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Manipulation of the fatty acids composition of poultry meat and giblets by dietary inclusion of two oil sources and conjugated linoleic acid

[*Mudança na composição de ácidos graxos das vísceras e da carne de aves tratadas com uma dieta contendo ácido linoléico conjugado e duas fontes de óleo*]

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ABSTRACT

The effect of dietary conjugated linoleic acid (CLA) in association with two vegetable oil sources on the fatty acids of meat and giblets of broiler chickens was evaluated. Two hundred 21-day-old broiler chickens were distributed in a completely randomized factorial design 2 x 5 (two oil sources, soybean or canola oil; and five levels of CLA, 0.0, 2.5, 5.0, 7.5, and 10.0g/kg). The addition of CLA to the diet resulted in an increase (P<0.05) in CLA deposition in the analyzed tissues. CLA supplementation also reduced (P<0.05) the rate of polyunsaturated to saturated fatty acids in thigh, breast, heart, and gizzard. There was interaction of CLA x oil source (P<0.05). The intake of soybean oil, associated with increasing CLA, resulted in an increase in lipid deposition in edible portions as observed by an increase in the overall content of fatty acids, including CLA, while the use of canola oil, associated with increasing CLA in the diet, resulted in a decrease in lipid content in edible portions, specifically regarding that of saturated fat (P<0.05) in breast meat and liver and in the content of monounsaturated fatty acids (P<0.05) in thigh, breast, liver, and gizzard.

Keywords: broiler, conjugated linoleic acid, canola oil, soybean oil, meat

RESUMO

Avaliou-se o efeito da suplementação de ácido linoléico conjugado (CLA) associado com duas fontes de óleo na dieta de frangos de corte sobre a composição de ácidos graxos das vísceras e da carne de aves. Duzentos frangos de corte, machos, com 21 dias de idade, foram distribuídos em delineamento inteiramente ao acaso, em arranjo fatorial 2 x 5 (duas fontes de óleo, soja e canola e cinco níveis de CLA, 0,0, 2,5, 5,0, 7,5 e 10,0g/kg). A adição de CLA na dieta resultou em aumento (P<0,05) de sua deposição na carne e nas vísceras de aves. Foi observado decréscimo (P<0,05) na taxa de poliinsaturados:saturados nas carnes da coxa e do peito, no coração e na moela com a suplementação de CLA. Houve interação (P<0,05) CLA x fonte de óleo. O uso de teores crescentes de CLA na dieta contendo óleo de soja na dieta resultou em aumento (P<0,05) no conteúdo lipídico. O contrário foi verificado com a utilização de óleo de canola, especificamente no conteúdo de ácidos graxos saturados (P<0,05) na carne do peito e no fígado e de monoinsaturados (P<0,05) nas carnes do peito e da coxa, fígado e moela.

Palavras-chave: frango de corte, ácido linoléico conjugado, canola, soja, carne

INTRODUCTION

The content and composition of fat in meat and giblets are affected by animal feeding, a fact that is exploited in the modification of the composition of the fatty acids in meat, and the best results have been obtained in monogastric animals such as pigs and poultry.

Several studies have shown that conjugated linoleic acid (CLA) influences the composition of meat. Dietary CLA is reported to reduce the content of

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monounsaturated and polyunsaturated fatty acids in meat (Szymczyk et al., 2001) and increase the concentration of saturated fatty acids (Schafer et al., 2001; Badinga et al., 2003), which is contrary to current dietary recommendations (Nutritional …, 1990). When CLA is used in diets with oleic, linoleic, or linolenic acids, the undesired effects of increasing saturated fatty acids was reduced (Du et al., 2000; Kim et al., 2007; Martin et al., 2007). The objective of this study is to investigate the effect of dietary CLA associated with oil sources that have different linoleic:linolenic acid ratio (soybean oil and canola oil) on the fatty acids composition of chicken meat and giblets.

MATERIAL AND METHODS

Two hundred 21-day-old male broiler chickens were distributed in a randomized factorial arrangement of 2 x 5 (two oil sources, soybean or canola oil, and five levels of CLA, 0.0, 2.5, 5.0, 7.5, and 10.0g/kg) with four experimental units each (five birds/pen). The source of CLA contained approximately 600g/kg conjugated isomers, as a 50:50 mixture of 18:2 cis-9, trans-11 and 18:2 trans-10, cis-12. The diet supplemented with soybean oil was the control, since this is the standard oil source used in poultry nutrition. The diets had 40g/kg of soybean or canola oil. CLA supplementation levels were obtained by isometrically replacing soybean or canola oil in the basal diets.

From one to 21 days of age, the chicks were raised on a corn-soy diet with 210g/kg protein and 12.34 MJ of metabolizable energy per kg of diet. The basal diet fed from 22 to 45 days of age is shown in Table 1.

