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Effects of Soybean Oil or Whole Cotton Seed Addition on Accumulation of Conjugated Linoleic Acid in Beef of Fattening Brahman×Thai-Native Cattle

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ABSTRACT : Effects of soybean oil or whole cotton seed addition on conjugated linoleic acid (CLA) and performance of fattening Brahman×Thai-Native cattle were studied. Eighteen fattening cattle averaging 241±24 kg body weight and approximately 1 year old were stratified by live weight into three groups and randomly assigned by group to one of three dietary treatments. The treatments were control (concentrated 14% crude protein), control and supplemented with 170 g/d soybean oil, control plus 170 g/d of oil from whole cotton seed. All animals were weighed before and after the experimental period and 4 cattle per treatment were randomly slaughtered then carcass measurements were obtained. There were no statistically significantly differences in the final body weight, average daily gain and dry matter intake among treatments. However, the crude protein intake was significantly decreased ($p<0.01$) when whole cotton seed was fed compared with control and soybean oil treatments. The carcass composition and carcass characteristics were not significantly different in *Longissimus* and *Semimembranosus* muscle by feeding soybean oil and whole cotton seed compared with the control treatment. Supplementation of soybean oil increased ($p<0.01$) *cis*-9, *trans*-11 CLA by 116% in *Longissimus* muscle and by 240% in *Semimembranosus* muscle. However, whole cotton seed did not increase *cis*-9, *trans*-11 CLA in both muscles. The present study successfully increased *cis*-9, *trans*-11 CLA content of muscle lipids by soybean oil but not by whole cotton seed. (**Key Words :** Conjugated Linoleic Acid, Fattening Cattle, Whole Cotton Seed, Soybean Oil)

INTRODUCTION

Conjugated linoleic acids (CLA) are fatty acids found naturally in products from ruminants, particularly meat and milk. They promoted health benefits in humans such as anticarcinogenesis (Ip et al., 1999; Belury, 2002; Corl et al., 2003), antiobaese effect (Park et al., 1997), modulation of the immune system (Cook et al., 1993), antiatherosclerosis (Nicolosi et al., 1997), antidiabates (Houseknecht et al., 1998) and CLA decreased body fat mass in human (Blankson et al., 2000; Gaullier et al., 2005). Conjugated linoleic acids are a mixture of geometric and positional isomers of linoleic acid with conjugated double bonds.

Researchers have successfully increased the cis-9, trans-11 CLA content of muscle lipids by plant oils (Eagle et al., 2000; Mir et al., 2002, 2003; Choi et al., 2006; Wang et al., 2006; Noci et al., 2007) and oil seeds (Bolte et al., 2002). Thus, supplementation of fat sources rich in linoleic acids such as plant oils or oil seeds may increase CLA content in muscle lipid. However, no comparison between soybean oil (SBO) and whole cotton seed (WCS) has been made in previous researches published.

Brahman×Thai-Native cattle are widely raised by Thai farmers and accounted for 40% of total beef cattle population of 8.8 million heads (Department of Livestock Development, 2007). Twenty percent of these cattle are raised for yearling cattle which are used as grilled beef in restaurants. The requirement of good quality beef for grilled beef is that cattle will be fattened for a short period of 3 to 4 mo and body weight at the start of fattening period is approximately 240-250 kg and the final weight of finishing stage is between 300 to 330 kg.

The objective of the present study was to determine the effect of whole cotton seed (WCS) or soybean oil (SBO) supplementation on CLA accumulation in beef and on carcass characteristics of young growing fattening cattle.

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Table 1. Ingredient composition of concentrate used in the trial

Ingredients	kg/100 kg
Cassava chip	38.0
Rice bran	12.0
Palm meal (Solvent extraction)	28.0
Soybean meal (44%)	10.0
Molasses	8.0
Urea	1.0
Mineral+premix[1]	3.0

[1] Provided per kg of concentrate: vitamin A, 5,000 IU; vitamin D_3, 2,200 IU; vitamin E, 15 IU; Ca 8.5 g; P 6 g; K 9.5 g; Mg 2.4 g; Na 2.1 g; Cl 3.4 g; S 3.2 g; Co 0.16 mg; Cu 100 mg; I 1.3 mg; Mn 64 mg; Zn 64 mg; Fe 64 mg; Se 0.45 mg.

