

THE STUDY OF SOYBEAN OIL OR WHOLE COTTONSEED SUPPLEMENTATION ON PERFORMANCE AND CLA ACCUMULATION IN BEEF

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Abstract

The effects of soybean oil (SBO) and whole cottonseed (WCS) supplementation of fattening cattle diets on performance and CLA accumulation in beef were investigated in this study. Eighteen fattening cattle, averaging 241 ± 24 kg live weight and approximately 1 year old, were stratified by live weights into three groups and each group was randomly assigned to one of three dietary treatments. The treatments were 1) control (concentrate 14% crude protein), 2) control and supplemented with 170 g/d SBO, and 3) control plus 170 g/d of oil from whole cottonseed (WCS). The animals were weighed and slaughtered and carcass measurements were obtained. There were no significant differences in the final body weight (BW), average daily gain (ADG) and dry matter intake (DMI) among the treatments. However, Crude protein intake (CPI) significantly decreased ($P < 0.01$) when fed with WCS in comparison with control and SBO treatments. Carcass composition and carcass characteristics of cattle fed by SBO and WCS were not significantly different in *longissimus* and *semimembranosus* muscle when compared with control treatment group. Supplementing SBO increased ($P < 0.01$) in C18:2 *cis*-9, *trans*-11 CLA by 116% in *longissimus* muscle and by 240% in *semimembranosus* muscle. However, feeding WCS in diet did not increase C18:2 *cis*-9, *trans*-11 CLA in both muscle. In this study, need a subject here have successfully increased the C18:2 *cis*-9, *trans*-11 CLA content of muscle lipids by SBO but not WCS.

Keywords: Fattening cattle, conjugated linoleic acid, fatty acid, soybean oil, whole cottonseed

Introduction

Conjugated linoleic acids (CLA) are fatty acids that are found naturally in foods derived from ruminant animals, mainly in meat and milk. Many research studies promote healthy benefits when these products are consumed. The benefits include anticarcinogenesis (Ip *et al.*, 1999; Belury,

2002; Corl *et al.*, 2003), antiobese effects (Park *et al.*, 1997), modulation of the immune system (Cook *et al.*, 1993), antiatherosclerosis (Nicolosi *et al.*, 1997), antidiabetes (Houseknecht *et al.*, 1998) and decrease of human body fat mass in humans (Blankson *et al.*, 2000; Gaullier *et al.*,

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2005). CLA is a mixture of geometric and positional isomers of linoleic acid with conjugated double bonds. CLA is intermediate in the biohydrogenation of linoleic acid, which originates from the incomplete biohydrogenation of unsaturated fat by rumen function (Baumam *et al.*, 1999). However, some research work found that cows can also synthesize CLA from *trans*-11 octadecadienoic acid, another intermediate in the rumen biohydrogenation process by Δ^9 desaturase enzyme in tissue (Griinari *et al.*, 1998; Corl *et al.*, 2001).

Researchers have successfully increased the C18:2 *cis*-9, *trans*-11 CLA content of muscle lipids by feeding source of plant oils (Engle *et al.*, 2000; Mir *et al.*, 2002; Mir *et al.*, 2003; Noci *et al.*, 2007) and oilseeds (Bolte *et al.*, 2002). Thus, supplementation with fat sources rich in linoleic acid such as plant oils and oilseeds may increase the proportion of CLA in meat. The objective of the present study was to investigate the effect of soybean oil (SBO) and oil from whole cottonseed (WCS) supplementation on CLA accumulation in beef.

Materials and Methods

Animals and Feeding

Eighteen fattening cattle (9 dairy bulls and 9 beef bulls), averaging 241 ± 24 kg live weight (LW) and approximate 1 year old, were stratified by their live weights into three groups and each group was randomly assigned to one of three dietary treatments. The treatments were control (T1) (concentrated 14% CP), control and supplemented with 170 g/d SBO (T2) and control plus 170 g/d of oil from whole cottonseed (WCS) (T3). The animals were individually housed with *ad libitum* access to concentrate feed and water. All cows were individually fed concentrate and received *ad libitum* rice straw. The experiment lasted for 109 days. At the end of the experiment the animals were weighed, and 6 animals per treatment (3 dairy bulls and 3 beef bulls) were randomly sampled and transported to a commercial abattoir (505 Pokphan Co., Ltd, Thailand) and then slaughtered.