The composition of fatty acids present in the oils (Table 2) was determined by gas liquid chromatography, according to Firestone (1998). The samples were subjected to transmethylation and the fatty acids were converted to methyl esters (Hartman and Lago, 1973). The lipids contained in the meat (thigh and breast) and giblets (heart, gizzard, and liver) were extracted using the Folch et al. (1957) technique and the composition of fatty acids was determined by gas liquid chromatography (Firestone, 1998). The composition of saturated, monounsaturated, and polyunsaturated fatty acids was evaluated in the meat and giblets: saturated (C10:0; C12:0; C14:0; C15:0; C16:0; C17:0; and C18:0); monounsaturated (C16:1n-7 and C18:1n-9); and polyunsaturated (C18:2n-6; C18:3n-3; C20:4n-6; C20:5n-3; C22:5n-6; C22:5n-3; and C22:6n-3).

Table 1. Ingredient composition and calculated nutritional levels of basal diet of broiles

Ingredient		$(g\ kg^{-1})$
Ground yellow maize		608.6
Soybean meal		315.0
Canola or soybean oil		40.0
Dicalcium phosphate		15.0
Limestone		12.0
Sodium chloride		4.0
Vitamin supplement[1]		2.0
Mineral supplement[2]		0.7
Salinomycin		0.5
DL- methionine		1.8
Zinc Bacitracin		0.3
Antioxidant (BHT)		0.1
Calculated composition		
Crude protein, $g\ kg^{-1}$		190.0
Metabolizable energy, $kcal\ kg^{-1}$	3,150.0	
Analysed composition		
Crude protein, $g\ kg^{-1}$		187.0
Total fat, $g\ kg^{-1}$		67.0

[1]Supply per kg of product the following vitamins and minerals: vit.A, 15.000.000UI; vit.D_3, 1.500.000UI; vit.E, 15.000UI; vit.K_3, 3g; vit.B_1, 2g; vit.B_2 4g; vit.B_6, 3g; vit.B_{12}, 0,015g; niacin, 2g; pantothenic acids, 10g; folic acids, 1g; choline, 250g; selenium, 100mg.
[2]Supply per kg of product: Fe, 80g; Cu, 10g; Co, 2g; Zn, 50g; Mn, 60g; I, 1g.

Table 2. Fatty acids composition of oils added to the broilers diets

Fatty Acids (%)	Soybean oil	Canola oil
C16:0	11.7	5.3
C18:0	3.8	2.6
C18:1n-9	24.2	64.1
C18:2n-6	54.8	19.4
C18:3n-3 alfa	4.5	6.1
C18:3n-6 gama	0.6	1.2
C20:0	0.2	0.2
C20:1n-11	0.2	1.1
Saturated	15.6	7.9
Monounsaturated	24.5	65.4
Polyunsaturated	59.9	26.7
omega-6 (n-6)	55.4	20.6
omega-3 (n-3)	4.5	6.1
Ratio of n-6:n-3	12.31	3.37
Ratio of linoleic:linolenic acid	12.17	3.18
Unsaturated:saturated	5.41	11.66

A gas chromatograph Varian 3900, equipped with a flame ionization detector, split/splitles injector, and capillary silica column, coupled to a Star Workstation was used. The injector was operated at 270°C, on split mode with flow of 100ml/min. The oven temperature was 120ºC/5min; 120°C to 220ºC (3ºC/min); 220 to 235ºC (1ºC/min), and 235ºC/12min. The carrier gas was hydrogen at a constant flow rate of 1.0ml/min and the detector temperature was 310°C.

Each fatty acid was identified in the form of a methyl ester by comparing the retention times with those of the standards. Quantification was made by normalization. In addition, analysis of the CLA-isomers of the oil included in the feed was performed by the method fore cited and quantified as total isomers of CLA. In the case of the poultry meat, the results were expressed in g kg^{-1} of edible portion, using the lipid conversion factor reported by Holland et al. (1994). The experimental data was analyzed using the analysis of variance by the SAEG (Sistema…, 1997). Significant differences among means were determined by the SNK test at P<0.05. Regression analysis were used to report the effects of CLA levels. When ANOVA indicated a significant interaction for a certain variable, the effect of oil source within each CLA level was determined.

RESULTS AND DISCUSSION

Addition of CLA in the diet resulted in an increase (P<0.05) in CLA deposition in analyzed tissues (Table 3), which agrees with previous studies (Badinga et al., 2003; Kim et al., 2007; Santos et al., 2007). The highest value for deposition of CLA was detected in the heart tissue and the lowest value for CLA was observed in breast meat (Table 3). The content of CLA of chicken meat varies from 0.03-0.9mg/g (Chin et al., 1992).

