Sheep & Goat Research Journal
Volume 25, 2010

Feedlot Performance, Carcass Characteristics, and Muscle CLA Concentration of Lambs Fed Diets Supplemented with Safflower Seeds and Vitamin E

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Acknowledgements

Authors wish to thank Ms. Amy Kelley and Dr. Janice Rumph for their contribution to this project. Research was funded by the Montana Agricultural Experiment Station and Montana Sheep Institute.

Summary

Sixty-eight Rambouillet ram lambs were used to evaluate the effects of safflower seed and vitamin-E supplementation on feedlot performance, carcass characteristics, and muscle-conjugated, linoleic-acid concentration. Lambs were fed finishing diets that were iso N and similar in estimated TDN containing safflower seed (SAFF) or no safflower seed (NOSAFF) in combination with 0 IU/d or 400 IU/d of supplemental vitamin E (NOVITE and VITE, respectively). Safflower seeds contained 43 percent oil with 79 percent linoleic acid, therefore SAFF diets were considered to contain 6 percent safflower oil. Final BW, DMI, ADG, and longissimus muscle area as measured by ultrasound did not differ ($P > 0.10$) between lambs fed SAFF and NOSAFF, or VITE and NOVITE. Gain:feed was lower ($P = 0.06$) for lambs fed SAFF compared to lambs fed NOSAFF (16.3 vs 14.3), but there was no difference ($P = 0.45$) in G:F between lambs fed VITE and NOVITE. Final weight, HCW, and fat thickness of slaughtered lambs were greater ($P < 0.05$) for lambs fed SAFF compared to NOSAFF (63.7 kg vs 59.7 kg final weight, 31.2 kg vs 29.0 kg HCW, and 0.3 cm vs 0.2 cm fat thickness); however, there were no differences ($P > 0.16$) in longissimus muscle area as measured by acetate traces, cooking loss, or Warner-Bratzler shear force between lambs fed SAFF versus NOSAFF. Final weight, HCW, fat thickness, longissimus muscle area, cooking loss, and Warner-Bratzler shear force did not differ ($P > 0.19$) between lambs fed VITE versus NOVITE. Dressing percentage was lower ($P < 0.10$) for lambs fed SAFF and VITE compared to lambs fed SAFF and NOVITE (47.6 percent vs 50.4 percent). Muscle from lambs fed SAFF had greater ($P \leq 0.001$) concentrations of conjugated linoleic acid (CLA; 4.9 percent vs 0.6 percent), total polyunsaturated fatty acid (17.8 percent vs 7.2 percent), and total unsaturated fatty acids (57.7 percent vs 50.7 percent); and lower ($P < 0.001$) concentrations of total SFA (35.7 percent vs 40.7 percent) and total monounsaturated fatty acid (39.9 percent vs 43.5 percent) than muscle from lambs fed NOSAFF. Lambs fed VITE had greater (P = 0.02) concentrations of total saturated fatty acids in muscle than lambs fed NOVITE (39.7 percent vs 36.7 percent). Lipid oxidation of muscle did not differ ($P > 0.32$) between lambs fed SAFF and NOSAFF or VITE and NOVITE. Vitamin E had few effects on feedlot performance, carcass characteristics, or muscle-fatty-acid concentrations; however, safflower-seed supplementation increased muscle concentration of CLA, linoleic acid, and polyunsaturated fatty acid to saturated-fatty-acid ratio resulting in a meat product that may be more beneficial to human health.

Key words: Conjugated Linoleic Acid, Fatty Acids, Lamb, Lipid Oxidation, Meat

Introduction

American consumers have become interested in the quality and health benefits of their food beyond that of basic nutrient content. The functional food market has focused on the health benefits of nutraceutical compounds found in plant products; however, milk and meat from ruminant animals contain conjugated linoleic acid (CLA), which have been shown to reduce carcinogenesis, atherosclerosis, the onset of diabetes, and body fat mass (Belury, 2002). Therefore, meat and milk products containing naturally high levels of CLA have the potential to be classified as functional foods (McGuire and McGuire, 2000). Conjugated linoleic acid is a long-chain, polyunsaturated fatty acid (PUFA), that is formed from linoleic acid via the process of biohydrogenation in the rumen or by the animal's tissues from trans-11 C18:1, another intermediate in the biohydrogenation of unsaturated fatty acids (Bauman et al., 2000). Safflower seed is high in linoleic acid (78 percent; Enig, 2000) and the concentration of CLA in lamb muscle has been increased through supplementation of safflower seeds or oil (Bolte et al., 2002; Kott et al., 2003; Boles et al., 2005).