Sample Collection and Chemical Analysis

The feeds given and refusals for individual cows were weighed and collected on two consecutive days of each period (21 days). Samples were taken and dried at 60°C for 48 h. At the end of the experiment, the feed samples were performed on well-mixed subsamples and then taken for further chemical analysis. The samples were ground through 1 mm screen and analyzed for chemical analysis. Dry matter (DM) was determined by hot air oven at 60°C for 48 h. The crude protein (CP) content was determined by Kjeldahl analysis (AOAC, 1995). Ether extract (EE) was determined by using petroleum ether in a Soxtec System (AOAC, 1995). Fiber fraction, NDF and ADF were determined by using the method described by Van Soest *et al.* (1991), adapted for Fiber Analyzer. Ash content was determined by ashing in a muffle furnace at 600°C for 3 h. The chemical analysis was expressed on the basis of the final DM. Fatty acids composition of concentrates and rice straw were determined by Gas chromatography.

Fatty acid Analysis

Feed and meat fat were extracted using a modified method based on that used by Folch *et al.* (1957) and Metcalfe *et al.* (1966). Before the extraction of meat samples were thawed and each sample was chopped coarsely and blended in blender machine. 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). After this, each sample was homogenized for 2 min with 30 ml of chloroform. Then, each sample was separated with a separating funnel and 30 ml of deionized water and 5 ml of 0.58% NaCl were added. The under layer of fatty acid methyl esters (FAME) was removed and placed in 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). The procedure involved placing approximately 30 mg of the extracted oil 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 were 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 were added. The solution was transferred to a 40-ml centrifuged tube and 5 ml of hexane were 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 vial for analyzing 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 randomized completely block design using ANOVA procedure of SAS (SAS, 1996).

Results and Discussion

The chemical composition of concentrate, whole cottonseed and rice straw are reported in Table 1. Diets were control diet, control diet supplemented with 170 g/day SBO and 170 g/d of oil from WCS and rice straw. The concentration of CP in the WCS supplemented diets was the lowest. SBO supplemented diets had more EE content than other diets. The fatty acid composition of concentrates, SBO and WCS are summarized in Table 2. The concentration of C18:2 was increased by supplementing SBO and WCS in the diets. The C18:3 content in this study was not detected in all diets.

The effects of dietary treatments on performance and nutrient intake of cattle are presented in Tables 3 and 4. The final BW,

average daily gain (ADG), the Feed: Gain ratio and dry matter intakes (DMI) of experimental animals were not significantly different among treatments. The addition of WCS in diet, DMI was the lowest ($P = 0.07$) compared with other treatments (6.56 vs. 6.69, 6.78 kgDM/d), especially DMI in rice straw was also the lowest ($P = 0.12$). The crude protein intake (CPI) in concentrate was significantly lower ($P < 0.01$) in cattle which received WCS treatment than control and SBO treatments. Moreover, ether extract intake (EEI) was significantly higher ($P < 0.01$) which received SBO and WCS treatments. The energy gain was significantly increased ($P < 0.05$) when receiving WCS treatments compared to the control treatment. Similarly, Luginbuhl *et al.* (2000) showed that the addition of 16 and 24% WCS in the diets of growing male goats decreased DMI ($P < 0.04$) and CPI ($P < 0.01$) DM and NDF digestibility. Decreases in DMI can be attributable to the fact that goats may refuse or be reluctant to consume WCS during the experiment. Moore *et al.* (1986) suggested that the additions of fat were higher than 4%, even in the form of whole cottonseed, and fiber digestion decreased.