MATERIALS AND METHODS

Animals and feeding

Experiment was conducted in accordance with the principles and guidelines approved by the Suranaree University of Technology Animal Care and Use Committee which followed Guidelines for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (1st revised edition, 1999; Association Headquarters, 1111 North Dunlap Avenue, Savoy, IL 61874). Eighteen crossbred Brahman beef bulls, averaging 241±24 kg of body weight and approximately 1 year of age, were stratified by body weight into three groups and randomly assigned by group to one of three dietary treatments. The treatments were control (commercial concentrate 14% crude protein; CP), control plus 170 g/d of SBO and control plus 170 g/d of oil from WCS. Ingredient and nutrient compositions of concentrate used in the experiment are given in Table 1 and Table 2 respectively. Cattle were individually housed and fed 3.5 kg/d of concentrate divided in two equal meals at 0800 and 1600 h and *ad libitum* rice straw and free access to clean water. Soybean oil and whole cotton seed were top-dressed on concentrates at each feeding. The experiment lasted for 109 d. Fasted live weights were recorded at the start of the trial and then every two weeks throughout the experimental period. At the end of the experiment, cattle were weighed and 4 cattle per treatment were randomly sampled and then slaughtered.

Sample collection and analysis

Feed offered and left after consuming of individual cattle were weighed and collected on two consecutive days of each period of 14 d. Samples were taken and dried at 60°C for 48 h. Feed intakes were then determined by the difference between feed offered and left after eating. At the end of the experiment, feed samples were performed on well-mixed subsamples and then taken for further chemical analysis. Samples were ground through 1 mm sieve and analyzed for proximate (AOAC, 1990) and detergent analyses (Van Soest et al., 1991).

Carcass collection and analysis

Muscle samples from 6 cattle per treatment were cut from outside Longissimus dorsi (LD) and Semimembranosus (SM) muscle on the left side of each carcass. All samples were placed in plastic bags and chilled on ice. At the laboratory, samples were chilled at 4°C for 48 h. Then measurements were made on Longissimus muscle area at 12th rib, color and shear force. Muscle samples were removed from the plastic bags and cut. These steaks were measured for meat color by Chroma meter (Minolta CO., LTD) and then L* (lightness), a* (redness) and b* (yellowness) value reading were made in six locations from each piece of meat. The LD muscle areas were measured (Delta-t Devices LTD. England). Shear force was done with

Table 2. Chemical composition of diets

	Control	+SBO	+WCS	WCS	Rice straw
DM (%)	92.9	94.3	93.8	91.3	92.2
Ash (%)	6.9	6.4	5.6	3.6	11.7
CP (%)	15.2	14.8	16.5	19.5	3.9
EE (%)	4.1	8.6	5.7	15.4	0.8
CF (%)	16.7	16.5	17.0	27.4	40.9
NDF (%)	46.5	41.4	42.4	47.8	71.0
ADF (%)	28.2	26.5	26.3	38.5	44.9
ADL (%)	10.6	11.2	11.7	11.8	6.9
TDN_{1X} (%)	63.0	71.0	66.8	78.2	45.9
DE_{1X} (Mcal/kg of DM)	2.84	3.17	3.01	3.52	1.95
ME (Mcal/kg of DM)	2.33	2.60	2.46	2.89	1.60
NE_M (Mcal/kg of DM)	1.46	1.65	1.58	1.94	0.76
NE_G (Mcal/kg of DM)	0.87	1.08	0.98	1.29	0.22

+SBO = Supplementation with 170 g/d soybean oil; +WCS = Supplementation with 170 g/d oil from whole cotton seed; WCS = Whole cotton seed; DM = Dry matter; CP = Crude protein; EE = Ether extract; CF = Crude fiber; NDF = Neutral detergent fiber; ADF = Acid detergent fiber; ADL = Acid detergent lignin; TDN_{1X} (%) = Total digestible nutrient at maintenance level = tdNFC+tdCP+(tdFA×2.25)+tdNDF-7 (NRC, 2001); DE_{1X} (Mcal/kg) = digestible energy at maintenance level = ((tdNFC/100)× 4.2) +((tdNDF/100)×4.2)+((tdCP/100)×5.6+((FA/100)×9.4)-0.3; ME = Meyabolizable energy = 0.82×DE (NRC, 1996); NE_M = Net energy for maintenance = $1.37ME-0.138ME^2+0.0105ME^3-1.12$ (NRC, 1996); NE_G = net energy for gain = $1.42ME-0.174ME^2+0.0122ME^3-1.65$ (NRC, 1996).