The data on the fatty acids composition of the thigh meat are presented in Table 4, for breast meat in Table 5, and for giblets in Tables 6, 7, and 8. In the thigh, breast, heart tissue, and gizzard, the highest content of the monounsaturated fatty acids occurred in broilers receiving the canola oil diet which differs (P<0.05) from that of chickens fed soybean oil diet. In contrast, chickens fed soybean oil diets had higher content of polyunsaturated fatty acids and n-6 fatty acids in thigh and breast meats, heart, liver, and gizzard, differing (P<0.05) from that of broilers fed the canola oil diets. Thus, a higher rate (P<0.05) of polyunsaturated:saturated (P:S) fatty acids in thigh (Table 4), heart (Table 6), and gizzard (Table 8), of chickens fed soybean oil diets in comparison to canola oil was observed. The fatty acids composition of lipids from meat and giblets reflected the fatty acids composition of the diet. This information corroborates previous findings (Zanini et al., 2004).

Increasing levels of CLA in the diet produced a linear reduction (P<0.05) in the levels of monounsaturated fatty acids in thigh meat ($\hat{Y} = 17.48 - 0.49x$, $R^2 = 0.93$) and an increase (P<0.05) in saturated fat in the thigh meat (Table 4) and gizzard (Table 8), which agree with a previous report (Kim et al., 2007). However, in the present study, the increase (P<0.05) in the content of saturated fatty acids was only observed in birds fed the soybean oil diets ($\hat{Y} = 11.03 + 0.40x$, $R^2 = 0.82$ for thigh meat; $\hat{Y} = 10.69 + 1.0x$, $R^2 = 0.92$ for gizzard). CLA also produced a reduction (P<0.05) in the rate of polyunsaturated:saturated (P:S) in the thigh (Table 4), breast (Table 5), heart (Table 6), and gizzard (Table 8).

Dietary CLA has been suggested to reduce unsaturated fatty acids in meat. CLA is known to decrease the activity and gene expression of stearoyl CoA delta9 desaturase (Choi et al., 2002) and may also suppress delta6 and delta5 desaturase (Chuang et al., 2001a; Eder et al., 2002) and elongase (Chuang et al., 2001b), resulting in accumulation of saturated fatty acids, which leads to a change of the composition of fatty acids in animal tissue (Watkins et al., 2003). Therefore, the modification of the profile of fatty acids in broiler tissue due to dietary CLA seems to be related to a likely inhibition of the desaturation of fatty acids. Also, the findings of the present study reveal that this inhibitory effect of CLA seems to be dependent of the oil source in the diet.

A significant interaction (P<0.05) between oil source and CLA supplementation was observed on lipid content and on fatty acids profile. An increase (P<0.05) in the lipid content was observed and was measured as g/100g in the thigh ($\hat{Y} = 3.26 + 0.09x$, $R^2=0.90$), heart (P<0.05, $\hat{Y} = 8.43 - 0.44x + 0.07x^2$, $R^2 = 0.87$), liver (P<0.05, $\hat{Y} = 1.03 + 0.13x$, $R^2 = 0.66$), and gizzard (P<0.05, $\hat{Y} = 4.52 + 0.09x$, $R^2 = 0.89$) of broilers fed increasing levels of CLA plus soybean oil. The opposite was observed in the breast meat (P<0.05, $\hat{Y} = 0.91 - 0.16x + 0.01x^2$, $R^2 = 0.93$). Thus, the increase (P<0.05) in the fat content in the meat and giblets was represented by a linear increase (P<0.05) in the content of saturated fat in the thigh (Table 4), in the heart tissue ($\hat{Y} = 16.0 + 2.07x$, $R^2 = 0.99$), and in the gizzard (Table 8). There was a linear increase (P<0.05) in the content of the monounsaturated fatty acids in the heart (Table 6) and in the gizzard (Table 8), and also in the content of the polyunsaturated fatty acids in these organs ($\hat{Y} = 13.61 + 0.83x$, $R^2=0.85$ for heart tissue; $\hat{Y} = 8.07 + 0.32x$, $R^2= 0.82$ for gizzard). These changes were accompanied by increases (P<0.05) in contents of ω6 fatty acids in the heart ($\hat{Y} = 12.78 + 0.61x$, $R^2=0.78$) and in the gizzard, and in the content of ω3 fatty acids in the heart ($\hat{Y} = 0.83 + 0.04x$, $R^2 = 0.83$). The reduction (P<0.05) in total lipids in the breast of birds fed soybean oil diets was associated with increasing levels of CLA (P<0.05), which was represented by a linear decrease (P<0.05) in the deposition of monounsaturated and polyunsaturated fatty acids ($\hat{Y}$ = 2.50 - 0.18x, R^2= 0.88), especially ω6 fatty acids ($\hat{Y}$ = 2.11 – 0.15x, R^2= 0.85). The intake of soybean oil diets with increasing CLA also resulted in an increase (P<0.05) of the saturated fatty acids ($\hat{Y}$ = 4.85 - 0.40x + 0.09x^2, R^2=0.88), monounsaturated fatty acids, polyunsaturated fatty acids ($\hat{Y}$= 2.66 – 0.34x + 0.04x^2, R^2= 0.86), both ω6 fatty acids ($\hat{Y}$= 2.22 – 0.25x + 0.03x^2, R^2= 0.81), and ω3 fatty acids in liver (Table 7).

