species, cultivation practices, climatic conditions, among others, and that plants grown under tropical climate have more of these compounds than plants grown in temperate climates (Tripathi and Mishra 2007).

Thus, as the canola used in the experiment came from Rio Grande do Sul, Brazil, which has a temperate climate, it may present a lower amount of glucosinolates, which would justify the absence of effect on consumption. This reduction in the glucosinolate content could be measured through the activity of the enzyme myrosinase, however under the conditions of this experiment, its measurement was not feasible since the enzyme acts rapidly after grinding the grain (Barekatain et al. 2017).

Although consumption was not affected, the intake of canola over 15% reduced body weight and weight gain of birds in the first and second week of age. From after the second week of age only the inclusion levels above 20% caused losses in performance. It is well known that the canola grain has a high oil and non-starch polysaccharides (NSPs) content, as well as possible anti-nutritional factors that reduce the performance of the birds (Barekatain et al. 2017; Meng et al. 2006). This high oil content of the grain harvested at the level of NSPs may have resulted in a decrease in the performance of the birds.

Since the digestion of NSPs by broiler chickens is low, this may cause an underutilization of dietary energy, in addition the presence of NSPs may influence the absorption of other nutrients from the diet (Pustjens et al. 2012). The gastrointestinal tract, although anatomically complete at the end of the incubation period, undergoes sensitive morphophysiological changes throughout growth which prepare the bird for the consumption and use of solid foods. Accompanied by the ingestion of exogenous food, there is a rapid gastrointestinal and organ development associated with digestion, aiming the assimilation of ingested nutrients (Uni et al. 1998).

After hatching, the absorption of the yolk contents by the intestinal tract can be made either by the yolk sac membrane or by the yolk diverticulum (Esteban et al. 1991). The passage of the contents of the yolk to the intestinal tract is improved when the chick receives solid food, this increase is due to the physical presence of the food in the lumen of the intestine, and the peristaltic movements of the gastrointestinal tract (Noy and Sklan 2001).

Since absorption of the yolk sac occurs in the first week of life, and according to Noble and Shand (1985), associated with the increase in yolk sac absorption, there is an increase in the relative weight of the liver. This plays an important role in the absorption of lipids within the yolk sac, mainly linoleic acid, the oil content of the canola grain may have been underutilized by the metabolism of the birds, which may be the cause of the loss of performance of the birds. However soon after hatching, biliary secretions are low which further limits the absorption of dietary fat, and the peak of biliary secretion will only be reached between 10 and 14 days of age (Noy and Sklan 1995).

In addition, the production of chymotrypsin and trypsin (units / kg body weight) increases with the passage of bird age, with the maximum values of these enzymes being reached at 15 days of age (Nir et al. 1993). This may lead to a protein under-utilization of canola protein. This protein and lipid underutilization can reduce the metabolizable energy of growing broiler diets, as reported by Barekatain et al. (2017), who also observed a reduction in the digestibility coefficients of methionine, leucine, threonine, alanine, glutamine and proline present in canola-containing diets when compared to a diet containing canola meal (Fernandez et al. 1994; Waldroup et al. 2005).

The poor performance of broilers with the dietary inclusion of canola was also observed by Leeson et al. (1987) it was concluded that additions of more than 10% of canola in the diet are detrimental to bird performance, this is potentially related to the additional fat that is provided from the canola grain. Similar results had already been reported by Summers et al. (1982), who tested levels above 10% and found a reduction in the weight of broiler chickens in the 4th and 7th weeks of age, however, when canola was added at 17.5% body weight gain and feed conversion was similar to the control group at these time points.

Regarding the carcass yield and piece cuts, it can be inferred that the canola levels used did not cause a nutritional imbalance capable of altering the absorption or protein deposition in the carcass. It is known that changes in the constituents of the carcass are linked to the absorption of nutrients, which when increased, may result in a higher protein synthesis (Woyengo et al. 2011). In view of this, it can be concluded that canola granola supplies the nutritional needs for maintenance of the carcass conformation without negative effects. The inclusion of canola in the diet also had no effect on the carcass for the experiments performed by (Lee et al. 1991; Nwokolo and Sim 1989). It is important to reiterate that there were no recent studies in the literature that analyzed carcass yield and piece cuts of broilers fed ground canola grain.

Since no differences were observed in the relative organ weights and blood biochemical profile, it can be affirmed that the use of canola in the diets did not interfere in the metabolism of the birds. It is well known that blood components can be influenced by physiological, pathological, and nutritional factors (Józefiak et al. 2010). The determination of blood component values using laboratory tests can provide reliable results for research in nutrition, physiology, and pathology (Bounous et al. 2000).

In relation to the use of canola in the diet on organ indices, the authors Barekatain et al. (2017) observed an effect only on the jejunum index, when comparing canola grain to canola meal, the other organs analyzed were not influenced. In this sense it is clear that there is no harm to the metabolism of birds when using canola in the diet, based on the relative weights of organs and blood biochemical profile.

