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Performance, Carcass Traits, and Body Composition of Broilers Fed Different Linseed Oil Levels between 21 and 56 Days of Age*

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■Keywords

Ether extract, weight gain, abdominal fat, crude protein, carcass yield.

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ABSTRACT

This study was carried out to evaluate the effect of the inclusion of different linseed oil levels (0.0, 3.3, 6.6, or 9.9%) in iso-energy diets fed during the period of 21 to 56 days of age on the performance, carcass traits, and body composition of broilers. A total of 1,600 broilers were distributed according to a completely randomized experimental design consisting of four treatments with eight replicates of 40 birds per experimental unit. In the period of 21-42 days of age, weight gain increased, feed and calorie conversion ratios quadratically improved, and feed and metabolizable energy intakes linearly increased as dietary linseed oil level increased. Considering the entire experimental period, dietary linseed oil linearly increased weight gain and feed and energy intakes, and feed and calorie conversion ratios in a quadratic manner. On days 42 and 56, abdominal fat percentage and carcass yield were quadratically influenced by dietary linseed oil. Total body fat content at 56 days of age was quadratically influenced by dietary linseed levels.

INTRODUCTION

Dietary fat addition enhances broilers performance in terms of feed intake (López-Ferrer *et al.*, 2001a), weight gain (Ajuyah *et al.*, 1991; Rodríguez *et al.*, 2005), and feed conversion ratio (Dvorin *et al.*, 1998). Improvements in body composition and meat characteristics have also been reported (Sanz *et al.*, 1999; Crespo & Esteve-Garcia, 2001). Its advantages under heat stress are attributed to the low heat increment of fat digestion and absorption (Dale & Fuller, 1979, 1980). Moreover, fat enhances feed palatability and reduces dust (Lara *et al.*, 2005).

Modern fast-growing broiler strains have high energy requirements, making oil addition to the diet almost mandatory due to its high energy concentration (Furlan & Macari, 2002). Oils with high levels of polyunsaturated fatty acids (PUFA) are absorbed easier than those containing saturated fatty acids, and therefore have higher energy value and may promote better broiler performance (Dvorin *et al.*, 1998). In addition, oils added to the feeds also supply essential fatty acids (Junqueira *et al.*, 2005).

The live performance and meat quality obtained with the addition of oils that are sources of omega-3 polyunsaturated fatty acids (PUFA n-3) to broiler diets, coupled with the increasing consumers' concern with healthy diets, has promoted the use of these oils.

Excessive abdominal fat deposition is a concern for broiler producers, as part of the fat is lost during carcass evisceration, and may impair carcass quality and yield. Therefore, PUFA-rich oils may be an alternative to reduce abdominal fat deposition due to their high oxidation capacity (Sanz *et al.*, 2000).



Despite being a good PUFA source, soybean oil contains about 50-54% linoleic acid, which is an omega-6 PUFA (PUFA n-6; Martin *et al.*, 2006). An alternative to increase the ratio of PUFA n-3 in the feed is to replace soybean oil by linseed oil, which contains more than 50% of α -linolenic acid, which is a precursor of omega-3 fatty acids. Ajuyah *et al.* (1991) added different combinations of canola oil and linseed oil at 10 and 20% to the diet of male Hubbard broilers and observed higher lipid content in the white than in the dark meat in all diets and those fed 20% linseed presented the lowest lipid deposition. Crespo & Esteve-Garcia (2001) fed broilers with a linseed oil-based diet and obtained 2.24 and 1.35% total lipids in the leg and breast, respectively.

This study was carried out to evaluate the effects of the inclusion of different linseed oil levels in iso-energy diets fed during the period of 21 to 56 days of age on the performance, carcass traits, and body composition of broilers.

