Effect of dietary vitamin A concentration and roasted soybean inclusion on marbling, adipose cellularity, and fatty acid composition of beef

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ABSTRACT: A feedlot trial was conducted to determine the effect of dietary vitamin A concentration and roasted soybean (SB) inclusion on carcass characteristics, adipose tissue cellularity, and muscle fatty acid composition. Angus-crossbred steers (n = 168; 295 ± 1.8 kg) were allotted to 24 pens (7 steers each). Four treatments, in a 2 × 2 factorial arrangement, were investigated: no supplemental vitamin A, no roasted soybeans (NANS); no vitamin A, roasted SB (20% of the diet on a DM basis; NASB); with supplemental (2,700 IU/kg) vitamin A, no roasted SB (WANS); and with supplemental vitamin A, roasted SB (WASB). Diets included high moisture corn, 5% corn silage, 10 to 20% supplement, and 20% roasted SB in the SB treatments on a DM basis. The calculated vitamin A concentration in the basal diet was <1,300 IU/kg of DM. Blood samples (2 steers/pen) were collected for serum vitamin A determination. Steers were slaughtered after 168 d on feed. Carcass characteristics and LM composition were determined. Fatty acid composition of LM was analyzed, and adipose cellularity in the i.m. and s.c. depots was determined. No vitamin A × SB interactions were detected ($P > 0.10$) for cattle performance, carcass composition, or muscle fatty acid composition. Low vitamin A diets (NA) did not affect ($P > 0.05$) ADG, DMI, or G:F. Quality grade tended ($P = 0.07$) to be greater in NA steers. Marbling scores and the percentage of carcasses grading ≥ Choice$^-$ were 10% greater for NA steers, although these trends were not significant ($P = 0.11$ and 0.13, respectively). Backfat thickness and yield grade were not affected ($P > 0.26$) by vitamin A supplementation. Composition of the LM was not affected ($P > 0.15$) by vitamin A or SB supplementation. Serum retinol at slaughter was 44% lower ($P < 0.01$) for steers fed NA than for steers supplemented with vitamin A (23.0 vs. 41.1 μg/dL). A vitamin A × SB interaction occurred ($P < 0.05$) for adipose cellularity in the i.m. depot; when no SB was fed, vitamin A supplementation decreased cell density and increased cell size. However, when SB was fed, vitamin A supplementation did not affect adipose cellularity. Adipose cellularity at the s.c. depot was not affected ($P > 0.18$) by vitamin A or SB treatments. Fatty acid profile of the LM was not affected by vitamin A ($P > 0.05$), but SB increased ($P < 0.05$) PUFA (7.88 vs. 4.30 g/100 g). It was concluded that feeding NA tended to increase marbling without affecting backfat and yield grade. It appeared that NA induced hyperplasia in the i.m. but not in the s.c. fat depot.

Key words: beef, marbling, roasted soybean, vitamin A

J. Anim. Sci. 2007. 85:2230–2242
doi:10.2527/jas.2006-780

INTRODUCTION

Beef carcass value is influenced by the site of fat deposition. Fat deposited in the i.m. depot increases carcass value, whereas fat deposited in the s.c. depot reduces carcass value (USDA, 1997). The mechanisms controlling the site of fat deposition within the carcass are not well understood.

Retinoic acid, a bioactive vitamin A isoform, inhibits adipocyte differentiation (Sato et al., 1980). Adipocyte differentiation is important in i.m. fat deposition because the i.m. depot grows largely by hyperplasia (Cianzio et al., 1985). Low levels of serum retinol have been correlated with increased i.m. fat deposition in Wagyu cattle (Oka et al., 1998). To our knowledge there is no information regarding the effects of feeding vitamin A in concentrations less than NRC (1996) recommendations on marbling in US cattle.

Conjugated linoleic acid is a group of positional and geometric fatty acid isomers that have multiple, beneficial, human health effects and that are found almost exclusively in ruminant products (Parodi, 1999). Increasing the content of CLA in beef may improve the demand for beef products as the perception of consumers of beef as a healthy product increases.

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Received November 27, 2006.
Accepted April 18, 2007.

Conflicting data have been published regarding the effects of retinol on stearoyl-CoA desaturase (**SCD**) enzyme activity, which is important in the endogenous synthesis of CLA (Alam and Alam, 1985; Daniel et al., 2004). Dietary vitamin A concentration may influence desaturase activity and the CLA content of beef. Feeding roasted soybeans (**SB**) increases CLA in milk (Dhiman et al., 1997), and it could increase the CLA content of beef. Feeding SB may interact with retinol to modify the fatty acid profile and the CLA content of beef.

The objectives of this experiment were to 1) determine the effect of dietary vitamin A supplementation on marbling; 2) determine the effect of feeding SB on the CLA content of beef; and 3) detect potential additive effects of dietary vitamin A and SB supplementation on marbling and CLA content of beef.

MATERIALS AND METHODS

A feedlot trial was conducted at the Ohio State University feedlot in Wooster. Animal care followed guidelines recommended in the Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching (FASS, 1998). Research procedures were approved by the Animal Care Committee of The Ohio State University.

One hundred sixty-eight Angus-crossbred steers (initial BW = 295 ± 1.8 kg) were randomly allotted to one of the following dietary treatments, in a 2 × 2 factorial arrangement: no supplemental vitamin A, no roasted soybeans (**NANS**); no vitamin A, roasted soybeans (20% of the diet on a DM basis; **NASB**); with supplemental (2,700 IU/kg) vitamin A, no roasted soybeans (**WANS**); and with supplemental vitamin A, roasted soybeans (**WASB**). To ensure that vitamin A supplementation exceeded the published requirements (NRC, 1996), 2,700 IU of vitamin A/kg of DM were added to the supplemental vitamin A treatments. Vitamin A equivalents from basal ingredients were calculated (NRC, 1996) to be < 1,300 IU/kg of DM. Diets were formulated to be isonitrogenous (Tables 1 and 2).

Steers were randomly allotted by BW in 24 pens with 7 steers each. Pens (5.4 × 5.4 m) were constructed of metal gates and cable; they had concrete, slatted floors and were located in an open-sided barn. Before initiation of the trial, all steers received a common 65% concentrate diet for 60 d.

Initial and final BW were determined using average BW measured on 2 consecutive days. Steers were weighed before feeding at 0800 and were not withheld from feed or water. Interim BW were determined at 14-d intervals.

The feeding period was divided into a backgrounding and a finishing phase. During the backgrounding phase, growth rate was limited to 1.1 kg/d to extend the duration of the trial and to allow time for hepatic vitamin A stores to be depleted. Growth rate was controlled by feeding a prescribed amount of feed to achieve a BW gain of 1.1 kg/d (NRC, 1996). The amount of feed delivered was adjusted every 14 d based on the average BW of steers in each pen. After 84 d, the steers were switched to the finishing phase feeding regimen. During the finishing phase, steers were offered feed for ad libitum access until the end of the trial. Backfat depth was determined by ultrasound (Classic Ultrasound Equipment, Classic Medical Supply, Tequesta, FL) on d 1, 84, and 154 by a certified ultrasound technician.

Feed samples were analyzed weekly for DM content to allow determination of DMI. Feed samples also were collected every 2 wk throughout the experiment and were stored frozen until analyzed for nutrient content. Composite feed samples were freeze-dried, ground to pass a 1-mm screen, and analyzed for DM, OM, N, and ether extract (**EE**; AOAC, 1996). Diet vitamin A content was calculated using the NRC (1996) tabular values for feed ingredients.