Table 3. Fatty acid compositions of experimental diets, soybean oil, whole cotton seed and rice straw

	Control	+SBO	+WCS	SBO	WCS	Rice straw
Total fatty acids						
mg/g fat	861.5	851.2	512.3	744.8	391.5	99.6
g/kg of DM	35.3	73.2	29.2	737.4	60.3	0.8
	mg/g fat					
C 12:0	313.3	155.8	34.5	0.01	0.11	4.5
C 14:0	113.5	56.5	14.6	0.61	2.4	2.9
C 16:0	104.5	95.0	126.4	77.6	104.1	27.9
C 18:0	24.5	27.2	12.4	26.6	9.6	15.0
C 18:1	162.3	161.3	80.5	141.6	51.2	14.8
C 18:2	97.5	289.6	234.4	430.6	216.8	12.3
C 18:3	ND	9.7	0.12	57.1	0.73	2.3
Others	45.8	56.0	9.4	10.7	6.7	19.9

+SBO = Supplementation with 170 g/d soybean oil; +WCS = Supplementation with 170 g/d oil from whole cotton seed; SBO = Soybean oil; WCS = Whole cotton seed; Others = Sum of C 6:0, C 8:0, C 10:0, C 16:1, C 17:1, C 20:1, C 20:2, C 20:3n3, C 20:3n6, C 20:5n3, C 22:0, C 22:1n9, C 23:0, C 24:1.

a Warner-Bratzle shear attachment by Texture analyzer (TA-TX2 Texture Analyzer, Stable Micro Systems, UK). Marbling score was measured by Thai Agricultural Commodity and Food Standard (TACFS 6001-2004: level 5 = Abundant, 4 = Moderate, 3 = Small, 2 = Slight, 1 = Devoid). The muscle samples (LD and SM) were ground using a blender machine (M 0531, Moulinex Swan, Birmingham, UK.). Subsamples were analyzed in duplicate for CP using the Kjeldahl method and for lipid by solvent extraction using petroleum ether extraction (AOAC, 1998).

Fatty acid analysis

Feed and meat fat were extracted using a modified method used by Folch et al. (1957) and Metcalfe et al. (1966). Before the extraction, meat samples were thawed and each sample was chopped coarsely and blended in a blender machine. A 15 g of each sample was homogenized for 2 min with 90 ml of chloroform-methanol (2:1) (Nissel AM-8 Homoginizer, Nihonseikikaisha, LTD., Japan). Each sample was further homogenized for 2 min with 30 ml of chloroform. Then, each sample was separated with separating funnel and 30 ml of deionized water and 5 ml of 0.58% NaCl were added. The lower layer was removed and placed in a screw-cap test tube and stored at -20°C until methylation.

Fatty acid methyl esters (FAME) were prepared by the procedure described by Ostrowska et al. (2000). In this procedure, approximately 30 mg of the extracted oil was placed into a 15-ml reaction tube fitted with a teflon-lined screw cap. One and a half ml of 0.5 M sodium hydroxide in methanol was added. The tubes were flushed with nitrogen, capped, heated at 100°C for 5 min with occasional shaking and then cooled to room temperature. One ml of C17:0 internal standard (2.00 mg/ml in hexane) and 2 ml of boron trifluoride in methanol were added and heated at 100°C for 5 min with occasional shaking. After methylation was completed, 10 ml of deionized water was added. The solution was transferred to a 40-ml centrifuged tube and 5 ml of hexane was added for FAME extraction. The solution was centrifuged at 2,000 g, at 10°C for 20 min and then the hexane layer was dried over sodium sulfate and was taken into a vial to be analyzed by gas chromatography (GC) (Hewlett Packard GC system HP6890 A; Hewlett Packard, Avondale, PA) equipped with a 100 m×0.25 mm×0.2 μm film fused silica capillary column (SP2560, Supelco Inc, Bellefonte, PA, USA). Injector and detector temperatures were 240°C. The column temperature was kept at 70°C for 4 min, then increased at 13°C/min to 175°C and held at 175°C for 27 min, then increased at 4°C/min to 215°C and held at 215°C for 31 min.