MATERIALS AND METHODS

A total of 1600 male Cobb 500 broilers were housed in 32 pens in a masonry broiler house. Pens were equipped with semiautomatic tube feeders and bell drinkers. The 35-d experimental period was divided in two phases: Grower (21-42 days of age) and finisher (43-56 days of age). Broilers were vaccinated against Marek's disease, infectious bursal disease (IBD), and fowl pox at the hatchery, and on days 5 and 21 against IBD and on day 8 against Newcastle disease.

A lighting program of 24 hours of light was adopted during the entire experimental period. Environmental temperature was daily recorded. Average minimum and maximum temperatures during the experiment were 17°C and 30°C, respectively.

During the starter period (1-21 days of age), birds were reared in an experimental broiler house and were fed a diet containing 3,005 kcal ME/kg and 21.6% crude protein to supply their nutritional requirements, according to the average of the recommendations of Rostagno *et al.* (2005) for the periods of 1-7 and 8-21 days of age. On day 21, broilers were weighed, selected according to the criterion of average weight per pen, and distributed according to a completely randomized experimental design consisting of four treatments (linseed oil levels) with eight replicates of 40 birds each.

The experimental diets contained equal nutritional levels in each phase and were formulated according to the recommendations of Rostagno *et al.* (2005). Diets were offered *ad libitum* as mash (Table 1). Linseed oil was included in the feed at the levels of 0.0, 3.3, 6.6, and 9.9% iso-calorically replacing corn starch, whereas the levels of the other ingredients were maintained. In order to maintain equal nutritional levels, as determined by formulation, inert material needed to be added to the diets as oil levels increased.

At the end of each experimental phase and for the entire experimental period, weight gain (WG; g), feed intake (FI; g), metabolizable energy intake (kcal), feed conversion ratio (g/g) and calorie conversion ratio (kcal/kg) were measured. Apparent metabolizable energy corrected for nitrogen balance (AMEn) of the diets used in each phases were determined in previous digestibility assays. Metabolizable energy intake (EI = determined AMEn * FI) and calorie conversion ratio (CCR = kcal intake/kg WG) were calculated based on the AMEn values analyzed in feeds according to feeding phase. On days 42 and 56, two birds per replicate were randomly selected and sacrificed to determine carcass yield, breast yield, leg yield (thighs+drumstick) and abdominal fat percentage. Carcass yield was determined as the weight of the eviscerated carcass with no head, neck, and feet relative to broiler live weight. Parts yield and abdominal fat percentage (adipose tissue around the bursa, proventriculus, gizzard, and cloaca) were determined relative to the weight of the eviscerated carcass with no head, neck, and feet.

Body composition was determined in one bird with the average body of the replicate per replicate. After 24-h fasting, birds were sacrificed by neck dislocation, plucked, and their carcasses were ground and dried in a forced-ventilation oven at 55°C for 72 hours. After drying, samples were submitted to the determination of dry matter, crude protein, ether extract, and ash contents, according to the methodology described by Silva (1990).

The obtained data were submitted to analysis of variance using the software package Statistical Analysis System (SAS, 2002). When statistical significance was obtained, data were submitted to analysis of regression, considering dietary linseed oil as independent variable. Means were compared by the test of Tukey at 5% probability level.



Table 1 – Ingredients and calculated nutritional composition of the experimental feeds supplied during the grower¹ and the finisher² phases.