Table 3. Conjugated linoleic acid in meat and giblets of broilers fed diets supplemented with soybean or canola oil and conjugated linoleic acid[1]

	Total isomers of CLA (g kg^{-1})		
	Thigh meat		
CLA (g kg^{-1})	Soybean oil[2]	Canola oil[3]	Average CLA[3]
0.0	0.037a	0.038a	0.038
2.5	0.138a	0.202a	0.170
5.0	0.374a	0.364a	0.369
7.5	0.431b	0.568a	0.500
10.0	0.892a	0.686b	0.789
Average Oil Source	0.374	0.372	
	Breast meat		
CLA (g kg^{-1})	Soybean oil[2]	Canola oil[2]	Average CLA[3]
0.0	0.005a	0.014a	0.010
2.5	0.010a	0.021a	0.015
5.0	0.032b	0.050a	0.041
7.5	0.020b	0.074a	0.047
10.0	0.065a	0.048b	0.057
Average oil source	0.026b	0.041a	
	Liver		
CLA (g kg^{-1})	Soybean oil	Canola oil	Average CLA[2]
0.0	0.023	0.009	0.016
2.5	0.024	0.021	0.023
5.0	0.012	0.040	0.026
7.5	0.067	0.048	0.058
10.0	0.105	0.118	0.112
Average oil source	0.046	0.047	
	Gizzard tissue		
CLA (g kg^{-1})	Soybean oil[3]	Canola oil[2]	Average CLA[3]
0.0	0.011a	0.011a	0.011
2.5	0.136b	0.266a	0.201
5.0	0.353a	0.442a	0.397
7.5	0.515b	0.675a	0.595
10.0	0.827a	0.704a	0.766
Average oil source	0.368	0.420	
	Heart tissue		
CLA (g kg^{-1})	Soybean oil[3]	Canola oil[2]	Average CLA[2]
0.0	0.052a	0.020a	0.036
2.5	0.151b	0.473a	0.312
5.0	0.579a	0.587a	0.583
7.5	1.111a	1.067a	1.089
10.0	1.392b	2.397a	1.894
Average oil source	0.657b	0.909a	

Values within the same row followed by distinct letters differ by SNK test (P<0.05).
[1]Each value represents mean of four replicates per treatment.
[2]Quadratic effect (P<0.05).
[3]Linear effect (P<0.05).

Table 4. Content of fatty acids in thigh meat of broilers [1]

	Total saturated fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil[2]	Canola oil	Average CLA[2]
0.0	11.87a	12.38a	12.13
2.5	10.89b	15.64a	13.27
5.0	12.94a	13.00a	12.97
7.5	14.24a	12.12a	13.18
10.0	15.21a	13.97a	14.59
Average oil source	13.03	13.42	
SE treatment	0.91		
	Total monounsaturated fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil	Canola oil	average CLA[2]
0.0	16.30	18.76	17.53
2.5	13.09	20.36	16.72
5.0	12.48	16.52	14.50
7.5	12.30	14.16	13.23
10.0	12.02	14.24	13.13
Average oil source	13.24b	16.81a	
SE treatment	1.29		
	Total polyunsaturated fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil	Canola oil	Average CLA
0.0	10.08	7.31	8.69
2.5	8.63	8.29	8.46
5.0	10.09	7.96	9.02
7.5	8.97	6.90	7.93
10.0	11.60	6.57	9.08
Average oil source	9.87a	7.41b	
SE treatment	0.77		
	Total of omega-6 fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil	Canola oil	Average CLA
0.0	9.28	6.34	7.81
2.5	7.86	7.33	7.59
5.0	8.96	6.89	7.93
7.5	7.83	6.04	6.94
10.0	8.68	5.41	7.05
Average oil source	8.52a	6.40b	
SE treatment	0.65		
	Polyunsaturated:saturated fatty acids		
CLA (g kg^{-1})	Soybean oil[2]	Canola oil	Average CLA[2]
0.0	0.84a	0.58b	0.71
2.5	0.79a	0.52b	0.66
5.0	0.77a	0.61b	0.69
7.5	0.63a	0.56a	0.60
10.0	0.76a	0.46b	0.61
Average oil source	0.76a	0.55b	
SE treatment	0.03		

Values within the same row followed by distinct letters differ by SNK test ($P<0.05$).
[1]Each value represents mean of four replicates per treatment.
[2]Linear effect ($P<0.05$).