Statistical analysis

All data were statistically analyzed as a completely randomized block design using ANOVA procedure of SAS (SAS, 1998). Differences between treatment means were statistically compared using Duncan's New Multiple Range Test (Steel and Torrie, 1980).

RESULT AND DISCUSSION

The chemical composition of experimental diets, whole cotton seed and rice straw are presented in Table 2. Soybean oil diet had higher fat content than other diets. Concentration of C18:2 was increased by supplementation of SBO or WCS in the diets. C18:3 was negligibly detected in SBO and WCS diets in the present study.

Final body weight (BW) and dry matter intake (DMI) of experimental animals were not statistically significantly different among treatments, however, average daily gain (ADG) tended to be higher ($p<0.10$) in SBO and WCS diets than in control diet (Table 4). Crude protein intake (CPI) was lower ($p<0.05$) in control and SBO diets than in WCS diets, and CPI was significantly lower ($p<0.05$) in cattle fed WCS diet than that fed SBO diet (Table 4). The cattle on

Table 4. Effects of SBO or WCS supplementation on feed intake and growth performance

	Control	+SBO	+WCS	SEM	p-value
DM intake (kg/d)					
Concentrate	3.04	3.04	3.02	0.008	0.396
Rice straw	3.65	3.74	3.54	0.286	0.882
Total	6.69	6.78	6.56	0.287	0.856
CP intake (g/d)					
Concentrate	460[b]	450[c]	505[a]	2.86	0.001
Rice straw	143	146	138	11.5	0.885
Total	603[b]	596[b]	643[a]	12.3	0.011
EE intake (g/d)					
Concentrate	125[c]	261[a]	172[b]	7.7	0.001
Rice straw	30	31	29	0.5	0.455
Total	155[c]	292[a]	201[b]	9.4	0.001
Initial BW (kg)	242	239	241	9.44	0.971
Final BW (kg)	296	305	312	8.42	0.449
BW change (kg)	54	66	70	4.66	0.062
ADG (g/d)	500	610	650	48.7	0.096

+SBO = Supplementation with 170 g/d soybean oil; +WCS = Supplementation with 170 g/d oil from whole cotton seed; SEM = Standard error of mean; BW = Body weight; ADG = Average daily gain.

SBO diet consumed higher ($p<0.01$) fat than the cattle on WCS and control diets (Table 4). Results of the present study are similar to those of Whitney et al. (2000) who reported that addition of 3 or 6% SBO in beef heifer diets had no effect on DMI, final BW and ADG. Similar results were also reported when cattle were fed 4% SBO (Griswold et al., 2003), 5% SBO (Beaulieu et al., 2002), 3 or 6% sunflower oil (SFO) (Mir et al., 2003), 5.5% SFO (Noci et al., 2005), 150 g/d SFO (Noci et al., 2007), or 5% Safflower oil (Hristov et al., 2005). In contrast, some reports showed a significant decrease in DMI, final BW and ADG due to 8.5% oil addition to diet (Andrae et al., 2001), or 4% SBO (Engle et al., 2000). The decreased DMI in SBO added diets may have been due to the high unsaturated fatty acid content of SBO affecting rumen fermentation, and inhibited fiber digestion and thus limited DMI (Engle et al., 2000).