DMI and CPI decreased when WCS was supplemented to cattle, 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 increasing retention time of the digesta and limited intake. Palmquist (1995) suggested that the delay in the digestion of cotton fibers after colonization was caused by the highly crystalline structure of cotton fibers, which slow hydrolization and cellulolytic activity resulted in a limited rate of cotton linter digestion.

The results of this study are similar to other studies. For example, the addition of 3% and 6% SBO in beef heifers diets had no effect on final BW and ADG (Whitney *et al.*, 2000). Griswold *et al.* (2003) fed 4% SBO diet to Angus-Hereford finishing steers, DMI, ADG and Gain: Feed ratios were similar, and was consistent with Beaulieu *et al.* (2002) when Angus-Wagyu heifers were fed finishing diets supplemented with 5% SBO. Mir

Table 1. Chemical composition of the diets

Items	Treatments ¹			WCS	RS
	T1	T2	T3		
	% of dry matter				
DM	92.94	94.34	93.83	91.28	92.16
Ash	6.93	6.39	5.56	3.61	11.68
Crude protein	15.12	14.78	13.55	19.51	3.91
Ether extract	4.11	8.58	5.73	15.37	0.83
CF	16.66	16.46	17.02	27.39	40.89
NDF	46.46	41.38	42.37	47.76	70.96
ADF	28.23	26.49	26.26	38.49	44.87
ADL	10.59	11.17	11.65	11.84	6.90
TDN _{1X} (%) ²	62.96	71.02	66.76	78.20	45.85
DE _{1X} (Mcal/kg) ³	2.84	3.17	2.96	3.52	1.95
ME (Mcal/kgDM) ⁴	2.33	2.60	2.43	2.89	1.60
NEm (Mcal/kgDM) ⁵	1.46	1.65	1.54	1.94	0.76
NEg (Mcal/kgDM) ⁶	0.87	1.08	0.95	1.29	0.22

¹ T1 = control, T2 = soybean oil 170 g/day, T3 = 170 g/d oil from whole cottonseed, WCS = Whole cottonseed; RS = Rice straw

² $TDN_{1X} (\%) = tdNFC + tdCP + (tdFA \times 2.25) + tdNDF - 7$ (NRC, 2001)

³ $DE_{1X} (Mcal/kg) = [(tdNFC/100) \times 4.2] + [(tdNDF/100) \times 4.2] + [(tdCP/100) \times 5.6] + [(FA/100) \times 9.4] - 0.3$

⁴ $ME = 0.82 \times DE$ (NRC, 1996)

⁵ $NEm = 1.37ME - 0.138ME^2 + 0.0105ME^3 - 1.12$ (NRC, 1996)

⁶ $NEg = 1.42ME - 0.174ME^2 + 0.0122ME^3 - 1.65$ (NRC, 1996)

Table 2. Fatty acid compositions of concentrate, soybean oil (SBO) and whole cottonseed (WCS)

Items	Treatments ¹			SBO	WCS	RS
	T1	T2	T3			
	% of total fatty acid					
C12:0	36.37	18.52	6.74	0.01	0.03	4.48
C14:0	13.18	6.72	2.84	0.08	0.61	2.95
C16:0	12.13	11.29	24.68	10.42	26.58	28.05
C18:0	2.84	3.24	2.43	3.57	2.44	15.07
C18:1	18.84	19.17	15.71	19.01	13.07	14.84
C18:2	11.32	34.42	45.76	57.82	55.38	12.33
C18:3	-	-	-	7.67	0.19	2.26
Other ²	5.32	6.65	1.84	1.43	1.71	20.00

¹ T1 = control, T2 = soybean oil 170 g/day, T3 = 170 g/d oil from whole cottonseed, WCS = Whole cottonseed; RS = Rice straw

² Other = (Sum of C6:0, C8:0, C10:0, C16:1, C17:1, C20:1, C20:2, C22:0, C20:3n6, C22:1n9, C20:3n3, C23:0, C20:5n3, C24:1)