Incorporating PUFA into the diet of ruminants also increases the concentration of unsaturated fatty acids in muscle tissue. Unsaturated fatty acids are more susceptible to lipid oxidation than saturated-fatty acids (SFA; Enig, 2000); therefore, it may be necessary to supplement animals with additional vitamin E (a potent antioxidant) in order to prevent flavor deterioration due to lipid oxidation (Wulf et al., 1995; Wood and Enser, 1997). Few researchers have investigated the effects of supplementing polyunsaturated acids in conjunction with vitamin E; therefore, the objectives of this study were to determine the effects of safflower-seed and vitamin-E supplementation on feedlot performance, carcass characteristics, and fatty acid concentration in muscle of ram lambs.

Materials and Methods

Sixty-eight Rambouillet ram lambs born in April and May at the Red Bluff Experimental Ranch grazed native range with their dams until weaning in late August. After weaning, lambs were moved to the Fort Ellis Sheep facilities near Bozeman, Mont. where a feedlot study was conducted. Ram lambs (average BW 32.4 kg ± 0.47 kg) were assigned to 1 of 12 feedlot pens in a manner that equalized average lamb BW across pens. Each pen was randomly assigned to 1 of 4 diets in 2 x 2 factorial arrangement with 3 pens of 5 to 6 lambs per diet. Diets included or did not include safflower seed (SAFF and NOSAFF) with 0 IU/d or 400 IU/d of vitamin E (NOVITE and VITE, respectively). Diets were formulated on a DM basis to be isocaloric, isonitrogenous, and to meet or exceed NRC (1985) requirements for Ca, P, and other nutrients (Table 1). Barley was rolled and safflower seeds were coarsely cracked. Safflower diets were assumed to contain 6 percent safflower oil based on the oil concentration of safflower seeds (43 percent oil with 79 percent linoleic acid). Lambs had ad libitum access to water and their respective diets, which were offered in self-feeders. Lambs were adjusted to their experimental diets during a 17-d step-up period and were then fed the finishing diets for 61 d. Feed bunks were monitored daily, and more feed was added to keep the bunks full. Feed refusals were removed, weighed, and recorded weekly throughout the trial. Random grab samples of the diets and feed refusals were collected, weighed, and dried in order to calculate DMI.

Feed samples were ground through a 1-mm screen and analyzed for DM, CP, and ether extract (AOAC, 2000). Weights were measured at the beginning and end of the finishing period after an 18-h fast from food and water. Real-time ultrasound was conducted to estimate longissimus muscle area at the end of the finishing period. Accuracy of ultrasound measurements was determined by comparing them to acetate traces of longissimus muscle area obtained at slaughter. Technician bias was -0.16 cm2 and the standard error of prediction was 0.37. The standard error of repeatability for this technician was not estimated during the current study, but was 0.22 in another research trial (unpublished data from our lab). All these values meet the requirements for accuracy suggested by Tait et al. (2005). Montana State University Institutional Animal Care and Use Committee approved all animal procedures.

Following the feeding period, two lambs from each pen (n = 24) weighing closest to the target final weight of 61 kg

Table 1. Ingredient and nutrient composition of finishing diets fed to ram lambs.