Table 5. Content of fatty acids in breast meat of broilers[1]

	Total saturated fatty acids ($g\ kg^{-1}$)		
CLA ($g\ kg^{-1}$)	Soybean oil[2]	Canola oil[3]	Average CLA[2]
0.0	2.54b	5.39a	3.97
2.5	2.26b	4.25a	3.25
5.0	1.55b	3.53a	2.54
7.5	1.79b	2.56a	2.17
10.0	2.71a	1.91b	2.31
		A	
Average oil source	2.17b	3.53a	
SE treatment	0.21		
	Total monounsaturated fatty acids ($g\ kg^{-1}$)		
CLA ($g\ kg^{-1}$)	Soybean oil[3]	Canola oil[2]	Average CLA[2]
0.0	1.92b	6.36a	4.14
2.5	1.81b	3.98a	2.90
5.0	1.02b	3.18a	2.10
7.5	1.03b	2.35a	1.69
10.0	1.23a	1.57a	1.40
Average oil source	1.40b	3.49a	
SE treatment	0.33		
	Total polyunsaturated fatty acids ($g\ kg^{-1}$)		
CLA ($g\ kg^{-1}$)	Soybean oil[3]	Canola oil[2]	Average CLA[2]
0.0	2.62a	1.34b	1.98
2.5	1.66a	0.98b	1.32
5.0	1.90a	0.76b	1.33
7.5	1.17a	0.75b	0.96
10.0	0.58b	1.18a	0.88
Average oil source	1.58a	1.00b	
SE treatment	0.12		
	Total of omega-6 fatty acids ($g\ kg^{-1}$)		
CLA ($g\ kg^{-1}$)	Soybean oil[3]	Canola oil[2]	Average CLA[2]
0.0	2.27a	1.25b	1.76
2.5	1.33a	0.72b	1.03
5.0	1.58a	0.67b	1.13
7.5	1.03a	0.62b	0.82
10.0	0.51b	0.96a	0.74
Average oil source	1.35a	0.85b	
SE treatment	0.10		
	Polyunsaturated:saturated fatty acids		
CLA ($g\ kg^{-1}$)	Soybean oil	Canola oil	Average CLA[3]
0.0	0.53	0.48	0.50
2.5	0.43	0.39	0.41
5.0	0.51	0.54	0.52
7.5	0.43	0.44	0.44
10.0	0.43	0.30	0.37
SE treatment	0.03		

Values within the same row with no common letter differ by SNK test (P<0.05).
[1]Each value represents mean of four replicates per treatment.
[2]Quadratic effect (P<0.05).
[3]Linear effect (P<0.05).

Table 6. Content of fatty acids in heart tissue of broilers[1]

	Total saturated fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil[3]	Canola oil[2]	Average CLA[2]
0.0	15.13b	20.74a	17.94
2.5	22.03b	30.19a	26.11
5.0	25.50a	23.25a	24.37
7.5	34.19a	27.45b	30.82
10.0	34.99b	48.06a	41.52
Average oil source	26.37b	29.94a	
SE treatment	1.72		
	Total monounsaturated fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil[3]	Canola oil[2]	Average CLA[2]
0.0	21.12b	36.45a	28.78
2.5	23.28b	46.54a	34.91
5.0	24.84a	30.02a	27.43
7.5	31.81a	30.99a	31.40
10.0	27.62b	50.20a	38.91
Average oil source	25.73b	38.84a	
SE treatment	2.36		
	Total polyunsaturated fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil[3]	Canola oil[2]	Average CLA[2]
0.0	14.45a	13.39a	13.92
2.5	13.95b	18.60a	16.27
5.0	17.86a	12.72b	15.29
7.5	21.70a	14.71b	18.21
10.0	21.04b	25.48a	23.26
Average oil source	17.80	16.98	
SE treatment	1.14		
	Total of omega-6 fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil[3]	Canola oil[2]	Average CLA[2]
0.0	13.43a	11.84a	12.63
2.5	12.80b	16.33a	14.57
5.0	15.99a	11.01b	13..50
7.5	19.12a	12.44b	15.78
10.0	18.00b	21.65a	19.82
Average oil source	15.87a	14.65b	
SE treatment	0.99		
	Polyunsaturated:saturated fatty acids		
CLA (g kg^{-1})	Soybean oil[2]	Canola oil[3]	Average CLA[2]
0.0	0.95a	0.64b	0.80
2.5	0.63a	0.61a	0.62
5.0	0.70a	0.54b	0.62
7.5	0.63a	0.55a	0.59
10.0	0.61a	0.53a	0.57
Average oil source	0.70a	0.57b	
SE treatment	0.03		

Values within the same row followed by distinct letters differ by SNK test (P<0.05).
[1]Each value represents mean of six replicate per treatment.
[2]Quadratic effect (P<0.05).
[3]Linear effect (P<0.05).