Two steers per pen were selected at the beginning of the trial, and 10 mL of blood was collected from these steers by jugular venipuncture every 28 d to determine serum vitamin A concentrations. Tubes containing blood samples were immediately wrapped in aluminum foil to avoid light damage and were kept on ice until serum was harvested. Serum was obtained by centrifuging the blood samples at 2,200 × *g* at 4°C for 10 min. Samples were frozen at –20°C until vitamin A analyses were performed. Serum vitamin A levels were analyzed according to the procedures of Weiss et al. (1995), with modifications. Briefly, the samples were extracted with hexane, and the extracted samples were dried under N_2 gas at 37°C, reconstituted with ethanol, and injected into a HPLC equipped with a reverse-phase column (Supelcosil LC-18, 25 cm × 4.6 mm; Supelco Inc., Bellefonte, PA). The solvent used was initially 75% water and 25% methanol and then was changed linearly to 100% methanol over 2 min. The flow rate was 1.8 mL/min. All-*trans* retinol obtained from Sigma Chemical Co. (St. Louis, MO) was used as the standard. All procedures were performed in the dark to avoid light damage to the retinol. The assay CV was less than 5%, and the limit of detection was 0.5 μg/dL.

Steers were slaughtered when the average BW of all animals was estimated to be 590 kg. Slaughtering was completed within a 2-wk period. Days on feed were kept constant across treatments. Hot carcass weight, backfat thickness, LM area, and KPH % were determined by trained Ohio State University personnel. Carcass yield grade was calculated (USDA, 1997). Quality grade and marbling score were determined by a USDA official. Carcass characteristics were measured after a 48-h chill.

Two steers per pen were selected for carcass sample collection. Selected steers had the BW closest to the average pen BW at slaughter. Samples from the 9th to 11th thoracic rib of the right side of the carcass were collected, deboned, ground thrice, and analyzed for moisture, N, and EE (AOAC, 1996). Final empty body composition of the edible carcass was estimated using the procedures of Hankins and Howe (1946) and the

Table 1. Diet composition (backgrounding phase)

Item	Diet[1]			
	NANS	WANS	NASB	WASB
Ingredient	% of DM			
Corn, high moisture	75.00	75.00	65.00	65.00
Soybean, whole roasted	—	—	20.00	20.00
Corn silage	5.00	5.00	5.00	5.00
Corn, ground	—	—	7.05	7.04
Soybean meal 44%	17.05	17.04	0.00	0.00
Urea	0.57	0.57	0.57	0.50
Limestone	1.35	1.35	1.35	1.35
Trace mineral salt[2]	0.46	0.46	0.46	0.46
Vitamin A, 30,000 IU/g	—	0.009	—	0.009
Vitamin D, 3,000 IU/g	0.009	0.009	0.009	0.009
Vitamin E, 44,000 IU/g	0.027	0.027	0.027	0.027
Selenium premix, 201 mg/kg	0.046	0.046	0.046	0.046
Rumensin-80[3]	0.016	0.016	0.016	0.016
Tylan-10[3]	0.046	0.046	0.046	0.046
Dynamate[4]	0.33	0.33	0.33	0.33
Animal-vegetable fat	0.10	0.10	0.10	0.10
Nutrient composition				
DM, %	70.3	70.4	72.6	72.6
OM, % of DM	95.5	95.4	95.8	95.8
CP, % of DM	15.9	15.5	16.1	16.3
NDF,[5] % of DM	10.2	10.2	11.3	11.3
Vitamin A,[5] 1,000 IU/kg of DM	0.9	3.6	1.3	4.0
Calcium,[5] % of DM	0.55	0.55	0.54	0.54
Phosphorus,[5] % of DM	0.36	0.36	0.37	0.37
Potassium,[5] % of DM	0.72	0.72	0.71	0.71
NE_m,[5] Mcal/kg of DM	2.18	2.18	2.22	2.22
NE_g,[5] Mcal/kg of DM	1.51	1.51	1.54	1.54

[1]NANS = no supplemental vitamin A, no roasted soybeans; WANS = with supplemental (2,700 IU/kg) vitamin A, no roasted soybeans; NASB = no vitamin A, with roasted soybeans; and WASB = with supplemental vitamin A, with roasted soybeans.
[2]Contained > 93% NaCl, 0.35% Zn, 0.28% Mn, 0.175% Fe, 0.035% Cu, 0.007% I, and 0.007% Co.
[3]Elanco, Greenfield, IN.
[4]Magnesium sulfate and potassium sulfate, contained 22% S, 18% K, 11% Mg (International Minerals and Chemical, Terre Haute, IN).
[5]Calculated using NRC (1996) values.

equations of Garrett and Hinman (1969). Longissimus muscle samples from the 11th to 12th thoracic rib were collected, trimmed of external fat, ground 3 times (model #4822, Hobart Co., Troy, OH), and analyzed for moisture, N, and EE content (AOAC, 1996). Additionally, fatty acids in LM and adipose tissue were extracted and methylated by alkaline transesterification and analyzed as described by Kramer et al. (1997). Methyl esters of fatty acids were separated on a 0.25 mm × 100 m, fused silica column (Supelco Inc.) using a Hewlett-Packard 5890 gas chromatograph with automated injection and data reduction (HP 3365 Chemstation software, Hewlett Packard Co., Santa Clarita, CA). Standards for the CLA isomers *c*9, *t*11; *t*10, *c*12; and *t*9, *t*11 were obtained from Matreya Inc. (Pleasant Gap, PA).

Subcutaneous and intramuscular adipose tissue was collected from the 6th to 8th thoracic rib after a 48-h chill. These samples were snap-frozen in liquid N_2 and stored at –20°C until adipose cellularity analyses were performed. To determine adipocyte size and number, frozen adipose tissue samples were fixed and sectioned at a thickness of 6 to 8 μm in a CM1900 Leica cryostat (Meyer Instruments Inc., Houston, TX). Samples were stained with a hematoxylin-eosin solution (Merck, Darmstadt, Germany) and mounted on Superfrost Plus slides (Fisher, Pittsburgh, PA). Adipocyte number and mean adipocyte diameter were determined by computerized image analysis (Image-Pro Plus v. 4.5, Media Cybernetics Inc., Silver Spring, MD). Adipocyte presence in the samples was confirmed by staining an additional slide with Sudan IV dye (Culling, 1974).

Liver retinol stores were determined in 2 steers per pen at slaughter. Liver samples were collected immediately after the steers were eviscerated, and were snap-frozen in liquid N_2, immediately placed on ice, and protected from light damage. Samples were stored at –80°C before retinol analysis. Before retinol extraction, liver samples were saponified by heating them at 70°C for 10 min with 5 mL of 50% KOH solution (Indyk, 1988). Samples were then extracted twice with hexane (10 mL each time). The extracts were combined, and 5 mL of H°O was added to allow for phase separation. After sample centrifugation at 2,200 × *g* for 10 min, a 5-mL aliquot of the extract was dried at 37°C under N_2 gas.