Huerta-Leidenz et al. (1991) fed 15 or 30% WCS showed no differences in final BW and ADG. Similar result were also reported when steers were fed 15% WCS (Cranston et al., 2006), and whole sunflower seed (Gibb et al., 2004). However, feeding 9 or 14% whole sunflower seed significantly increased DMI and ADG (Gibb et al., 2004). Addition of 8, 16 or 24% WCS to growing male goats decreased DMI linearly and CPI (Luginbuhl et al., 2000). Decreases in DMI caused by WCS supplementation probably because WCS is protected from ruminal digestion due to its encapsulation by the seed coat, which is high in CF, NDF and ADF (27.39, 47.76 and 38.49, respectively). Moreover, WCS has been associated with slow rates of ruminal passage digesta thus increases in the retention time of digesta and limits intake. Palmquist (1995) suggested that the delay in digestion of cotton fibers after colonization was caused by the highly crystalline structure of cotton fibers thus the rate of cotton linter digestion was limited by slow hydrolization and cellulolytic activity. Furthermore, the decreased DMI in SBO added diets may have been due to the high unsaturated fatty acid content of SBO affecting rumen fermentation, and inhibited fiber digestion (Engle et al., 2000).

There were no significant differences in protein, lipid and moisture content of both *Longissimus* muscle (LM) and *Semimembranosus* muscle due to SBO or WCS supplementation (Table 5). Carcass characteristics including dressing percentage, *Longissimus dorsi* area, shear force, color and marbling score were also not statistically significantly different among treatment diets (Table 5).

CLA contents of muscle tissues were mainly *cis*-9, *trans*-11, with no *trans*-10, *cis*-12 being detectable. In the present study, CLA content (*cis*-9, *trans*-11) of LM was significantly increased ($p<0.01$) by 116% and 214% when feeding SBO compared with control and WCS respectively (Table 6). Supplementation of WCS in the present study significantly reduced ($p<0.001$) *cis*-9, *trans*-11 in *Longissimus* muscle tissues. CLA content (*trans*-10, *cis*-12) was unaffected by SBO or WCS supplementation (Tables 6 and 7).

Researchers have successfully increased *cis*-9, *trans*-11 CLA content of muscle lipids by various sources of oils (Engle et al., 2000; Mir et al., 2002, 2003; Noci et al., 2007). CLA contents of muscle were increased by 45% when feeding 4% SBO (Engle et al., 2000), by 339% when feeding 6% SFO (Mir et al., 2002), by 30 or 75% when feeding 3 or 6% SFO (Mir et al., 2003) and by 144 or 73% when feeding SFO or linseed oil (LSO) respectively (Noci et al., 2007). However, some reports found no significant differences in CLA content in adipose or muscle tissues (Dhiman et al., 1999; Beaulieu et al., 2000; Dhiman et al., 2005).

Table 5. Effects of SBO or WCS supplementation on carcass composition and carcass characteristics

	Control	+SBO	+WCS	SEM	p-value
Carcass composition (% of wet weight)					
Longissimus muscle					
Protein	22.07	22.22	21.89	0.238	0.650
Lipid	5.18	5.27	6.99	1.219	0.533
Moisture	72.43	72.11	72.35	0.276	0.723
Semimembranosus muscle					
Protein	22.20	22.53	23.08	0.217	0.073
Lipid	4.17	4.54	4.14	0.857	0.937
Moisture	72.26	72.60	72.28	0.379	0.787
Carcass characteristics					
Dressing percentage	44.66	45.55	45.05	0.436	0.395
Longissimus muscle area (cm^2)	83.45	79.83	84.52	5.287	0.811
Longissimus muscle					
Shear force (kg)	5.76	7.12	6.14	0.522	0.246
Color L*	45.52	44.40	48.39	5.431	0.869
a*	14.34	14.58	13.50	1.114	0.779
b*	6.18	7.53	6.63	0.586	0.554
Semimembranosus muscle					
Shear force (kg)	9.69	14.44	8.88	2.067	0.202
Color L*	44.87	43.12	47.09	6.078	0.900
a*	15.12	14.32	14.10	0.829	0.678
b*	7.66	9.54	8.14	0.566	0.126
Marbling score	1	1	1	-	-

+SBO = Supplementation with 170 g/d soybean oil; +WCS = Supplementation with 170 g/d oil from whole cotton seed; SEM = Standard error of mean.