In addition to the previously discussed, it is interesting to note that our work analyzed the performance of birds consuming canola from the first day of life. This fact may explain the difference in poultry performance in the first weeks, which was reflected in the final weight. Based on this, new work should be done to determine the best age to include canola in the diet and to determine the optimal inclusion levels.

It is concluded that the inclusion level of canola in milled grain in the diet of up to 15% can be used without losses in the performance of birds at 42 days of age, and without influencing the metabolism of the same.

Declarations

Statement of Animal Rights

All applicable international, national, and institutional guidelines for the care and use of animals were followed. Study was approved by Committee of Ethics in Animal Experimentation - CETEA of Udesc, and our ethical clearance number is 27262701162.

Conflict of Interest Statement

The authors declare that they have no conflict of interest

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Authors' contributions All authors contributed to the study conception and design. Conceptualization: 1Souza, C., Souza, C.d., Gewehr, C.E., Nunes, R.V. Design of Methodology: 1Souza, C., Gewehr, C.E., Cesar, P.H. Data acquisition: 1Souza, C., Gewehr, C.E., Cesar, P.H. Data Analysis: 1Souza, C. Writing and editing: 1Souza, C., Gewehr, C.E., Souza, C.d.

Ethics approval All applicable international, national, and institutional guidelines for the care and use of animals were followed. Study was approved by Committee of Ethics in Animal Experimentation - CETEA of Udesc, and our ethical clearance number is 27262701162.

Consent to participate Not applicable

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References

Agah, M.J., Nassiri-Moghaddam, H., Tahmasbi, A.M. and Lotfollahian, H., 2010. Performance and fatty acid compositions of yolk lipid from laying hens fed with locally produced canola seed (*Brassica napus* L.), Research Journal of Biological Sciences, 5(2), 228–232.

Assadi, E., Janmohammadi, H., Taghizadeh, A. and Alijani, S., 2011. Nutrient composition of different varieties of full-fat canola seed and nitrogen-corrected true metabolizable energy of full-fat canola seed with or without enzyme addition and thermal processing, Journal of Applied Poultry Research, 20(1), 95–101.

Barbour, G. and Sim, J., 1991. True metabolizable energy and true amino acid availability in canola and flax products for poultry, Poultry Science, 70(10), 2154–2160.

Barekatain, M.R., Wu, S.B., Toghyani, M. and Swick, R.A., 2015. Effects of grinding and pelleting condition on efficiency of full-fat canola seed for replacing supplemental oil in broiler chicken diets, Animal Feed Science and Technology, 207, 140–149.

Barekatain, R., Swick, R.A., Toghyani, M. and Koning, C.T., 2017. Interactions of full-fat canola seed, oat hulls as an insoluble fiber source and pellet temperature for nutrient utilization and growth performance of broiler chickens, Poultry Science, 96(7), 2233–2242.

Bounous, D.I., Wyatt, R.D., Gibbs, P.S., Kilburn, J.V. and Quist, C.F., 2000. Normal hematologic and serum biochemical reference intervals for juvenile wild turkeys, Journal of Wildlife Diseases, 36(2), 393–396.

Brand, T.S., Brabander, L., Van Schalkwyk, S.J., Pfister, B. and Hays, J.P., 2000. The true metabolisable energy content of canola oilcake meal and full-fat canola seed for ostriches (*Struthio camelus*), British Poultry Science, 41(2), 201–203.

CANOLA. Canola Council of Canada. 2014. http://www.canolacouncil.org/canola-encyclopedia/. Accessed 18 Feb 2015.

Chavarria, G., Tomm, G.O., Muller, A., Mendonça, H.F., Mello, N. and Betto, M.S., 2011. Índice de área foliar em canola cultivada sob variações de espaçamento e de densidade de semeadura, Ciência Rural, 41(12), 2084–2089.

Esteban, S., Rayó, J.M., Moreno, M., Sastre, M., Rial, R.V. and Tur, J.A., 1991. A role played by the vitelline diverticulum in the yolk sac resorption in young post-hatched chickens, Journal of Comparative Physiology B, 160, 645–648.

Fernandez, S.R., Aoyagi, S., Han, Y., Parsons, C.M. and Baker, D.H., 1994. Limiting order of amino acids in corn and soybean meal for growth of the chick, Poultry Science, 73(12), 1887–1896.

Jia, W., Slominski, B.A., Guenter, W., Humphreys, A. and Jones, O., 2008. The effect of enzyme supplementation on egg production parameters and omega-3 fatty acid deposition in laying hens fed flaxseed and canola seed, Poultry Science, 87(10), 2005–2014.

Józefiak, D., Ptak, A., Kaczmarek, S., Mackowiak, P., Sassek, M. and Slominski, B.A., 2010. Multi-carbohydrase and phytase supplementation improves growth performance and liver insulin receptor sensitivity in broiler chickens fed diets containing full-fat rapeseed, Poultry Science, 89(9), 1939–1946.