Table 2. Diet composition (finishing phase)

Item	Diet[1]			
	NANS	WANS	NASB	WASB
Ingredient	% of DM			
Corn, high moisture	80.00	80.00	65.00	65.00
Soybean, whole roasted	—	—	20.00	20.00
Corn silage	5.00	5.00	5.00	5.00
Corn, ground	—	—	7.62	7.61
Soybean meal 44%	11.67	11.66	—	—
Urea	0.80	0.80	—	—
Limestone	1.35	1.35	1.35	1.35
Trace mineral salt[2]	0.46	0.46	0.46	0.46
Vitamin A, 30,000 IU/g	—	0.009	—	0.009
Vitamin D, 3,000 IU/g	0.009	0.009	0.009	0.009
Vitamin E, 44,000 IU/g	0.027	0.027	0.027	0.027
Selenium, 201 mg/kg	0.046	0.046	0.046	0.046
Rumensin-80[3]	0.016	0.016	0.016	0.016
Tylan-10[3]	0.046	0.046	0.046	0.046
Potassium chloride	0.15	0.15	—	—
Dynamate[4]	0.33	0.33	0.33	0.33
Animal-vegetable fat	0.10	0.10	0.10	0.10
Nutrient composition				
DM, %	64.9	64.9	68.2	68.3
OM, % of DM	94.2	94.0	93.9	93.9
CP, % of DM	14.2	14.0	14.1	14.1
NDF,[5] % of DM	10.3	10.3	11.4	11.4
Vitamin A,[5] 1,000 IU/kg of DM	0.9	3.6	1.3	4.0
Calcium,[5] % of DM	0.53	0.53	0.54	0.54
Phosphorus,[5] % of DM	0.34	0.34	0.37	0.37
Potassium,[5] % of DM	0.70	0.70	0.71	0.71
NE_m,[5] Mcal/kg of DM	2.19	2.19	2.24	2.24
NE_g,[5] Mcal/kg of DM	1.51	1.51	1.55	1.55

[1]NANS = no supplemental vitamin A, no roasted soybeans; WANS = with supplemental (2,700 IU/kg) vitamin A, no roasted soybeans; NASB = no vitamin A, with roasted soybeans; and WASB = with supplemental vitamin A, with roasted soybeans.
[2]Contained > 93% NaCl, 0.35% Zn, 0.28% Mn, 0.175% Fe, 0.035% Cu, 0.007% I, and 0.007% Co.
[3]Elanco, Greenfield, IN.
[4]Magnesium sulfate and potassium sulfate, contained 22% S, 18% K, 11% Mg (International Minerals and Chemical, Terre Haute, IN).
[5]Calculated using NRC (1996) values.

Samples was reconstituted with ethanol and analyzed by HPLC, as described for the serum samples.

The data were analyzed statistically using the MIXED procedure (SAS Inst. Inc., Cary, NC). Serum retinol and ultrasound backfat data were analyzed as a completely randomized design with repeated measures. The model included terms for vitamin A level, SB inclusion, days on feed at the time of sample collection, and their respective interactions. The error structure used was unstructured because it resulted in the lowest Bayesian criteria. Time effects were partitioned into linear, quadratic, and cubic contrasts.

Feedlot performance, carcass characteristics, muscle fatty acid composition, and adipose cellularity data were analyzed as a completely randomized design. The model included the fixed effects of vitamin A level and SB inclusion and their interaction. For the cellularity data, fat depot (i.m. or s.c.), and its respective interactions also were included in the model. Treatment means were compared using the PDIFF statement of SAS when protected by a significant ($P < 0.05$) F-value. Pen averages were used as the experimental unit for all statistical analyses.

RESULTS AND DISCUSSION

No interactions between vitamin A level and SB inclusion were detected ($P > 0.10$) for feedlot performance, carcass characteristics, or fatty acid profile. Therefore, the main effects of dietary vitamin A concentration and SB inclusion are presented and discussed. Feed efficiency and DMI (Table 3) were similar ($P > 0.10$) between vitamin A levels. Steers fed NA diets had slightly lower (3%) ADG than those fed WA diets ($P = 0.08$). Further research is warranted to determine if this small effect of vitamin A on growth rate is biologically relevant.

Based on the performance data and the absence of clinical symptoms for steers fed no supplemental vitamin A, it is unlikely that a vitamin A deficiency occurred. The NRC (1996) recommends dietary vitamin A concentration of 2,200 IU/kg of DM for feedlot cattle.

Table 3. Main effects of dietary vitamin A concentration and roasted soybean inclusion on feedlot performance of Angus-crossbred steers

	Added vitamin A, IU/kg		Roasted soybean, %			*P*-value[1]		
Item	0	2,700	0	20	SEM	VA	SB	VA × SB
BW, kg								
Initial	293.1	293.1	292.9	293.2	0.30	0.98	0.45	0.43
Backgrounding[2]	396.9	397.3	397.9	396.4	2.0	0.89	0.61	0.21
Final	574.6	583.0	583.1	574.5	3.2	0.08	0.07	0.43
ADG, kg/d								
Backgrounding	1.236	1.242	1.249	1.228	0.025	0.87	0.57	0.27
Finishing	2.027	2.113	2.110	2.030	0.037	0.11	0.14	0.90
Total	1.640	1.689	1.690	1.639	0.019	0.08	0.07	0.41
DMI, kg/d								
Backgrounding	5.775	5.783	5.842	5.717	0.016	0.72	<0.01	0.28
Finishing	9.57	9.65	10.02	9.20	0.12	0.62	<0.01	0.37
Total	7.78	7.83	8.06	7.55	0.060	0.63	<0.01	0.29
G:F, g/kg								
Backgrounding	214.7	215.2	214.7	215.2	4.0	0.93	0.93	0.27
Finishing	212.2	219.4	210.5	221.1	3.0	0.10	0.02	0.57
Total	210.9	215.6	209.7	216.7	2.5	0.21	0.06	0.89

[1]VA = vitamin A; SB = roasted soybean.
[2]Limit-fed for 84 d.

This recommendation was established in 1976 (NRC, 1976). The recommendation was based on sparse published information (Perry et al., 1965, 1968; Eaton et al., 1972), and no reports on the requirements of growing cattle have been published since that time. High moisture corn was fed in this experiment because it was assumed to contain insignificant amounts of vitamin A precursors as a result of carotenoid degradation during storage of high moisture corn (NRC, 1996). However, no data have been published reporting changes in corn carotenoid content during the fermentative process that accompanies storage of high moisture corn. Further research is warranted to determine whether feeding diets without supplemental vitamin A during the finishing period affects cattle health and immune status. Accurate characterization of provitamin A carotenoids in feed ingredients also is required to precisely define the actual vitamin A requirement of feedlot cattle.

Roasted soybean inclusion reduced ($P < 0.05$) DMI and increased ($P = 0.06$) feed efficiency for the total trial reflecting the greater energy density of the diet when roasted soybeans were fed. Average daily gain tended to be reduced only slightly with SB, suggesting that 20% SB did not change energy intake by cattle.

Hot carcass weight, carcass characteristics (except KPH %), and USDA quality and yield grades (Table 4) were not affected by SB inclusion (all $P > 0.15$). Roasted soybean inclusion tended to increase ($P = 0.07$) KPH % from 1.93 to 2.07. Hot carcass weight was similar ($P = 0.58$) between NA and WA confirming that the vitamin A effects on cattle growth were negligible. Carcass quality grade tended ($P = 0.07$) to be improved in NA because marbling scores were increased from small to modest in this group. Pyatt et al. (2005) reported that feeding low vitamin A diets did not increase marbling in steers and heifers. However, in those experiments low vitamin A diets were not below NRC (1996) requirements as opposed to the low vitamin A diets fed in this experiment. Thus, it can be speculated that in order to increase marbling, vitamin A levels in the diet need to be below NRC (1996) recommendations.

As expected, ultrasound backfat depth increased over time ($P < 0.01$), but dietary treatments did not affect the rate at which backfat was deposited ($P > 0.05$, data not shown). At slaughter, backfat ($P > 0.05$) did not differ and visceral fat (% KPH; $P < 0.05$) was reduced with NA. Carcass yield grade was not affected ($P = 0.26$) by dietary vitamin A concentration.