Ingredients	Linseed oil levels (%) ¹ 21 to 42 days of age				Linseed oil levels (%) ² 43 to 56 days of age			
	0.0	3.3	6.6	9.9	0.0	3.3	6.6	9.9
Corn	36.80	36.80	36.80	36.80	44.05	44.05	44.05	44.05
Soybean meal	29.80	29.80	29.80	29.80	20.05	20.05	20.05	20.05
Corn gluten	5.00	5.00	5.00	5.00	8.00	8.00	8.00	8.00
Linseed oil	0.00	3.30	6.60	9.90	0.00	3.30	6.60	9.90
Corn starch	24.00	16.00	8.00	0.00	24.00	16.00	8.00	0.00
Dicalcium phosphate	2.25	2.25	2.25	2.25	1.85	1.85	1.85	1.85
Limestone	1.19	1.19	1.19	1.19	1.05	1.00	1.00	1.00
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
DL-Methionine (99%)	0.16	0.16	0.16	0.16	0.08	0.08	0.08	0.08
L-Lysine HCL (78.5%)	-	-	-	-	0.11	0.11	0.11	0.11
Rice hulls	0.00	4.70	9.40	14.10	0.00	4.75	9.45	14.15
Vit. + min. supplement*/**	0.50	0.50	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	100.00	100.00
Calculated values								
ME (kcal/kg)	2998	2998	2998	2998	3131	3131	3131	3131
CP (%)	20.00	20.00	20.00	20.00	18.00	18.00	18.00	18.00
Ca (%)	1.07	1.07	1.07	1.07	0.90	0.90	0.90	0.90
Avail. phosphorus (%)	0.512	0.512	0.512	0.512	0.427	0.427	0.427	0.427
Lysine (%)	1.00	1.00	1.00	1.00	0.85	0.85	0.85	0.85
Met. + cys (%)	0.83	0.83	0.83	0.83	0.72	0.72	0.72	0.72

¹ Grower. Supplied per kg feed: Vit. A 1500 IU/kg, Vit E 20 mg, Vit. K 0.5 mg, Vit. B₁ 2 mg, Vit. B₂ 3.6 mg, Vit. B₁₂ 20 mcg, calcium pantothenate 10 mg, folic acid 0.5 mg, growth promoter 50 mg, niacin 100 mg, copper 75 mg, iodine 1.25 mg, selenium 0.25 mg, manganese 120 mg, zinc 100 mg, iron 50 mg, antioxidant 0.5 mg coccidiocide 110 mg. ² Finisher. Supplied per kg feed: Vit. A 1500 IU/kg, Vit E 1 mg, Vit. K 0.49 mg, Vit. B₁ 2 mg, Vit. B₂ 1.75 mg, Vit. B₁₂ 5 mcg, calcium pantothenate 10 mg, folic acid 0.25 mg, growth promoter 15 mg, niacin 100 mg, copper 75 mg, iodine 1.25 mg, selenium 0.25 mg, manganese 120 mg, zinc 100 mg, iron 50 mg, antioxidant 0.625 mg coccidiocide 125 mg.

RESULTS AND DISCUSSION

Linseed inclusion level had a quadratic influence ($p < 0.05$) on broiler WG during the period of 21 to 42 days ($WG = 1.450.852 + 43.10122X - 2.23735X^2$; $R^2 = 0.98$; Table 2), up to 9.63% dietary inclusion. This result is consistent with the findings of Lopez-Ferrer *et al.* (2001b), who added different linseed oil and tallow ratios to Cobb broiler diets and observed higher weight gain in those fed high linseed oil levels. On the other hand, Almeida *et al.* (2009), replaced soybean oil by linseed oil in the diet of male and female Cobb broilers and did not observe any influence of lipid source on feed intake, weight gain or feed conversion ratio ($P > 0.05$). Murakami *et al.* (2010) found lower weight gain when broilers were fed 6.5 and 4.95% linseed oil in the periods of 1-21 and 22-49 days of age, respectively.

However, in the period of 21-56 days, the analysis of regression showed that increasing linseed oil levels linearly increased broiler weight gain ($WG = 2.561.463 + 27.3078X$; $R^2 = 0.90$; $p < 0.01$). Consistent results were obtained by Lopez-Ferrer *et al.* (2001b), who added different linseed oil to tallow ratios in the diet

of Cobb broilers and reported higher weight gain as linseed oil levels increased.

Crespo & Esteve-Garcia (2002c) fed broilers with diets containing tallow, olive oil, sunflower oil, and linseed oil also found higher weight gain and better feed conversion ratio compared to a basal diet during the phase of 28-53 days of age.