Increases in *cis*-9, *trans*-11 CLA accumulation in muscle by SBO can be attributed to the fact that SBO is rich in C18:2 which is used to promote direct synthesis of CLA. The biohydrogenation is incomplete in the rumen; CLA isomer and C18:1 trans-11 vaccenic acid are intermediates escaped from the rumen and then converted to produce CLA (C18:2 *cis*-9, *trans*-11) in tissue by the action of Δ^9 desaturase (Griinari et al., 1998; Baumam et al., 1999; Corl et al., 2001). In the present study, supplementation of WCS did not affect the CLA content in muscle although it is rich in C18:2 content. Palmquist et al. (1995) suggested that digestion and utilization of fatty acids in whole cotton seed and whole sunflower seed are dependent upon rumination and mastication to provide microbial access to seed contents. Page et al. (1997) expected that WCS depresses stearoyl-coenzyme A desaturase activity in subcutaneous adipose tissue and liver due to its cyclopropene fatty acid content in WCS if fed for a sufficiently long period of time. Madron et al. (2002) suggested that possibility of the biohydrogenation is more complete in the rumen, resulting in the formation of more stearic acid and thus less C18:1 trans-11 vaccenic acid and CLA would escape the rumen.

There were significant decreases ($p<0.001$) in C12:0, C14:0, C14:1 and C15:0 in LM and SM when WCS diet was fed compared with control diet (Tables 6 and 7). Feeding SBO or WCS diet reduced ($p<0.05$) C16:0 and C16:1 in LM and C16:1 in SM. The present study confirms the result of Engle et al. (2000) who found a decrease in C16:1 but not in C16:0 in muscle and adipose tissues when steers were fed diet containing 4% SBO. Similar results were also reported with 5% SBO (Beaulieu et al., 2002), with 6% SFO (Mir et al., 2002), and with 3 or 6% SFO (Mir et al., 2003). However, Noci et al. (2007) indicated that C12:0, C14:0 and C16:0 were increased in muscle tissue when cattle were fed SFO and LSO. Dhiman et al. (2005) reported that C12:0-C16:0 in adipose and muscle tissues from steers fed 2 or 4% SBO were unaffected while C14:0 was increased and C16:1 was decreased. The reduction in C16:0 and C16:1 caused by SBO or other plant oils addition to the diets is probably due to the negative feedback inhibition of fatty acid synthesis by the exogenous fatty acids.

Stearic acid (C18:0) in LM and SM were similar in all diets. However, both LM and SM lipids showed a reduction in C18:1 when WCS was fed. Moreover, the addition of WCS decreased C18:2 in SM and C18:3 in LM. The soybean oil supplemented cattle showed similar C18:1, C18:2 and C18:3 in LM and SM to the control cattle. Other reports showed 10 and 12% increases in C18:0 when 5% SBO was supplemented (Beaulieu et al., 2002) and 10% increase in C18:0 when 4% SBO was fed (Dhiman et al., 2005). Griswold et al. (2003) reported a linear increase in C18:2, while C18:3 was unaffected when 0, 4 or 8% SBO were fed to steers. Mir et al. (2003) also found an increase in C18:2 when 3 or 6% SFO was added to diets. Recently, Noci et al. (2007) indicated that C18:1 and C18:2 were significantly increased while C18:0 was reduced by SFO and LSO supplementation. Short- and medium- chain fatty

Table 6. Effects of SBO or WCS supplementation on fatty acid composition of *Longissimus* muscle (mg/g fat)