Feeding NA numerically increased the percentage of carcasses grading Choice$^-$ or above (89.5 vs. 81.8%, $P = 0.12$) and those grading Choice^o or above (52.4 vs. 45.7%, $P = 0.32$). Although these differences were not statistically significant, they may have important implications for the beef industry. Numerous branded beef programs offer economic incentives for carcasses grading ≥ Choice^o (USDA Agricultural Marketing Service, 2006). To illustrate the importance of these findings, utilizing a grid-pricing formula published by the USDA Market News Service for the week of July 11, 2005 (USDA, 2005), NA steers were valued approximately $8.00/animal more than WA steers.

Edible carcass and LM composition data are presented in Table 5. Composition of edible carcass and LM were not affected by vitamin A or SB ($P > 0.10$). Edible carcass EE content was not affected ($P = 0.22$) by vitamin A. This was expected based on the similar USDA yield grade of NA and WA steers. Considering the trend for increased marbling scores and carcass quality grades in NA steers, it was expected that the EE of longissimus muscle would be greater in NA than in WA steers. However, the EE content in LM of NA and WA steers was almost identical. Marbling score

Table 4. Main effects of dietary vitamin A concentration and roasted soybean on carcass characteristics of Angus-crossbred steers

	Added vitamin A, IU/kg		Roasted soybean, %			*P*-value[1]		
Item	0	2,700	0	20	SEM	VA	SB	VA × SB
HCW, kg	352.1	354.9	354.5	352.5	3.6	0.58	0.70	0.33
Backfat, cm	1.33	1.34	1.30	1.37	0.051	0.83	0.38	0.50
Dressing %	61.35	60.77	60.82	61.30	0.3	0.13	0.21	0.40
Marbling score[2]	607	581	588	600	11	0.11	0.46	0.61
LM area, cm^2	80.5	79.5	80.6	79.4	1.1	0.54	0.43	0.94
KPH, %	1.93	2.08	1.93	2.07	0.050	0.05	0.07	0.25
Yield grade	3.15	3.26	3.13	3.27	0.067	0.26	0.15	0.44
Quality grade[3]	5.63	5.33	5.48	5.48	0.11	0.07	1.00	0.84
Select, %	10.5	17.9	14.3	14.1	3.4	0.14	0.97	0.19
$Choice^-$, %	36.5	35.6	36.7	35.4	5.1	0.89	0.86	0.30
$Choice^o$,%	36.5	33.7	35.6	34.6	5.6	0.72	0.90	0.61
$Choice^+$, %	3.7	5.6	4.2	5.2	2.8	0.64	0.82	0.79
Prime, %	11.3	5.8	7.8	9.3	3.3	0.26	0.75	0.47
≥ $Choice^-$, %	89.5	81.8	85.7	85.6	3.4	0.12	0.99	0.17
≥ $Choice^o$, %	52.4	45.7	48.5	49.7	4.7	0.32	0.86	0.96
Carcass value $/45 kg[4]	135.47	134.41	134.88	135.00	4.1	0.08	0.85	0.60

[1]VA = vitamin A; SB = roasted soybean.
[2]Slight = 400 to 499, small = 500 to 599, and modest = 600 to 699.
[3]4 = Select, 5 = $Choice^-$, 6 = $Choice^o$, 7 = $Choice^+$, and 8 = $Prime^-$.
[4]Based on the grid price formula published by the USDA Market News Service for the week of 11 July 2005. Base price of $135.00/45 kg ($Choice^-$, yield grade 3.0); premiums (per 45 kg), Prime = $8.00, $Choice^{o,+}$ = $1.00; discounts (per 45 kg), Select = ($8.00); yield grade 4.0 to 4.9 = ($13.90).

and carcass USDA quality grade were determined in all experimental animals, whereas muscle composition analyses were performed in a subset of steers (2/pen). It is possible that our ability to confirm the effects of vitamin A on i.m. fat deposition was compromised by reducing the number of samples analyzed.

Interactions of days on feed with vitamin A and SB for serum retinol concentrations were partitioned into linear, quadratic, and cubic contrasts; these contrasts were not significant (P = 0.32, 0.92, and 0.34, respectively). Thus, only the interactions of vitamin A × days on feed and of SB × days on feed are discussed. Roasted soybean inclusion did not reduce serum retinol over time (linear contrast, $P > 0.05$; data not shown), and at the end of the experiment, serum retinol was similar between NS and SB (NS = 34.2 and SB = 29.9 μg/dL, $P > 0.05$). Dietary vitamin A concentration affected serum retinol over time (linear contrast, $P < 0.01$; Figure 1). Serum retinol of WA steers was maintained or increased as days on feed increased, whereas NA steers had significantly lower serum retinol levels than WA steers from d 56 to 168. Differences in serum retinol levels between WA and NA steers increased over time, and at the end of the experiment WA steers had almost

Table 5. Main effects of dietary vitamin A concentration and roasted soybean inclusion on edible carcass and LM composition of Angus-crossbred steers

	Added vitamin A, IU/kg		Roasted soybean, %			*P*-value[1]		
Item	0	2,700	0	20	SEM	VA	SB	VA × SB
Edible carcass[2]								
DM, %	50.54	51.59	50.54	51.58	0.63	0.26	0.26	0.91
OM, %	98.41	98.45	98.43	98.44	0.13	0.83	0.97	0.18
CP, %	14.27	13.95	14.07	14.15	0.16	0.18	0.70	0.74
Ether extract, %	34.7	36.1	34.9	35.9	0.79	0.22	0.40	0.70
LM[2]								
DM, %	28.95	28.56	28.41	29.10	0.29	0.35	0.11	0.78
OM, %	97.247	97.295	97.303	97.238	0.031	0.28	0.15	0.64
CP, %	20.48	20.17	20.08	20.57	0.24	0.37	0.17	0.63
Ether extract, %	6.52	6.23	6.23	6.52	0.44	0.64	0.65	0.95

[1]VA = vitamin A; SB = roasted soybean.
[2]As-is basis.

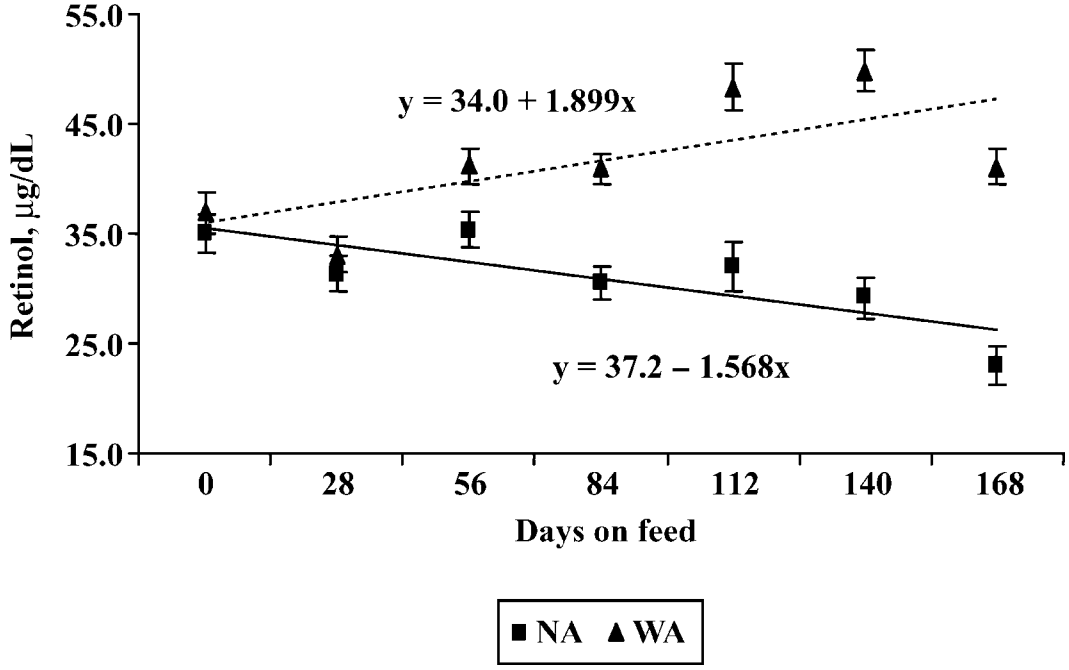

Figure 1. Effect of dietary vitamin A concentration and days on feed on serum retinol of Angus-crossbred steers. NA = no supplemental vitamin A; WA = with supplemental vitamin A (2,700 IU/kg of DM).