Table 3. Effects of soybean oil (SBO) and whole cottonseed (WCS) on performance and nutrient intake of cattle

Items	Treatments ¹			SEM	P-value
	T1	T2	T3		
Initial BW, kg	242.00	239.00	241.00	8.91	0.9683
Final BW, kg	296.00	305.00	312.00	8.01	0.4121
BW change, kg	54.00	66.00	70.00	4.66	0.0619
ADG, kg/d	0.50	0.61	0.65	0.04	0.0673
Feed: Gain ratio		14.21	11.31	10.66	1.0400
0.0680					
Energy gain ²	1.64 ^b	2.09 ^{ab}	2.28 ^a	0.17	0.0465
DM intake (kg/d)					
Concentrate	3.04	3.04	3.02	0.02	0.3927
Rice straw	3.65	3.74	3.54	0.08	0.1205
Total	6.69	6.78	6.56	0.08	0.0724
CP intake (g/d)					
Concentrate	460.00 ^a	450.00 ^b	409.00 ^c	2.12	0.0001
Rice straw	143.00	146.00	138.00	3.19	0.1294
Total	603.00 ^a	596.00 ^a	547.00 ^b	3.57	0.0001
EE intake (g/d)					
Concentrate	125.00 ^c	261.00 ^a	172.00 ^b	0.77	0.0001
Rice straw	30.00	31.00	29.00	0.54	0.4554
Total	155.00 ^c	292.00 ^a	201.00 ^b	0.94	0.0001

¹ T1 = Control, T2 = Control + 170 g/d soybean oil, T3 = Control + 170 g/d oil from whole cottonseed
 DM intake = Dry matter intake, CP intake = Crude protein intake, EE intake = Ether extract intake

² Energy gain was calculated by the equation $EG = (0.0493BW^{0.75}) * ADG^{1.097}$, where EG is the daily energy deposited (Mcal/d) and BW is the mean of body weight (NRC, 1984 as reviewed by NRC, 1996)

Table 4. Intake of individual fatty acids

Items	Treatments ¹		
	T1	T2	T3
	g/day		
C12:0	39.32	40.83	6.10
C14:0	14.28	14.85	26.07
C16:0	14.28	25.67	22.69
C18:0	3.52	7.58	3.05
C18:1	20.75	42.57	14.36
C18:2	12.57	75.99	40.92

¹ T1 = Control, T2 = Control + 170 g/d soybean oil, T3 = Control + 170 g/d oil from whole cottonseed

et al. (2003) reported that the performance parameters such as live weight gain, DMI, and feed: gain ratio were similar when 3 and 6% sunflower oil (SFO) supplemented diets were fed. The addition of 5.5% SFO in concentrates did not affect the final live weight and ADG (Noci *et al.*, 2005) which is similar to Noci *et al.* (2007), when 150 g/d SFO and 150 g/d linseed oil (LSO) were fed. Hristov *et al.* (2005) reported that DMI, ADG and gain: feed were unaffected by 5% safflower oil supplementation. Others have reported that the addition of oil to diet decreased DMI (Andrae *et al.*, 2000; Engle *et al.*, 2000). For example, steers fed 8.5% high oil diet caused a decrease in DMI and ADG compared with control treatment (Andrae *et al.*, 2000). Engle *et al.* (2000) also reported that final BW, ADG and DMI were decreased when fed 4% SBO. The decreased DMI in SBO added steers may have been due to the high unsaturated fatty acid content of SBO affecting rumen fermentation, and inhibiting fiber digestion (Engle *et al.*, 2000). Huerta-Leidenz *et al.* (1991), fed 15 and 30% WCS which showed no differences in the final BW, ADG and gain: feed ratios among treatments. Similar results were obtained when steers were fed 15% WCS compared with control treatments (Cranston *et al.*, 2006). Moreover, increased DMI ($P = 0.02$), ADG ($P = 0.01$) and gain: feed ($P = 0.01$) when feeding 9 and 14% whole sunflower seed (WSFS) were used. However, supplementing WSFS rich in linoleic acid did not affect DMI, ADG and gain: feed ratio (Gibb *et al.*, 2004).