Table 7. Content of fatty acids in hepatic tissue of broilers[1]

	Total saturated fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil[2]	Canola oil[2]	Average CLA[2]
0.0	4.53a	5.20a	4.86
2.5	5.50a	6.13a	5.81
5.0	3.94a	3.12a	3.53
7.5	7.81a	3.25b	5.53
10.0	10.24a	5.62b	7.93
Average oil source	6.40a	4.66b	
SE treatment	0.47		
	Total monounsaturated fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil[2]	Canola oil[2]	Average CLA[2]
0.0	2.24b	3.39a	2.81
2.5	3.00a	3.28a	3.14
5.0	1.54a	2.43a	1.99
7.5	2.11a	1.33a	1.72
10.0	4.06a	2.64b	3.35
Average oil source	2.59	2.61	
SE treatment	0.35		
	Total polyunsaturated fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil[2]	Canola oil	Average CLA[2]
0.0	2.48a	2.03a	2.26
2.5	2.59a	2.93a	2.76
5.0	1.76a	1.46a	1.61
7.5	2.84a	1.31b	2.07
10.0	4.09a	2.37b	3.23
Average oil source	2.75a	2.02b	
SE treatment	0.25		
	Total of omega-6 fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil[2]	Canola oil	Average CLA[2]
0.0	2.04a	1.64a	1.84
2.5	2.27a	2.38a	2.32
5.0	1.54a	1.26a	1.40
7.5	2.34a	1.07b	1.70
10.0	3.41a	1.83b	2.62
Average oil source	2.32a	1.63b	
SE treatment	0.20		
	Total of omega-3 fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil[2]	Canola oil	Average CLA[2]
0.0	0.31a	0.20b	0.25
2.5	0.19b	0.31a	0.25
5.0	0.14a	0.13a	0.14
7.5	0.37a	0.14b	0.25
10.0	0.39a	0.22b	0.31
Average oil source	0.28a	0.20b	
SE treatment	0.03		

Values within the same row followed by distinct letters differ by SNK test (P<0.05).
[1]Each value represents mean of six replicate per treatment.
[2]Quadratic effect (P<0.05).

Table 8. Content of fatty acids in gizzard tissue of broilers[1]

	Total saturated fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil[2]	Canola oil	Average CLA[2]
0.0	11.48b	16.71a	14.09
2.5	12.58b	18.71a	15.64
5.0	14.22a	15.38a	14.80
7.5	19.75a	16.94a	18.35
10.0	20.40a	14.95b	17.68
Average oil source	15.69	16.54	
SE treatment	1.14		
	Total monounsaturated fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil	Canola oil[2]	Average CLA[2]
0.0	13.01b	26.18a	19.59
2.5	12.11b	24.50a	10.31
5.0	12.01b	17.57a	14.79
7.5	15.79a	19.57a	17.68
10.0	17.01a	16.32a	16.66
Average oil source	13.99b	20.83a	
SE treatment	1.44		
	Total polyunsaturated fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil[2]	Canola oil[2]	Average CLA
0.0	8.36a	9.67a	9.01
2.5	8.47a	9.36a	8.92
5.0	9.30a	7.69a	8.49
7.5	11.48a	8.22b	9.85
10.0	10.97a	7.41b	9.19
Average oil source	9.71a	8.47b	
SE treatment	0.78		
	Total of omega-6 fatty acids (g kg^{-1})		
CLA (g kg^{-1})	Soybean oil[2]	Canola oil[2]	Average CLA
0.0	7.56a	8.65a	8.10
2.5	7.57a	7.65a	7.61
5.0	8.19a	6.47a	7.33
7.5	10.41a	6.77b	8.59
10.0	9.19a	5.93b	7.56
Average oil source	8.59a	7.09b	
SE treatment	0.66		
	Polyunsaturated:saturated fatty acids		
CLA (g kg^{-1})	Soybean oil	Canola oil	Average CLA[2]
0.0	0.72	0.57	0.65
2.5	0.68	0.50	0.59
5.0	0.65	0.49	0.57
7.5	0.57	0.48	0.53
10.0	0.55	0.49	0.52
Average oil source	0.63a	0.51b	
SE treatment	0.03		

Values within the same row followed by distinct letters differ by SNK test (P<0.05).
[1]Each value represents mean of six replicate per treatment.
[2]Linear effect (P<0.05).

Brown et al. (2001) observed that CLA-treated cultures of preadipocyte supplemented with increasing levels of linoleic acid had greater TG contents and greater numbers of larger cells than cultures treated with only CLA. These data demonstrate that the linoleic acid partially reverses attenuation of CLA of TG content, suggesting that these unsaturated fatty acids may compete for incorporation into TG or phospholipid-derived eicosanoids that regulate preadipocyte differentiation.