Although the experimental diets were iso-caloric, the analysis of regression for feed intake (FI) showed a significant lineal increase both in the periods of 21-42 days ($FI = 2.965.1049 + 21.953X$; $R^2 = 0.95$; $p < 0.01$) and 21-56 days ($FI = 5.826.813 + 22.069X$; $R^2 = 0.90$; $p < 0.05$), as shown in Table 2. These results are consistent with those of Murakami *et al.* (2009), who observed a quadratic increase in feed intake in the period of 1-7 days with increasing dietary linseed oil levels, with an estimated maximum level of 4.6%. Also Lopez-Ferrer *et al.* (1999) compared the feed intake of Cobb broilers fed diets supplemented with 8.2% fish oil or 8.2% linseed or canola oil and obtained higher daily FI in those fed vegetable oils. On the other hand, Murakami *et al.* (2010) observed feed intake reduction when broilers were fed linseed oil, which, according to



Almeida *et al.* (2009), may be attributed to organoleptic differences between linseed oil and soybean oil.

Pucci *et al.* (2003) also found that the dietary inclusion of up to 7.5% of soybean oil linearly increased feed intake of broilers in the periods of 1-21 and 22-42 days of age. On the other hand, Tabeeidian *et al.* (2005) observed lower feed intake when broilers were fed 7.5% soybean oil in the period of 7-21 days of age.

Dietary linseed oil inclusion levels had a quadratic influence ($p < 0.05$) on feed conversion ratio (Table 2) in both studied periods, as shown by the equations $FCR = 1.9342 - 0.032015X + 0.0020349X^2$, $R^2 = 0.92$ and $FCR = 2.1884 - 0.03445X + 0.00203547X^2$, $R^2 = 0.90$, up to the levels of 7.87 and 8.46% for the periods of 21-42 and 21-56 days of age, respectively. This behavior may be related to the linear increase in feed intake without the corresponding increase in weight gain. These results are consistent with those of Murakami *et al.* (2009), who included increasing linseed oil levels in broiler diets during the period of 1-43 days of age and observed a linear improvement in feed conversion ratio, demonstrating the beneficial effects of this oil source on broiler performance. However, in a subsequent study, Murakami *et al.* (2010) found that feed conversion ratio worsened when linseed oil was fed during the starter phase (1-21 days) and no effect thereafter (22-49 days).

Table 2 – Weight gain (WG), feed intake (FI), metabolizable energy intake¹ (MEI), feed conversion ratio (FCR), and calorie conversion ratio (CCR) of broilers fed four linseed oil level during the phases of 21-42 and 21-56 days of age.

Linseed oil levels (%)	21-42 days of age				
	WG (g) ³	FI (g) ⁴	CA ³	CE (kcal) ⁴	CC (kcal/kg) ³
0.0	1.451.60	2.956.40	1.94	8.869.20	6.11
3.3	1.564.65	3.029.55	1.84	9.155.30	5.85
6.6	1.641.60	3.147.35	1.82	9.555.35	5.82
9.9	1.656.80	3.159.70	1.81	9.542.29	5.76
P values	0.0035	<0.0001	<0.0001	<0.0001	0.0006
CV (%)	3.05	2.26	1.51	2.27	2.08
Linseed oil levels (%)	21-56 days of age				
	WG (g) ⁴	FI (g) ⁴	CA ³	CE (kcal) ⁴	CC (kcal/kg) ³
0.0	2.532.70	5.833.95	2.19	18.289.43	7.22
3.3	2.682.80	5.867.20	2.08	18.552.09	6.91
6.6	2.764.50	6.013.50	2.07	18.744.08	6.78
9.9	2.805.35	6.027.75	2.04	18.517.25	6.60
Valores de P	<0.0001	0.0014	<0.0001	0.050	0.0011
CV (%)	2.77	2.98	1.37	3.00	1.36

¹ Determined AMEn values (calculated values) on day 22: 3000 (2998), 3022 (2998), 3036 (2998), and 3020 (2998) kcal/g MN. On day 42: 3135 (3131), 3162 (3131), 3117 (3131), and 3072 (3131) kcal/g MN.