	Control	+SBO	+WCS	SEM	p-value
C 12:0	4.2[a]	3.1[a]	0.9[b]	0.34	0.001
C 14:0	29.6[a]	19.6[b]	10.0[c]	1.29	0.0001
C 14:1	4.4[a]	2.4[b]	0.9[b]	0.46	0.005
C 15:0	2.7[a]	1.8[b]	1.4[b]	0.15	0.002
C 15:1	1.0	0.5	0.5	0.20	0.231
C 16:0	121.3[a]	90.3[b]	72.1[b]	5.53	0.002
C 16:1	15.3[a]	9.0[b]	6.8[b]	1.44	0.015
C 17:1	3.3[a]	1.9[ab]	1.5[b]	0.40	0.046
C 18:0	68.9	73.5	65.3	5.53	0.584
C 18:1	121.9[a]	108.7[ab]	77.0[b]	9.59	0.040
C 18:2	15.4	18.6	12.7	3.30	0.492
C 18:3	1.3[a]	1.2[a]	0.4[b]	0.20	0.035
≥C 20:0	15.9	14.9	10.7	2.69	0.402
cis-9, *trans*-11 CLA	1.4[b]	2.4[a]	0.6[c]	0.16	0.0006
Summation by source[1]					
<C 16:0	41.8[a]	27.5[b]	13.8[c]	1.7	0.0001
C 16:0 and C 16:1	136.6[a]	99.3[b]	78.9[b]	6.6	0.002
>C 16:0	228.1	221.1	168.1	17.7	0.101
Saturated fatty acids	231.7[a]	191.7[b]	152.2[c]	10.4	0.005
Unsaturated fatty acids	174.7[a]	156.2[ab]	108.5[b]	15.5	0.053

+SBO = Supplementation with 170 g/d soybean oil; +WCS = Supplementation with 170 g/d oil from whole cotton seed; SEM = Whole standard error of mean.

[1] Fatty acids: <C 16:0 originated from de novo synthesis fatty acids; >C 16:0 were performed fatty acids.

Table 7. Effects of SBO or WCS supplementation on fatty acid composition of *Semimembranosus* muscle (mg/g fat)

	Control	+SBO	+WCS	SEM	p-value
C 12:0	2.3[a]	1.6[ab]	0.5[b]	0.31	0.020
C 14:0	18.4[a]	12.2[ab]	6.1[b]	2.82	0.058
C 14:1	2.6[a]	1.7[ab]	0.4[b]	0.52	0.065
C 15:0	1.7	1.6	0.8	0.28	0.145
C 15:1	1.1[a]	<0.01[b]	0.2[b]	0.24	0.044
C 16:0	97.1[a]	67.0[ab]	47.1[b]	13.40	0.097
C 16:1	11.7[a]	6.9[b]	4.5[b]	1.37	0.027
C 17:1	3.4[a]	1.4[b]	1.0[b]	0.40	0.011
C 18:0	54.8	46.2	41.2	9.23	0.602
C 18:1	106.7[a]	83.3[ab]	52.5[b]	14.08	0.089
C 18:2	20.1[a]	15.8[ab]	10.3[b]	2.50	0.084
C 18:3	1.3	0.9	0.3	0.28	0.113
≥C 20:0	21.6[a]	12.2[b]	8.4[b]	2.46	0.022
Cis-9, *trans*-11 CLA	0.8[ab]	1.8[a]	0.3[b]	0.34	0.046
Summation by source[1]					
<C 16:0	26.1[a]	16.6[ab]	8.0[b]	3.77	0.040
C 16:0 and C 16:1	108.8	73.9	51.6	14.64	0.083
>C 16:0	208.7	161.6	113.9	25.24	0.097
Saturated fatty acids	180.2	130.4	96.8	25.85	0.151
Unsaturated fatty acids	163.4[a]	121.7[ab]	76.7[b]	17.64	0.037

+SBO = Supplementation with 170 g/d soybean oil; +WCS = Supplementation with 170 g/d oil from whole cotton seed; SEM = Standard error of mean.

[1] Fatty acids: <C 16:0 originated from de novo synthesis fatty acids; >C 16:0 were performed fatty acids.

acids (<16 carbons) in LM and SM lipids were significantly decreased ($p<0.01$) by SBO or WCS addition, however, long-chain fatty acids (>16 carbons) were significantly increased ($p<0.01$). Saturated and unsaturated fatty acids were not significantly affected by the supplementation of either SBO or WCS. The variation in fatty acid composition in muscle lipid in response to plant oils or oil seeds supplementation is probably due to variations in the fatty acid composition of oils from plants or seeds.

CONCLUSION

It can be clearly concluded, in the present study, that the CLA content in beef was increased by SBO

supplementation, but not by WCS, however, both SBO and WCS had no effect on DMI, final body weight, and ADG.

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