However, in the present study, the use of canola oil with increasing CLA levels resulted in a reduction ($P<0.05$) in the total lipids, that was measured in g/100g, in the thigh ($\hat{Y} = 4.68 - 0.08x$), breast ($\hat{Y} = 1.44 - 0.07x$, $R^2=0.78$), liver ($\hat{Y} = 1.70 - 0.21x + 0.02x^2$), and gizzard ($\hat{Y} = 6.48 - 0.19x$). In the heart, the opposite was observed ($P<0.05$, $\hat{Y} = 10.54 - 1.06x + 0.15x^2$). Therefore, the reduction ($P<0.05$) in total lipids content was represented by a decrease ($P<0.05$) in the deposition of saturated fatty acids ($\hat{Y} = 5.26 - 0.34x$, $R^2=0.99$), monounsaturated fatty acids ($\hat{Y} = 6.18 - 0.81x + 0.03x^2$, $R^2=0.98$), and ω3 fatty acids ($\hat{Y} = 0.15 - 0.01x$, $R^2= 0.91$) in the breast. Also, there was a linear decrease ($P<0.05$) in the content of the monounsaturated fatty acids ($\hat{Y} = 25.75 - 0.98x$, $R^2= 0.81$), polyunsaturated fatty acids ($\hat{Y} = 9.60 - 0.22x$, $R^2= 0.79$), ω6 fatty acids ($P<0.05$, $\hat{Y}= 8.36 - 0.25x$, $R^2= 0.87$), and ω3 fatty acids ($P<0.05$, $\hat{Y} = 0.78 - 0.02x$, $R^2= 0.95$) in the gizzard. In the liver, there was a decrease ($P<0.05$) in the deposition of saturated fatty acids and monounsaturated fatty acids at 5.0-7.5g/kg of CLA with canola oil.

It is known that a major factor in the short-term control of hepatic mitochondrial fatty acid oxidation is the inhibition of CPT-I by malonyl-CoA, the end product of the reaction catalyzed by ACC. Considering that the latter enzyme is a key regulatory site of fatty acid synthesis, inhibition of CPT-I by malonyl-CoA allows for an elegant explanation of the coordinated control of partitioning hepatic fatty acids between esterification and oxidation. Priore et al. (2007) investigated the metabolic fate and short-term effects of CLA compared to linoleic acid (LA) on lipid metabolism. A significant increase in the activity of carnitine palmitoyltransferase I (CPT-I) was observed when compared to the untreated cells, both in CLA or linoleic acid (LA) treated hepatocytes. However, no significant difference was detected between CLA- or LA-induced CPT-I stimulation. In addition, acetyl-CoA carboxylase (ACC) activity was significantly decreased by CLA when compared to the untreated and LA-treated cells. Also, the CLA-treated hepatocytes had the lower content of malonyl-CoA when compared with untreated and treated cells with LA. Contrary to CLA, the LA had no significant effect on both ACC activity and malonyl-CoA level, showing that LA could regulate only liver fatty acids oxidation by increase of CPT-I activity. Also, it was shown that rat hepatocytes produce more CO_2 and acid-soluble products from CLA than from LA. These data showed individual effect of CLA and LA on lipid metabolism. It is worthy noting that, in the present study, there was interaction between CLA and oil source in the lipid content of meat and giblets ($P<0.05$). It is also noteworthy that the oils used in the diet had different contents of linoleic acid - C18:2ω6 (Table 2) and as such this probably influenced the results. It is therefore suggested that the action of CLA could be attenuated by the addition of high levels of linoleic acid which was also shown in a previous report (Brown et al., 2001). In summary, the effects produced by CLA are dependent upon other dietary factors such as the composition of the oil source.

CONCLUSIONS

Feeding CLA to broilers promoted the incorporation of CLA into muscle tissue and giblets and provides a potential CLA-rich source for human consumption. The intake of soybean oil with CLA resulted in an increase in the overall content of fatty acids, including CLA, due to an increase in the lipid content. The benefits of CLA in canola oil-based diet was the replacement of saturated and monounsaturated fatty acids by CLA with reduction in the lipid content.

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REFERENCES

BADINGA, L.; SELBERG, K.T.; DINGES, A.C. et al. Dietary conjugated linoleic acid alters hepatic lipid content and fatty acid composition in broiler chickens. *Poult. Sci.*, v.82, p.111-116, 2003.

BROWN, M.; EVANS, M.; McINTOSH, M. Linoleic acid partially restores the triglyceride content of conjugated linoleic acid-treated cultures of 3T3-L1 preadipocytes. *J. Nutr. Biochem.*, v.12, p.381-387, 2001.