² Calculated considering the AMEn values determined in digestibility assay.

NS – not significant; ³ quadratic effect; ⁴ quadratic effect; CV – coefficient of variation.

Zelenka *et al.* (2006) verified better feed intake, weight gain and feed conversion ratio in broilers fed 5 and 7% linseed oil compared to those fed 1 and 3% between 20 and 40 days of age. Crespo & Esteve-Garcia (2002c) also found better feed conversion ratio in broilers fed diets containing tallow, olive oil, sunflower oil, and linseed oil during the phase of 28-53 days of age.

The linear increase in weight gain may be explained by the linear increase in metabolizable energy intake, as shown by the equations $MEI = 9,392.465 + 76.74X$; $R^2 = 0.88$; ($p < 0.01$) for the period of 21-42 days and $MEI = 18,898.30 + 56.118X$; $R^2 = 0.75$ ($p = 0.05$) for the period of 21-56 days. The results obtained for the total experimental period show that the replacement of carbohydrates by fat as energy source promoted better live performance, demonstrating the superiority of fats relative to carbohydrates. On the other hand, Plavnik *et al.* (1997) did not obtain clear evidences suggesting any superiority of fat relative to carbohydrates as energy source in terms of weight gain, feed intake or feed conversion ratio of broilers of different ages.

Linseed oil levels had a quadratic influence ($p < 0.05$) on calorie conversion ratio (Table 2), as shown by equations $CCR = 5,8004 - 0.074746X + 0.0043054X^2$; $R^2 = 0.90$ ($p < 0.05$) e $CCR = 6,6998 - 0.083695X + 0.0036708X^2$; $R^2 = 0.92$ ($p < 0.05$) up to the levels of 8.68 and 11.40% for the periods of 21-42 and 22-56 days, respectively.

Average carcass yield, breast yield, and leg yield determined when broilers were 42 days old were not influenced ($p > 0.05$) by linseed oil dietary level (Table 3), as previously found by Almeida *et al.* (2009). However, the analysis of regression revealed a quadratic effect on abdominal fat percentage ($AF = 1.9193 + 0.1798X - 0.01313X^2$; $R^2 = 0.99$; $p < 0.05$), estimating a maximum level of 6.85% linseed oil. When broilers were 56 days old (Table 3), dietary linseed oil levels had a quadratic influence on abdominal fat ($AF = 2.20 + 0.1897X - 0.0155X^2$; $R^2 = 0.77$; $p < 0.05$), at a maximum inclusion level of 6.12%. These results are different from those of Murakami *et al.* (2010), who found that broilers fed linseed oil deposited less abdominal fat when fed soybean oil during the phase of 1-49 days of age. According to those authors, abdominal fat deposition can be changed as a function of dietary fatty acid profile. Crespo & Esteve-Garcia (2001) also observed lower abdominal fat deposition when broilers were fed linseed oil.

According to Crespo & Esteve-Garcia (2002b), this lower abdominal fat deposition in broilers fed PUFA-



rich diets is due to the high oxidation capacity of those acids. In addition, poly-unsaturated fatty acids, particularly n-3 acids, are preferably deposited as membrane phospholipids, differently from saturated fatty acids, which, if consumed in excess, are deposited as triglycerides in fatty tissues (Ponnampalam *et al.*, 2001).

Table 3 – Carcass yield (CY), breast yield (BY), leg yield (LY), and abdominal fat percentage (AF) of broilers fed four linseed oil levels during the phases of 21-42 and 21-56 days of age.