	Diets[1]			
	NOSAFF		SAFF	
Item	NOVITE	VITE	NOVITE	VITE
Ingredient, % DM basis				
Alfalfa pellets	29.4	29.4	38.3	38.3
Barley	49.3	49.4	24.4	24.4
Safflower seeds	-	-	16.2	16.2
Vitamin premix (control)	21.3	-	21.1	-
Vitamin E premix	-	21.2	-	21.1
Nutrient composition, % DM basis				
TDN	78.2	78.3	83.2	83.4
Crude protein	17.6	17.6	19.2	19.2
Ether extract	1.6	1.6	8.4	8.4
Vitamin E2, mg/kg	63	225	91	250
Calcium[2]	0.5	0.5	0.7	0.7
Phosphorus[2]	0.3	0.3	0.3	0.3
Fatty acid profile, % of total fatty acids				
Palmitic acid (C16:0)	15.2	15.4	12.1	12.4
Stearic acid (C18:0)	1.5	1.5	1.6	1.6
Oleic acid (C18:1)	16.2	16.6	14.3	14.7
Linoleic acid (C18:2)	36.1	36.7	39.5	40.2

[1] SAFF = supplemented with safflower seed, NOSAFF = not supplemented with safflower seed, VITE = supplemented with 400IU/d vitamin E, NOVITE = not supplemented with vitamin E.
[2] Calculated based on NRC tabular values of ingredients (NRC, 1982).

were selected and sent to a commercial slaughter facility approximately 100 miles west of Bozeman. Hot-carcass weights were collected at slaughter. Carcasses were chilled for 24 h at 2°C and then transported to the Montana State University Meat Laboratory. After a 5-d chill, carcasses were ribbed between the 12th and 13th ribs to allow for measurement of fat thickness and longissimus muscle area using traces drawn on acetate paper and measured with a planimeter. The carcasses were then fabricated according to the Institutional Meat Purchase Specifications (NAMP, 1988). Two loin chops 2.54 cm thick were removed from the right loin, deboned, vacuum-packaged, frozen, and stored at -77°C for future analysis of cooking loss, Warner-Bratzler shear force, lipid oxidation, and fatty acid concentration. Cooking loss and Warner-Bratzler shear force were estimated after cooking the meat in a plastic cook bag in an 80°C water bath to an internal temperature of 75°C. After cooking, the chops were placed in ice water and cooled to room temperature in order to prevent additional cooking once the desired temperature of 75°C was achieved. Chops were weighed before and after cooking in order to calculate cooking loss. Multiple 1.27 cm2 core samples were taken from each chop parallel to the muscle fibers, sheared with a TMS 30 Food Texturometer (Food Technology Corp., Rockville, Md.) fitted with Warner-Bratzler shear-force attachment. The shear-force values from all the cores from each animal were averaged and used for data analysis. Lipid oxidation was determined on loin chops thawed overnight at 4°C using the 2-thiobarbituric acid (TBARS) method described by Witte et al. (1970) and modified by Bedinghaus and Ockerman (1995).

Fatty acid methyl esters (FAME) of feed and muscle tissue were prepared according to the procedure described by Murrieta et al. (2003) and optimized to identify the different CLA methyl esters. Cross sections of the longissimus muscle, including any residual intramuscular fat, were freeze-dried and ground in an electric coffee grinder. Gas liquid chromatography was used to analyze for FAME using a Hewlett Packard 5890 GLC equipped with a flame ionization detector and an auto-sampler (Hewlett Packard, Avondale, Penn.). The column used for the chromatographic separations was a 100 m x 0.25 mm x 0.2 µm film thickness, fused-silica column (SP-2560; Sigma-Aldrich, Co., St. Louis, Mo.). Helium was used as the carrier gas, with a split ratio of 30:1 and 0.9 mL•m-1 column flow. Column temperature was programmed to be a constant temperature of 175°C for 65 min. Standard samples from Nu-Chek-Prep (Elysian, Minn.) were used to identify the various fatty acids, and the internal method of Murrieta et al. (2003) was used to determine fatty acid concentrations, with tridecanoic acid methyl ester added as an internal standard before extraction.