twice the serum retinol as NA steers (WA = 41.1 vs. NA = 23.1 μg/dL, $P < 0.01$). Liver retinol content at slaughter confirmed the serum retinol observations. Steers fed NA had significantly lower retinol stores in the liver than WA steers (6.5 vs. 77.8 μg/g, $P < 0.01$). Roasted soybean inclusion did not affect hepatic vitamin A stores (NS = 42.4 vs. SB = 41.9 μg/g, $P > 0.10$). It was concluded that vitamin A status (liver and serum concentrations) in NA steers was reduced to levels that appeared to enhance marbling and carcass quality grade without affecting animal health or performance.

Retinol is stored in the liver and released to the circulation to maintain adequate vitamin A for body functions. Serum retinol concentrations are relatively constant unless hepatic stores are depleted, at which point a decline in serum retinol is observed (Blaner and Olson, 1994). Scarce information is available about the depletion kinetics of retinol in feedlot cattle. Further research in this area is advised because it is likely that hepatic vitamin A stores need to be depleted in order to observe the effects of feeding low vitamin A diets on marbling scores.

Japanese authors reported that serum retinol and the intramuscular fat content in cattle are correlated (Torii et al., 1996; Adachi et al., 1999). Pyatt and Berger (2005) hypothesized that seasonal variations of beef carcass quality grades in the United States may be explained, at least partially, by intake of vitamin A prior the feedlot phase. Marbling scores and serum retinol at slaughter observed in our experiment were negatively correlated (–0.45, $P < 0.05$). The regression of these 2 variables seems to confirm those Japanese reports: $y = 646.6 - 1.64x$ ($P = 0.03$), where y = marbling score, and x = serum retinol on d 168 (μg/dL). Conversely, the regression of serum retinol at slaughter and intramuscular EE was not significant ($P > 0.05$). It is likely that the reduced number of observations for intramuscular EE (n = 48) compared with marbling scores and carcass quality grades (n = 168) caused this discrepancy. Alternatively, serum retinol at slaughter may not be a good predictor of the i.m. fat content in feedlot steers as some authors have suggested (Matsuda et al., 2004).

A vitamin A × SB × adipose depot interaction ($P < 0.05$) for adipocyte density and cell size distribution was detected. Dietary treatments affected the cellularity of the i.m. fat depot but not that of the s.c. depot (Tables 6 and 7, respectively). This observation provides evidence that dietary management could be used to specifically affect the i.m. depot without affecting the s.c. depot.

In the i.m. fat depot, a significant vitamin A × SB interaction was observed ($P < 0.03$) for adipocyte cellularity. When SB was not included, NA increased adipocyte density and reduced adipocyte size (NANS vs. WANS, $P < 0.05$) suggesting that NA increased adipocyte differentiation. The WASB steers had similar adipocyte density and size as NANS and NASB steers ($P > 0.05$), suggesting that when SB was fed, increased differentiation occurred regardless of dietary vitamin A concentration. The apparent stimulatory effect of SB on adipocyte differentiation has not been previously reported. It is possible that fatty acids or other components of SB (such as estrogenic compounds) stimulated adipocyte differentiation. It has been reported that many fatty acids can act as ligands of the proadipogenic peroxisome proliferator-activated receptor gamma

Table 6. Effects of dietary vitamin A concentration and roasted soybean inclusion on i.m. adipose tissue cellularity of Angus-crossbred steers

	Diet[1]					*P*-value[2]		
Item[3]	NANS	WANS	NASB	WASB	SEM	VA	SB	VA × SB
Cell number/mm^2	156.6^x	119.0^y	154.0^x	156.4^x	8.8	0.06	0.06	0.03
Mean diameter, μm	85.8^x	97.8^y	87.7^x	86.3^x	3.0	0.09	0.12	0.04
Cells ≤ 50 μm, % of total cells	26.8	23.2	27.5	27.2	2.5	0.44	0.35	0.51
Cells > 50 ≤ 100 μm, % of total cells	44.5^x	34.8^y	44.3^x	45.7^x	2.6	0.13	0.06	0.05
Cells > 100 μm, % of total cells	28.7^x	42.0^y	28.2^x	27.1^x	3.1	0.06	0.02	0.03

^{x,y}Within a row, means without a common superscript letter differ ($P < 0.05$).
[1]NANS = No supplemental vitamin A, no roasted soybeans; WANS = with supplemental (2,700 IU/kg) vitamin A, no roasted soybeans; NASB = no vitamin A, with roasted soybeans; and WASB = with supplemental vitamin A, with roasted soybeans.
[2]VA = vitamin A; SB = roasted soybean.
[3]Measured in hematoxylin-eosin-stained adipose tissue slides (>1.5 mm^2 per sample).

(Ding et al., 2003; Lee et al., 2003). Further research is advised to determine the potential of utilizing SB as an adipocyte-differentiation regulator.

To further characterize the vitamin A × SB effects on i.m. adipocyte differentiation, the adipocyte size distribution pattern is presented in Figure 2. Steers fed WANS had a greater proportion of cells with a mean diameter of 110 μm or more, whereas the other 3 treatments had more of the smaller cells ($P < 0.05$). Steers fed NANS, NASB, and WASB had approximately 10% of the measured cells with a mean diameter of 80 μm, compared with 7% in the WANS steers ($P < 0.05$). This difference has biological relevance; it has been reported that when adipocytes reach a mean diameter of 80 μm, a signal is triggered for a new population of adipocytes to differentiate (Schoonmaker et al., 2004), thus stimulating hyperplasia in the depot.

It was expected that hyperplasia would lead to enlargement in the fat depot. Steers fed diets without vitamin A supplementation had a greater i.m. fat depot as suggested by the trend for greater marbling scores and USDA quality grades. Interestingly, when vitamin A-supplemented diets were fed, SB inclusion also induced changes in adipocyte cellularity suggesting hyperplasia. However, the size of the depot remained unchanged based on the carcass data. Thus, feeding supplemental vitamin A may have counteracted the hyperplasic stimulatory effect of SB. Further research is advised to investigate the effects of SB inclusion in the diet on adipose cellularity and marbling in beef.

In the s.c. fat depot, adipocyte cellularity was not affected ($P > 0.05$) by dietary treatment. Adipocyte size distribution pattern was similar among treatments (Figure 3). These data support the carcass data, reflecting that dietary vitamin A concentration does not affect s.c. fat deposition. The presumed mechanism of action of low vitamin A diets is to release the inhibition for adipocyte differentiation (Villaroya, 1998; Ribot et al., 2001). This may affect the i.m. depot in which hyperplasia takes place during the finishing period (Albrecht et al., 2006). However, when cattle are placed in the feedlot, most hyperplasia in the s.c. fat depot is completed, and this depot grows mainly by hypertrophy, or the enlargement of existing fat cells (Hood and Allen, 1973). The results of our experiment seem to confirm this observation.