Linseed oil levels (%)	42 days of age			
	CY (%)	BY (%)	LY (%)	AF (%) ¹
0.0	64.6	33.15	29.73	1.82
3.3	64.6	32.68	30.30	2.22
6.6	64.31	32.96	29.83	2.43
9.9	64.12	32.58	29.35	2.28
P values	0.0836 ^{NS}	0.0759 ^{NS}	0.0842 ^{NS}	0.036*
CV (%)	1.60	3.60	3.90	22.99

Linseed oil levels ¹ de linhaça (%)	56 days of age			
	CY (%)	BY (%)	LY (%)	AF (%) ¹
0.0	68.67	30.56	30.29	2.14
3.3	67.26	32.00	30.056	2.37
6.6	67.62	31.58	29.91	2.79
9.9	68.29	31.67	29.89	2.36
P values	0.0941 ^{NS}	0.0657 ^{NS}	0.0893 ^{NS}	0.015*
CV (%)	2.49	4.62	3.95	21.39

NS – not significant; ¹ quadratic effect; CV - coefficient of variation.

Cortinas *et al.* (2004) added different PUFA and vitamin E levels to Ross broiler diets and found that vitamin E and PUFA did not influence breast weight, but leg yield relative of eviscerated carcass weight tended to improve with increasing dietary PUFA levels.

Analyzing the obtained results, the quadratic influence of linseed oil dietary inclusion on abdominal fat determined on days 42 and 56 is possibly related to the quadratic behavior observed on weight gain during the period of 21 to 42 days of age.

There was no effect ($p>0.05$) of linseed oil inclusion levels on carcass moisture, crude protein, dry matter or ash content of the carcasses of 56-d-old broilers, differently from the findings of Murakami *et al.* (2010), who obtained significant reduction of moisture content in the leg of broilers fed linseed oil. However, linseed oil levels linearly increased ether extract content ($EE = 37.74 + 0.275X$; $R^2 = 0.70$; $p<0.05$), showing that as carbohydrates were replaced by linseed oil, body fat deposition increased. This suggests that there is a limit for abdominal fat deposition, after which the excess of fat is directed to other carcass parts.

Table 4 – Dry matter (DM), humidity (H), crude protein (CP), ether extract (EE), and ash (A) contents(AF) of the carcasses of broilers fed four linseed oil level during the phases of 21-42 and 21-56 days of age.

Linseed oil levels (%)	DM (%)	H (%)	CP (%)	EE ¹ (%)	Ash (%)
0.0	32.26	62.74	46.27	38.40	6.34
3.3	33.15	61.84	46.82	38.20	6.40
6.6	34.03	60.97	45.35	38.72	6.59
9.9	33.38	61.62	45.30	41.14	6.47
P values	0.0833 ^{NS}	0.0659 ^{NS}	0.0542 ^{NS}	0.00125	0.0426
CV (%)	3.92	2.14	5.22	5.55	8.15

* Values expressed on 100% DM; NS – not significant; ¹Linear effect; CV - coefficient of variation

These results are different from those of Laurin *et al.* (1985), who fed three broiler strains with iso-calorie and iso-protein diets with 2 or 9% fat and did not find any increase in body fat deposition. On the other hand, Deaton *et al.* (1981) fed broilers with diets containing 4, 7 or 10% animal fat and verified that abdominal fat and carcass fat deposition increased as dietary fat content increased.

The observed increase in body fat content may be attributed to the linear increase in energy intake, supplying energy in excess of bird requirements that was deposited in other body parts, as abdominal fat percentage presented a quadratic behavior.

CONCLUSIONS

The dietary addition of linseed oil presents variable effects on broiler performance and carcass traits; however, considering feed conversion ratio as an important parameter, maximum linseed oil inclusion levels of 7.86% for the period of 21-42 days and of 8.46% for the period of 21-56 days were calculated. Nevertheless, linseed oil inclusion levels higher than 6.85% and 6.12% increase abdominal fat percentage in the carcasses of 42- and 56-d-old broilers, respectively. In addition, linseed oil dietary inclusion may linearly increase carcass ether extract content.

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