The fatty acid composition of fat extracted from *Longissimus dorsi* (LD) and *Semimembranosus* (SM) muscle are presented in Tables 5 and 6. There were significant decreases ($P < 0.05$) in C12:0, C14:0 and C14:1 in LD and SM muscle when WCS was fed, in comparison with control and SBO treatments. Feeding SBO and WCS significantly decreased ($P < 0.05$) C16:0 and C16:1 in LD muscle and C16:1 in SM muscle. The present report confirms the results of Engle *et al.* (2000), who found a decrease in C16:1 content in muscle and adipose tissue but not in C16:0 content in LD muscle when steers were fed diets containing 4% SBO. Supplementation with 5% SBO, the proportion of C16:0 and C16:1

tissue lipid from loin decreased (Beaulieu *et al.*, 2002). Dhiman *et al.* (2005), reported in adipose tissue and muscle from steers fed 2% and 4% SBO were not affected the C12:0 - C16:0 content, except for C14:0 content that increased and C16:1 content decreased. Moreover, Mir *et al.* (2002) reported the decreases in C16:0 and C16:1 when 6% SFO was supplemented because of negative feedback inhibition of fatty acid synthesis by the exogenous fatty acids. Mir *et al.* (2003) showed that C16:0 and C16:1 decreased ($P < 0.05$) by 3% and 6% SFO supplementation. However, Noci *et al.* (2007) indicated that the proportion of C12:0, C14:0, and C16:0 increased in muscle tissue when cattle were supplemented with SFO and LSO (linseed oil) compared with the control treatment.

Stearic acid (C18:0) in LD and SM muscle of cattle fed WCS diet were higher ($P < 0.01$) than those fed with control and SBO diets. However, both LD and SM muscle showed no differences in C18:1, C18:2 and C18:3 contents among treatments. Other researchers have reported 10 and 12% increase in C18:0 of forequarter and loin, respectively, while there was no change C18:2 concentration in muscle by feeding 5% SBO (Beaulieu *et al.*, 2002) and 10% increased in C18:0 in adipose and muscle tissue when adding 4% SBO to steer diets compared with control and 2% SBO treatments (Dhiman *et al.*, 2005). Griswold *et al.* (2003) reported a linear increase ($P = 0.04$) in C18:2 content in tissue, while C18:3 was not affected when SBO (0, 4 and 8% SBO of diet DM) was added to steers diets. Mir *et al.* (2003) found that C18:2 in beef muscle increased by 3 and 6% SFO addition because SFO contains high levels (68%) of C18:2. Noci *et al.* (2007) reported that C18:1 and C18:2 contents increased ($P < 0.01$), while C18:0 content decreased ($P < 0.05$) by SFO and LSO supplementation.

The main objective of this study was to increase the concentration of beneficial fatty acid, especially CLA by SBO and WCS supplemented in diets because SBO and WCS are major sources of C18:2 linoleic acid (57.82 and 55.38, respectively) which is a substrate in rumen biohydrogenation. CLA content (C18:2 *cis*-9, *trans*-11) significantly increased ($P < 0.01$) by

116% in LD muscle when SBO were fed and compared with control and increased by 214% when compared with WCS treatments. In SM muscle, the addition of SBO in diet significantly increased ($P < 0.01$) CLA content by 240% when compared with control and by 386% when compared with WCS treatments. However, the *trans*-10, *cis*-12 CLA content in LD and SM muscle were not detected in this study. Many reports demonstrated that C18:2 *cis*-9, *trans*-11 CLA is a major fatty acid in tissue and little to no *trans*-10, *cis*-12 CLA was detected (Beaulieu *et al.*, 2002; Madron *et al.* 2002; Griswold *et al.*, 2003). Increasing CLA content accumulation in muscle by SBO, can be explained by the fact that SBO is rich in C18:2 and 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 intermediate that escaped from the rumen and then converted to produce CLA (C18:2 *cis*-9, *trans*-11) in tissue by the action of ∇^9 desaturase enzyme (Griinari *et al.*, 1998; Baumam *et al.*, 1999; Corl *et al.*, 2001). In this study, the supplementation of WCS did not affect CLA content in muscle although it was rich in C18:2 content. Page *et al.* (1997) expected that WCS depress stearoyl-coenzyme a desaturase enzyme 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 the possibility of the biohydro-