The vitamin A × SB interaction for muscle total CLA and desaturase activity index (Table 8) was not significant ($P > 0.10$). The desaturase activity index is an indirect measurement that reflects changes in the activ-

Table 7. Main effects of dietary vitamin A concentration and roasted soybean inclusion on subcutaneous adipose tissue cellularity of Angus-crossbred steers

	Added vitamin A, IU/kg		Roasted soybean, %			*P*-value[1]		
Item[2]	0	2,700	0	20	SEM	VA	SB	VA × SB
Cell number/mm^2	62.0	63.1	61.5	63.6	2.63	0.78	0.57	0.89
Mean diameter, μm	136.8	137.9	138.5	136.2	2.9	0.80	0.59	0.92
Cells ≤ 50 μm, % of total cells	8.5	7.7	7.3	8.8	0.72	0.46	0.15	0.18
Cells > 50 ≤ 100 μm, % of total cells	24.6	23.0	24.1	23.5	1.5	0.46	0.76	0.83
Cells > 100 μm, % of total cells	67.0	69.4	68.6	67.7	1.8	0.35	0.74	0.71
Cells ≤ 100 μm, % of total cells	33.1	30.6	31.4	32.3	1.8	0.35	0.74	0.71
Cells > 100 ≤ 200 μm, % of total cells	60.1	62.9	62.5	60.5	1.8	0.28	0.43	0.76
Cells > 200 μm, % of total cells	6.9	6.5	6.1	7.3	1.3	0.84	0.53	0.94

[1]VA = vitamin A; SB = roasted soybean.
[2]Measured in hematoxylin-eosin-stained adipose tissue slides (>1.5 mm^2 per sample).

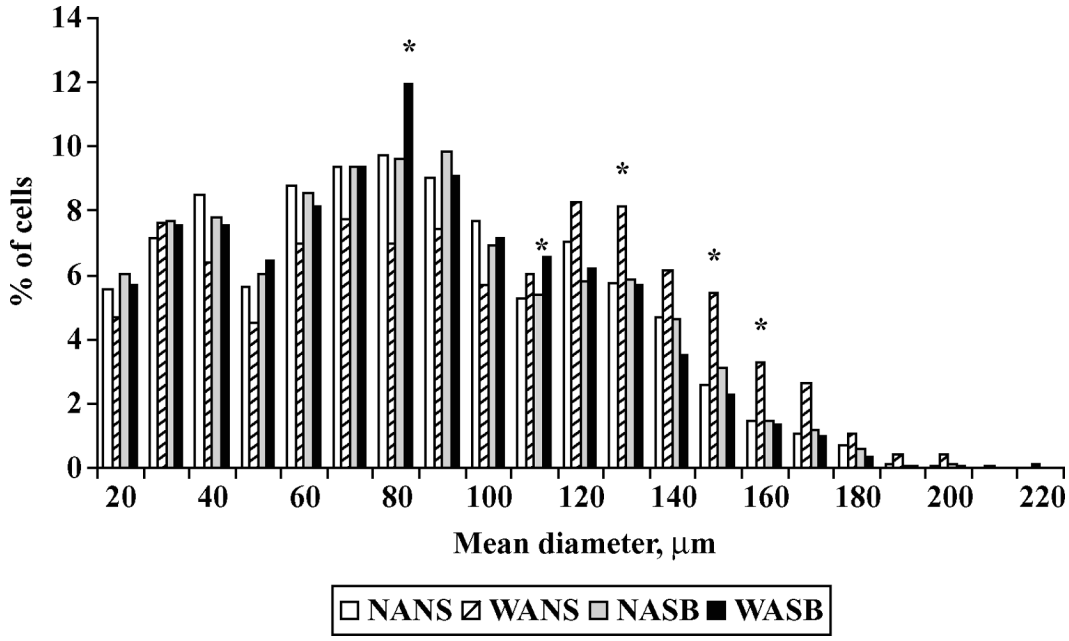

Figure 2. Effect of dietary vitamin A concentration and soybean inclusion on the intramuscular adipocyte size distribution of Angus-crossbred steers. NANS = no supplemental vitamin A, no roasted soybeans; WANS = with supplemental (2,700 IU/kg) vitamin A, no roasted soybeans; NASB = no vitamin A, with roasted soybeans; and WASB = with supplemental vitamin A, with roasted soybeans. *Vitamin A × SB interaction, $P < 0.05$.

ity of SCD based on substrate to product ratios (Corl et al., 2001; Smith et al., 2002). It was hypothesized that dietary vitamin A concentration and SB inclusion would interact to affect SCD activity, thus modifying the muscle fatty acid profile. Our results do not support this hypothesis. Therefore, vitamin A and SB main effects are presented (Table 8) and discussed. Feeding NA did not affect ($P > 0.10$) the concentration of total

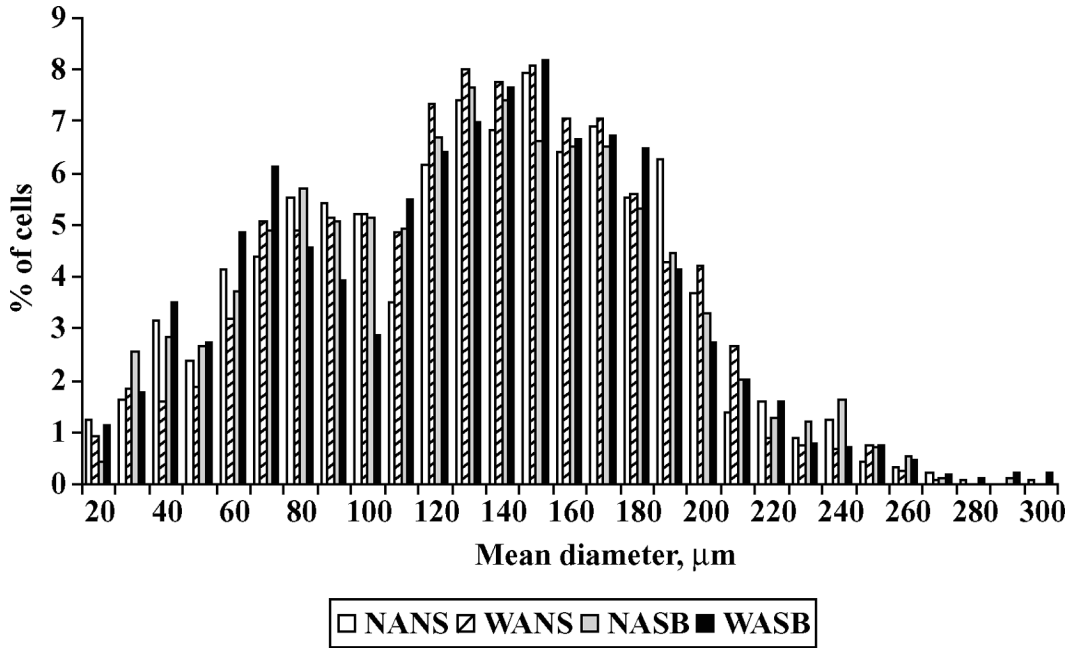

Figure 3. Effect of vitamin A level and soybean inclusion on the subcutaneous adipocyte size distribution of Angus-crossbred steers. NANS = no supplemental vitamin A, no roasted soybeans; WANS = with supplemental (2,700 IU/kg) vitamin A, no roasted soybeans; NASB = no vitamin A, with roasted soybeans; and WASB = with supplemental vitamin A, with roasted soybeans.