Kakani, R., Fowler, J., Haq, A.U., Murphy, E.J., Rosenberger, T.A., Berhow, M. and Bailey, C.A., 2012. Camelina meal increases egg n-3 fatty acid content without altering quality or production in laying hens, Lipids, 47(5), 519–526.

Lee, K.H., Olomu, J.M. and Sim, J.S., 1991. Live performance, carcass yield, protein and energy retention of broiler chickens fed canola and flax full-fat seeds and the restored mixtures of meal and oil, Canadian Journal of Animal Science, 71(3), 897–903.

Leeson, S., Atteh, J.O. and Summers, J.D., 1987. Effects of increasing dietary levels of full-fat canola on performance, nutrient retention, and bone mineralization, Poultry Science, 66(5), 875–880.

Meng, X., Slominski, B.A., Campbell, L.D., Guenter, W. and Jones, O., 2006. The use of enzyme technology for improved energy utilization from full-fat oilseeds. Part I: canola seed, Poultry Science, 85(6), 1025–1030.

Montoya, C.A. and Leterme, P., 2010. Validation of the net energy content of canola meal and full-fat canola seeds in growing pigs, Canadian Journal of Animal Science, 90(2), 213–219.

Nir, I., Nitsan, Z. and Mahagna, M., 1993. Comparative growth and development of the digestive organs and of some enzymes in broiler and egg type chicks after hatching, British Poultry Science, 34(3), 523–532.

Noble, R.C. and Shand, J.H., 1985. Unsaturated fatty acid compositional changes and desaturation during the embryonic development of the chicken (*Gallus domesticus*), Lipids, 20(5), 278–82.

Noy, Y. and Sklan, D., 1995. Digestion and absorption in the young chick, Poultry Science, 74(2), 366–373.

Noy, Y. and Sklan, D., 2001. Yolk and exogenous feed utilization in the posthatch chick, Poultry Science, 80(10), 1490--1495.

Nunes, R.V., Broch, J., Wachholz, L., Souza, C., Damasceno, J.L., Oxford, J.H., Bloxham, D.J., Billard, L. and Pesti, G.M., 2018. Choosing sample sizes for various blood parameters of broiler chickens with normal and non-normal observations, Poultry Science, 97(10), 3746–3754.

Nwokolo, E. and Sim, J., 1989. Barley and full-fat canola seed in broiler diets, Poultry Science, 68(10), 1374–1380.

Pustjens, A.M., De Vries, S., Schols, H.A., Gruppen, H., Gerrits, W.J.J. and Kabel, M.A., 2014. Understanding carbohydrate structures fermented or resistant to fermentation in broilers fed rapeseed (*Brassica napus*) meal to evaluate the effect of acid treatment and enzyme addition, Poultry Science, 93(4), 926–934.

Rostagno, H.S., Albino, L.F.T., Donzele, J.L., Gomes, P.C., Oliveira, R.F., Lopes, D.C., Ferreira, A.S., Barreto, S.L.T. and Euclides, R.F., 2011. Brazilian tables for poultry and swine: composition of feedstuffs and nutritional requirements. (UFV, Viçosa).

Summers, J.D., Shen, H. and Leeson, S., 1982. The value of canola seed in poultry diets, Canadian Journal of Animal Science, 62, 861–868.

Szczurek, W., 2009. Standardized ileal digestibility of amino acids from several cereal grains and protein-rich feedstuffs in broiler chickens at the age of 30 days, Journal of Animal and Feed Sciences, 18(4), 662–676.

Szczurek, W., 2010. Standardized ileal digestibility of amino acids in some cereals, rapeseed products and maize DDGS for broiler chickens at the age of 14 days, Journal of Animal and Feed Sciences, 19(1), 73--81.

Toghyani, M., Rodgers, N., Barekatain, M.R., Iji, P.A. and Swick, R.A., 2014. Apparent metabolizable energy value of expeller-extracted canola meal subjected to different processing conditions for growing broiler chickens, Poultry Science, 93(9), 2227–2236.

Tripathi, M.K. and Mishra, A.S., 2007. Glucosinolates in animal nutrition: A review, Animal Feed Science and Technology, 132(1-2), 1–27.

Uni, Z., Ganot, S. and Sklan, D., 1998. Posthatch development of mucosal function in the broiler small intestine, Poultry Science, 77(1), 75–82.

Waldroup, P.W., Jiang, Q. and Fritts, C.A., 2005. Effects of supplementing broiler diets low in crude protein with essential and nonessential amino acids, International Journal of Poultry Science, 4(6), 425–431.

Woyengo, T.A., Kiarie, E. and Nyachoti, C.M., 2011. Growth performance, organ weights, and blood parameters of broilers fed diets containing expeller-extracted canola meal, Poutry Sciece, 90(11), 2520–2527.