Table 5. Effects of soybean oil (SBO) and whole cottonseed (WCS) on fatty acid composition in *Longissimus dorsi* muscle

Items	Treatments ¹			SEM	P-value
	T1	T2	T3		
	—% of total fatty acid—				
C 12:0	1.09 ^a	0.91 ^a	0.35 ^b	0.12	0.0060
C 14:0	7.13 ^a	5.64 ^a	3.88 ^b	0.51	0.0062
C 14:1	0.94 ^a	0.69 ^{ab}	0.35 ^b	0.12	0.0253
C 15:0	0.66	0.53	0.55	0.06	0.2595
C 15:1	0.26	0.14	0.19	0.07	0.5085
C 16:0	29.37 ^a	25.92 ^b	27.63 ^{ab}	0.64	0.0154
C 16:1	3.64 ^a	2.62 ^b	2.60 ^b	0.21	0.0126
C 17:1	0.83	0.56	0.57	0.08	0.0651
C 18:0	17.51 ^c	21.06 ^b	25.21 ^a	0.99	0.0019
C 18:1	29.51	31.38	29.52	1.07	0.4025
C 18:2	4.15	5.29	4.78	0.74	0.5728
C 18:3	0.33	0.33	0.15	0.06	0.1167
≥ C 20:0	4.27	4.26	4.02	0.64	0.9533
c-9,t-11CLA	0.32 ^b	0.69 ^a	0.22 ^b	0.04	0.0001
Summation by source²					
< C16:0	10.08 ^a	7.90 ^b	5.30 ^b	0.67	0.0033
C16:0 and C16:1	33.00 ^a	28.54 ^b	30.23 ^b	0.69	0.0055
> C16:0	56.92 ^b	63.57 ^a	64.47 ^a	1.18	0.0038
Saturated fatty acid	57.05	55.03	58.57	1.62	0.3489
Unsaturated fatty acid	42.96	44.97	41.44	1.62	0.3489

¹ T1 = control, T2 = soybean oil 170 g/day, T3 = 170 g/d oil from whole cottonseed

² Fatty acids : < C16:0 represent de novo synthesized fatty acids, > C16:0 represent preformed fatty acids taken up from circulation, C16:0 fatty acids are derived from both sources

genation 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.

Researchers have successfully increased the C18:2 *cis*-9, *trans*-11 CLA content of muscle lipids by sources of oils. For example, the addition of 4% SBO increased ($P < 0.05$) C18-conjugated dienes by 45% (Engle *et al.*, 2000). Mir *et al.* (2002) found the increase ($P < 0.01$) in CLA contents in LD muscle by 339% but not muscle fat content when adding of 6% SFO in steer diets. Similarly, CLA content of muscle increased 30% and 75% ($P < 0.05$) by 3% and 6% SFO supplementation, respectively (Mir *et al.*, 2003). The addition of SFO and LSO in diets

significantly increased ($P < 0.01$) C18:2 *cis*-9, *trans*-11 CLA content in LD muscle by 144 and 73%, respectively while *trans*-10, *cis*-12 CLA content was similar (Noci *et al.*, 2007). Moreover, the addition of oilseeds increased CLA content in muscle tissue. Bolte *et al.* (2002), reported that safflower seeds added to lamb diets increased ($P < 0.01$) *cis*-9, *trans*-11 CLA content in adipose tissue and muscle.