CHIN, S.F.; LIU, W.; STORKSON, J.M. et al. Dietary sources of conjugated dienoic isomers of linoleic acid, a newly recognised class of anticarcinogens. *J. Food Comp. Anal.*, v.5, p.185-197, 1992.

CHOI, Y.; PARK, Y.; STORKSON, J.M. et al. Inhibition of stearoyl-CoA desaturase activity by the cis-9, trans-11 isomer and the trans-10, cis-12 isomer of conjugated linoleic acid in MDA-MB-231 and MCF-7 human breast cancer cells. *Biochem. Bioph. Res. Commun.*, v.294, p.785-790, 2002.

CHUANG, L.T.; LEONARD, A.E.; LIU, J.W. et al. Inhibitory effect of conjugated linoleic acid on linoleic acid elongation in transformed yeast with human elongase. *Lipids*, v.36, p.1099-1103, 2001b.

CHUANG, L.T.; THURMOND, J.M.; LIU, J.W. et al. Effect of conjugated linoleic acid on fungal Δ6-desaturase activity in a transformed yeast system. *Lipids*, v.36, p.139-143. 2001a.

DU, M.; AHN, D.U.; SELL, J.L. Effects of dietary conjugated linoleic acid and linoleic:linolenic acid ratio on polyunsaturated fatty acid status in laying hens. *Poult. Sci.*, v.79, p.1749-1756, 2000.

EDER, K.; SLOMMA, N.; BECKER, K. Trans-10, cis-12 conjugated linoleic acid suppresses the desaturation of linoleic and α-linolenic acids in HepG2 cells. *J. Nut.*, v.132, p.1115-1121, 2002.

FIRESTONE, D. (Ed). *Official Methods and Recommended Practices of the American Oil Chemists Society*. 5.ed., Champaign: AOCS, 1998. v.I-II, method 1-62.

FOLCH, J.; LEES, M.; SLOANE-STANLEY, G.H. A simple method for the isolation and purification of total lipids from animal tissues. *J. Biol. Chem.*, v.226, p.497-509, 1957.

HARTMAN, L.; LAGO, R.C. Rapid preparation of fatty acid methyl esters from lipids. *Lab. Pract.*, v.22, p.475-476, 1973.

KIM, J.H.; HWANGBO, J.; CHOI, N.J. et al. Effect of dietary supplementation with conjugated linoleic acid, with oleic, linoleic, or linolenic acid, on egg quality characteristics and fat accumulation in the egg yolk. *Poult. Sci.*, v.86, p.1180-6, 2007.

HOLLAND, B.; WELCH, A.A.; UNWIN, I.D. et al. (Eds). *The composition of food.* Cambridge: McCance and Widdowson´s, 1994. p.8-9.

MARTIN, D.; ANTEQUERA, T.; GONZALEZ, E. et al. Changes in the fatty acid profile of the subcutaneous fat of swine throughout fattening as affected by dietary conjugated linoleic acid and monounsaturated fatty acids. *J. Agric. Food Chem.*, v.55, p.10820-10826, 2007.

NUTRITIONAL recommendations. Ottawa: Canadian Government Publishing Centre, 1990.

PRIORE, P., GIUDETTI, A.M.; NATALI, F. et al. Metabolism and short-term metabolic effects of conjugated linoleic acids in rat hepatocytes. *Biochim. Biophys. Acta*, v.1771, p.1299-1307, 2007.

SANTOS, L.D.; FURUYA, W.M.; MATSUSHITA, M. et al. Deposição de ácido linoléico conjugado (CLA) em tilápias-do-nilo. *Rev. Bras. Zootec.*, v.36, p.1225-1230, 2007

SCHAFER, K.; MANNER, K.; SAGREDOS, A. et al. Incorporation of dietary linoleic and conjugated linoleic acids and related effects on eggs of laying hens. *Lipids*, v.36, p.1217-1222, 2001.

SISTEMA de análises estatísticas - SAEG. Viçosa: UFV, 1997.

SZYMCZYK, B.; PISULEWSKI, P.M.; SZCZUREK, W. et al. Effects of conjugated linoleic acid on growth performance, feed conversion efficiency, and subsequent carcass quality in broiler chickens. *Br. J. Nut.*, v.85, p.465-473, 2001.

WATKINS, B.A.; FENG, S.; STROM, A.K. et al. Conjugated linoleic acids alter the fatty acid composition and physical properties of egg yolk and albumen. *J. Agric.Food Chem.*, v.51, p.6870-6876, 2003.

ZANINI, S.F.; TORRES, C.A.A.; BRAGAGNOLO, N. et al. Effect of oil sources and vitamin E levels in the diet on the composition of fatty acids in rooster thigh and breast meat. *J. Sci. Food Agric.*, v.84, p.672-682, 2004.