Table 8. Main effects of dietary vitamin A concentration and roasted soybean inclusion on LM fatty acid composition of Angus-crossbred steers

	Added vitamin A, IU/kg		Roasted soybean, %			*P*-value[1]		
Item	0	2,700	0	20	SEM	VA	SB	VA × SB
Fatty acid	g/100 g of total fatty acids							
10:0	0.066	0.063	0.063	0.067	0.0022	0.43	0.19	0.19
12:0	0.056	0.054	0.053	0.058	0.0054	0.83	0.52	0.39
14:0	3.04	3.08	3.04	3.08	0.089	0.76	0.77	0.51
14:1	0.557	0.587	0.590	0.574	0.036	0.86	0.76	0.69
15:0	0.51	0.48	0.52	0.48	0.18	0.29	0.18	0.90
16:0	27.13	26.91	27.39	26.65	0.25	0.53	0.05	0.99
16:1	3.09	3.23	3.34	2.98	0.10	0.33	0.02	0.45
17:0	1.518	1.385	1.527	1.376	0.046	0.06	0.03	0.41
18:0	13.43	13.50	13.79	13.14	0.26	0.85	0.09	0.65
18:1, *t*-10	3.97	2.54	2.18	4.33	0.46	0.04	<0.01	0.01
18:1, *t*-11	0.387	0.399	0.348	0.437	0.035	0.81	0.09	0.35
18:1, *t*-other[2]	2.64	3.49	3.04	3.08	0.49	0.23	0.95	0.26
18:1, *c*-9	34.52	35.40	37.14	32.78	0.45	0.18	<0.01	0.12
18:1, *c*-11	1.703	1.746	1.827	1.621	0.022	0.18	<0.01	0.57
18:2	5.70	5.64	3.77	7.57	0.29	0.90	<0.01	0.71
20:0	0.0817	0.0800	0.0800	0.0817	0.0017	0.51	0.51	0.51
18:2, CLA *c*9*t*11	0.249	0.268	0.237	0.281	0.031	0.66	0.32	0.80
18:2, CLA *t*10*c*12	0.108	0.094	0.097	0.106	0.016	0.53	0.68	0.74
20:1	0.342	0.289	0.154	0.477	0.046	0.43	<0.01	0.36
20:2	0.053	0.049	0.038	0.066	0.0054	0.59	<0.01	0.59
22:0	0.048	0.047	0.034	0.062	0.016	0.97	0.24	0.97
20:3n-6	0.013	0.040	0.036	0.017	0.014	0.20	0.37	0.80
20:3n-3	0.058	0.084	0.037	0.105	0.018	0.32	0.02	0.77
20:4	0.173	0.152	0.300	0.025	0.022	0.50	<0.01	0.40
20:5	0.043	0.036	0.044	0.035	0.058	0.37	0.27	0.27
22:1	0.386	0.236	0.210	0.412	0.071	0.15	0.06	0.94
22:2	0.017	0.017	0.012	0.022	0.0037	1.0	0.07	1.0
24:0	0.042	0.034	0.047	0.029	0.0052	0.31	0.03	0.74
24:1	0.014	0.019	0.011	0.023	0.0038	0.37	0.04	0.23
22:6	0.042	0.043	0.041	0.043	0.010	0.95	0.86	0.26
Total CLA	0.357	0.363	0.333	0.387	0.043	0.94	0.38	0.79
Desaturase index[3]	0.4742	0.4800	0.4883	0.4658	0.0032	0.21	<0.01	0.21
MUFA[4]	47.62	47.93	48.84	46.71	0.32	0.50	<0.01	1.0
PUFA[5]	6.09	6.06	4.30	7.88	0.31	0.94	<0.01	0.78
SFA[6]	45.93	45.64	46.55	45.02	0.30	0.50	<0.01	0.74

[1]VA = vitamin A; SB = roasted soybean.
[2]18:1, *t*6, 7, 8, 9, and 12.
[3](16:1 + 18:1, *c*-9 + 18:1, *c*-11)/(14:0 + 16:0 + 18:0 + 16:1 + 18:1, *c*-9 + 18:1, *c*-11).
[4]14:1 + 16:1 + 18:1, *t*-10 + 18:1, *t*-11 + 18:1, *t*-other + 18:1, *c*-9 + 18:1, *c*-11 + 20:1 + 22:1 + 24:1.
[5]18:2 + 18:3, n-6 + 18:3, n-3 + 20:2 + 20:3, n-6 + 20:3, n-3 + 20:4 + 20:5 + 22:2 + 22:6.
[6]10:0 + 12:0 + 14:0 + 15:0 + 16:0 + 17:0 + 18:0 + 20:0 + 22:0 + 24:0.

CLA in muscle fatty acids. The activity of SCD appeared not to be affected ($P > 0.05$) by supplemental vitamin A, based on the similar activity index values when NA and WA diets were fed. Despite the trend for greater marbling in NA steers, when CLA were expressed as mg/100 g of muscle, dietary vitamin A did not affect ($P = 0.68$) CLA concentration in muscle (NA = 42.3 vs. WA = 39.2 mg of CLA/100 g of muscle).

The effect of SB was not significant for total muscle CLA ($P > 0.05$). A small but significant ($P < 0.05$) reduction in the desaturase index when SB was included was observed due to decreases in the concentration of C16:1 ($P < 0.02$) and *cis*-9 C18:1 ($P < 0.01$) that were larger than the corresponding decrease in C16:0 ($P < 0.05$) and C18:0 ($P < 0.09$) when SB was fed. Polyunsaturated fatty acids were almost doubled by SB inclusion ($P < 0.05$), and this increase was accompanied by a decrease in total MUFA and SFA ($P < 0.01$). The increase in PUFA concentration may have been partly responsible for the slight inhibition of desaturase activity with SB (Kouba et al., 2003). Proportions of SFA in muscle were slightly reduced with SB (46.55 vs. 45.02%; $P < 0.01$). Thus, SB increased muscle PUFA and reduced MUFA and saturated fats without affecting muscle CLA.

Most rumenic acid is synthesized endogenously in animal tissues by the desaturation of vaccenic acid (Palmquist et al., 2004). Even though the SCD activity was not affected by the vitamin A × SB interaction, the rumenic acid to vaccenic acid ratio tended ($P = 0.09$) to be affected by a dietary vitamin A concentration × SB

Table 9. Main effects of dietary vitamin A concentration and roasted soybean inclusion on subcutaneous adipose tissue fatty acid composition of Angus-crossbred steers