However, many researchers have shown that CLA content in tissue did not affect when supplemented with oils. For example, Dhiman *et al.* (1999), supplementing with 4% SBO to diets did not affect the C18:2 *cis*-9, *trans*-11 CLA content of muscle lipids. Similar to Beaulieu *et al.* (2000), who reported that feeding 5%

Table 6. Effects of soybean oil (SBO) and whole cottonseed (WCS) on fatty acid composition in *Semimembranosus* muscle

Items	Treatments ¹			SEM	P-value
	T1	T2	T3		
	—% of total fatty acid—				
C 12:0	0.69 ^a	0.62 ^a	0.32 ^b	0.05	0.0011
C 14:0	5.28 ^a	4.53 ^{ab}	3.42 ^b	0.36	0.0185
C 14:1	0.68 ^a	0.63 ^a	0.20 ^b	0.12	0.0409
C 15:0	0.50	0.43	0.48	0.03	0.2388
C 15:1	0.34	ND	0.13	0.11	0.1359
C 16:0	27.92	25.64	26.85	0.82	0.2092
C 16:1	3.39 ^a	2.65 ^b	2.54 ^b	0.21	0.0407
C 17:1	1.03	0.51	0.51	0.17	0.0930
C 18:0	16.25 ^b	18.30 ^b	24.00 ^a	0.96	0.0012
C 18:1	30.85	32.94	29.81	0.94	0.1156
C 18:2	6.07	7.13	6.32	1.11	0.7868
C 18:3	0.36	0.32	0.16	0.09	0.3180
≥ C 20:0	6.45	5.61	5.15	1.18	0.7366
c-9,t-11CLA	0.20 ^b	0.68 ^a	0.14 ^b	0.04	0.0001
Summation by source²					
< C16:0	7.49 ^a	6.21 ^a	4.54 ^b	0.43	0.0041
C16:0 and C16:1	31.30	28.30	29.39	0.93	0.1268
> C16:0	61.21 ^b	65.50 ^a	66.07 ^a	1.27	0.0525
Saturated fatty acid	52.31	50.42	55.71	1.68	0.1386
Unsaturated fatty acid	47.69	49.58	44.29	1.68	0.1386

¹ T1 = control, T2 = soybean oil 170 g/day, T3 = 170 g/d oil from whole cottonseed

² Fatty acids : < C16:0 represent de novo synthesized fatty acids, > C16:0 represent preformed fatty acids taken up from circulation, C16:0 fatty acids are derived from both sources

SBO did not affect in C18:2 *cis*-9, *trans*-11 CLA content of muscle tissue, but increased *trans*-10, *cis*-12 CLA content in tissue lipid from forequarters ($P < 0.03$) and hindquarters ($P < 0.04$). Feeding 2 and 4% SBO did not affect C18:2 *cis*-9, *trans*-11 CLA content in adipose and muscle tissue, but increased *trans*-10, *cis*-12 CLA content in adipose tissue of the LD muscle (Dhiman *et al.*, 2005). However, the levels of 0%, 4%, and 8% SBO of diet DM supplemented to Angus-Hereford steer diets decreased CLA content in lean tissues (Griswold *et al.*, 2003).

The proportions of short- and medium-chain fatty acid (<16 carbons) significantly decreased ($P < 0.01$) in LD muscle by SBO and WCS supplementation compared with control treatment. However, the proportion of long-chain fatty acids (>16 carbons) significantly increased ($P < 0.01$) in the same treatments. In SM muscle, the supplementation of WCS significantly decreased ($P < 0.01$) <16 carbons, while it increased >16 carbons. Saturated fatty acid and unsaturated fatty acid were not significantly affected by supplementation of either SBO or WCS.

In conclusion, this study demonstrated that supplementation of fattening cattle with SBO and WCS were rich in C18:2 linoleic acid. There are increases in C18:2 *cis*-9, *trans*-11 CLA content of muscle tissue by SBO supplementation. The addition of WCS was not improved in CLA accumulation in muscle although it is rich in C18:2 linoleic acid. Thus, this study suggested that SBO supplementation in diets is better than WCS in accumulation of CLA in beef.

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