	Added vitamin A, IU/kg		Roasted soybean, %			*P*-value[1]		
Item	0	2,700	0	20	SEM	VA	SB	VA × SB
Fatty acid	g/100 g of total fatty acids							
10:0	0.051	0.042	0.044	0.048	0.0043	0.08	0.08	0.04
12:0	0.067	0.071	0.064	0.074	0.0051	0.53	0.21	0.07
14:0	2.97	3.10	2.93	3.15	0.35	0.71	0.52	0.32
14:1	0.53	0.53	0.54	0.52	0.14	1.00	0.88	0.95
15:0	0.560	0.562	0.512	0.610	0.074	1.00	0.20	0.67
16:0	26.25	26.32	26.66	25.91	0.52	0.90	0.16	0.24
16:1	4.04	3.89	4.32	3.61	0.21	0.50	<0.01	0.72
17:0	1.42	1.42	1.60	1.24	0.11	0.96	<0.01	0.62
18:0	11.86	12.43	11.93	12.35	0.58	0.34	0.48	0.85
18:1, *t*-10[2]	3.60	3.24	2.84	4.00	0.75	0.63	0.14	0.94
18:1, *t*-11	0.46	0.63	0.50	0.59	0.073	0.04	0.23	0.80
18:1, *t*-other[3]	4.27	3.00	3.30	3.98	0.75	0.11	0.38	0.59
18:1, total *trans*	8.33	6.86	6.63	8.56	0.71	0.05	0.01	0.50
18:1, *c*-9	36.6	37.8	39.1	35.3	1.1	0.29	<0.01	0.16
18:1, *c*-11	1.96	1.82	2.07	1.71	0.11	0.21	<0.01	0.66
18:2	4.28	4.28	2.9	5.65	0.40	1.00	<0.01	0.31
20:0	0.04	0.06	0.05	0.06	0.016	0.23	0.42	0.76
18:2, CLA *c*9*t*11	0.37	0.46	0.40	0.44	0.057	0.12	0.47	0.26
18:2, CLA *t*10*c*12	0.04	0.06	0.04	0.06	0.016	0.46	0.35	0.58
18:2, other CLA	0.10	0.10	0.01	0.18	0.064	0.95	0.01	0.89
18:3n-6	0.25	0.24	0.13	0.36	0.054	0.80	<0.01	0.89
18:3n-3	0.42	0.48	0.36	0.53	0.076	0.45	0.04	0.44
20:1	0.08	0.11	0.10	0.09	0.035	0.34	0.83	0.29
20:2	0.04	0.05	0.03	0.06	0.012	0.83	0.05	0.94
22:0	0.093	0.087	0.090	0.091	0.0080	0.55	0.33	1.00
20:3n-6	0.041	0.038	0.040	0.039	0.0061	1.00	0.77	0.38
20:3n-3	0.03	0.04	0.03	0.04	0.013	0.80	0.25	0.70
20:4	0.02	0.03	0.02	0.03	0.0060	0.02	0.51	0.89
22:1	0.01	0.00	0.00	0.01	0.0051	0.45	0.45	0.88
24:0	0.01	0.05	0.02	0.04	0.016	0.03	0.11	0.11
24:1	0.02	0.02	0.03	0.02	0.0069	1.00	0.23	0.63
22:6	0.32	0.32	0.35	0.29	0.039	0.92	0.11	0.29
Total CLA	0.51	0.62	0.45	0.68	0.14	0.10	0.27	0.63
16:1/16:0	0.13	0.13	0.14	0.12	0.050	0.44	0.01	0.64
Desaturase index[4]	0.51	0.51	0.53	0.50	0.0099	0.79	0.01	0.11
MUFA[5]	48.9	47.4	50.2	46.1	1.3	0.27	0.01	0.34
PUFA[6]	5.24	5.27	3.70	6.82	0.44	0.96	<0.01	0.27
SFA[7]	42.9	43.4	43.3	43.0	0.68	0.47	0.65	0.21

[1]VA = vitamin A; SB = roasted soybean.
[2]Includes small amounts of 18:1, *t*9.
[3]18:1, *t*6, 7, 8, and 12.
[4](16:1 + 18:1, *c*-9 + 18:1, *c*-11)/(14:0 + 16:0 + 18:0 + 16:1 + 18:1, *c*-9 + 18:1, *c*-11).
[5]14:1 + 16:1 + 18:1, *t*-10 + 18:1, *t*-11 + 18:1, *t*-other + 18:1, *c*-9 + 18:1, *c*-11 + 20:1 + 22:1 + 24:1.
[6]18:2 + 18:3, n-6 + 18:3, n-3 + 20:2 + 20:3, n-6 + 20:3, n-3 + 20:4 + 20:5 + 22:2 + 22:6.
[7]10:0 + 12:0 + 14:0 + 15:0 + 16:0 + 17:0 + 18:0 + 20:0 + 22:0 + 24:0.

interaction. When SB was included, feeding NA diets tended ($P = 0.10$) to reduce the rumenic to vaccenic acid ratio (NASB = 0.33 vs. WASB = 0.43), suggesting that vitamin A supplementation may have reduced SCD activity. Lucchi et al. (2005) reported that human patients with reduced serum retinol had increased serum CLA suggesting reduced desaturase activity. When no SB was included, dietary vitamin A concentration did not affect this ratio (NANS = 0.42 vs. WANS = 0.38; $P = 0.44$). However, contrary to our hypothesis, rumenic acid level in muscle was not affected by the vitamin A × SB interaction or by the vitamin A and SB main effects (all $P > 0.10$). It remains unclear whether dietary vitamin A concentration and SB inclusion affect SCD activity.

A significant vitamin A × SB interaction ($P < 0.01$) was observed for the *trans*-10 C18:1 fatty acid content in muscle. Steers fed NASB had more than twice the *trans*-10 C18:1 than did the other treatments (NASB = 6.0 vs. NANS 2.0, WANS 2.4, and WASB 2.7; $P < 0.01$). The *trans*-10 C18:1 isomer appears in the rumen during the biohydrogenation process of linoleic acid to stearic acid. This isomer is commonly found when high-concentrate, low-forage diets such as the ones used in this

experiment are fed (Griinari and Bauman, 1999; Madron et al., 2002). It was expected that with SB inclusion, an increase in fatty acids intermediate in the linoleic acid biohydrogenation pathway (e.g., CLA) would be observed. However, the lack of response in *trans*-10 C18:1 in the WASB treatment was not expected. To our knowledge no data have been reported regarding the effects of vitamin A supplementation on rumen biohydrogenation. The vitamin A × SB interaction on *trans*-10 C18:1 suggests that dietary vitamin A level may affect *cis*-9, *cis*-12 C18:2 biohydrogenation in the rumen when SB are fed. However, the absence of a significant vitamin A × SB interaction in other biohydrogenation intermediates of *cis*-9, *cis*-12 C18:2 (e.g., *trans*-11 C18:1 and *trans*-10, *cis*-12 C18:2) and the lack of response of these intermediates to dietary vitamin A concentration (vitamin A main effect, $P > 0.05$) were believed to be due to vitamin A not having an effect on biohydrogenation of *cis*-9, *cis*-12 C18:2 in the rumen.

Dietary treatment effects on s.c. fatty acid composition are presented in Table 9. The vitamin A × SB interaction for total CLA and desaturase activity index was not significant ($P > 0.10$), and therefore main effects are presented and discussed. As observed in the LM fatty acid composition, SB inclusion increased PUFA ($P < 0.01$) due to increases in linoleic (C18:2), linolenic (18:3, n-3, and n-6), and 20:2 fatty acids (all $P < 0.05$). Total SFA were not reduced in s.c. fat, but MUFA were significantly ($P = 0.01$) reduced by SB inclusion. Whole roasted soybeans provide a good source of PUFA that can resist to some extent ruminal biohydrogenation and thus be stored in ruminant tissues. As in the LM, increases in PUFA in s.c. fat may have been responsible for the slight but significant ($P < 0.01$) reduction in desaturase activity index.

In s.c. fat, vitamin A restriction tended ($P = 0.10$) to decrease total CLA. The different CLA response to dietary vitamin A restriction between LM and s.c. fat was not expected. Differences between SCD responsiveness to vitamin A restriction between the i.m. and the s.c. adipose depots could be causing this effect. The proposed mechanism of action by which vitamin A restriction would increase CLA in ruminant tissues is that feeding low vitamin A diets would increase SCD activity and therefore the conversion of vaccenic to rumenic acid. The rumenic:vaccenic ratio was not different ($P > 0.10$, data not shown) between vitamin A treatments. Additionally, desaturase activity index and the 16:0/16:1 fatty acid ratio were also not affected (both, $P > 0.10$) by vitamin A level in the diet. Therefore, it remains unclear whether the observed increases in total CLA in s.c. fat were indeed caused by dietary vitamin A restriction.

In conclusion, adipose cellularity and carcass data suggest that hyperplasia took place in the intramuscular depot when diets were not supplemented with vitamin A and that these changes affected the carcass USDA quality grade but not yield grade. No vitamin A × SB interaction or vitamin A main effect were detected for muscle fatty acid profile. Dietary inclusion of SB did not affect carcass characteristics but improved the beef fatty acid profile by increasing muscle PUFA while reducing SFA.

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