Data were analyzed as a completely randomized design using the GLM procedure of SAS (SAS Inst., Inc., Cary, N.C.) with pen as the experimental unit for feedlot data and individual animal as the experimental unit for carcass and fatty acid data. The effects of safflower seed, vitamin E, and their interaction were included in the model. Hot-carcass weight was included as a covariate for analysis of dressing percent, LMA, fat thickness and cooking loss. Least square means and associated standard errors are reported.

Results and Discussion

Growth and feed intake

There were no interactions ($P > 0.31$) between safflower and vitamin E supplementation for any feedlot-performance characteristics (Table 2). Initial BW, final BW, DMI, ADG, and longissimus muscle (LM) area as measured by ultrasound did not differ ($P > 0.10$) between lambs fed SAFF and NOSAFF; however, G:F was lower ($P = 0.06$) for lambs fed SAFF compared to lambs fed NOSAFF (.16 vs .14 ± .006). Initial weight, final weight, DMI, ADG, G:F, and longissimus muscle area as measured by ultrasound did not differ ($P > 0.24$) between lambs fed VITE compared to NOVITE.

In agreement with our results, no differences in final weight, DMI (Kott et al., 2003; Boles et al., 2005), or ADG (Mir et al., 2000; Bolte et al., 2002; Boles et al., 2005) were observed due to supplementation with safflower seed or

Table 2. Effect of safflower seed and vitamin E supplementation on growth, feed intake, and ultrasonic longissimus muscle area of ram lambs.

	Diets[1]					P-value[2]		
	NOSAFF		SAFF					
Item	NOVITE	VITE	NOVITE	VITE	SE[3]	S	V	S x V
N, pens	3	3	3	3				
Initial weight, kg	38.2	38.4	39.9	41.0	1.18	0.11	0.58	0.76
Final weight, kg	57.5	55.9	56.1	56.9	1.13	0.86	0.74	0.32
DM intake, kg/d	1.88	1.84	1.86	1.84	0.045	0.85	0.59	0.90
Daily gain, kg	0.32	0.29	0.27	0.26	0.021	0.11	0.45	0.53
G:F, g/kg	168.80	155.6	143.0	142.40	8.75	0.06	0.45	0.49
LMA[4], cm2	16.9	16.1	16.3	15.6	0.57	0.39	0.25	0.94

[1] SAFF = supplemented with safflower seed, NOSAFF = not supplemented with safflower seed, VITE = supplemented with vitamin E, NOVITE = not supplemented with vitamin E.
[2] S = effect of safflower seed supplementation, V = effect of vitamin E supplementation.
[3] SE for the four means.
[4] Longissimus muscle area (LMA) measured by ultrasound on all lambs (technician bias = -0.16 and standard error of prediction = 0.37).

oil. In contrast to our data, Mir et al. (2000) reported decreased DMI when lambs were supplemented with safflower oil and Kott et al. (2003) reported greater ADG when lambs were fed diets containing safflower seeds. We were the only researchers to observe lower G:F with safflower supplementation. Other researchers reported similar feed efficiencies when lambs were fed safflower oil or seeds (Mir et al. 2000; Bolte et al., 2002; Boles et al., 2005), but Kott et al. (2003) observed higher G:F when lambs were supplemented with safflower seeds. In the current study, initial weight tended to be lower and ADG tended to be higher for lambs fed NOSAFF ($P < 0.11$), which probably explains higher G:F by lambs on this diet. Oil may have more energy potential; however, its utilization and efficiency can be limited by negative effects on ruminal digestion, decreased intestinal absorption at high intakes, low contribution to total nutrient oxidation, or nutrient imbalance (Palmquist, 1994).

Similar to our findings, vitamin E supplementation had no affect on final weight or ADG in some other experiments (Macit et al., 2003b; Aksu et al., 2004). Wulf et al. (1995) also reported similar ADG and final weights between lambs supplemented with 0 or 500 IU vitamin E per day, but lower ADG for lambs supplemented with 1000 IU/d. Final weight, DMI, and ADG were also similar among lambs fed control diets, diets supplemented with soybean oil, and diets supplemented with soybean oil and vitamin E (Chen et al., 2008). In contrast to these and our results, vitamin E supplementation increased ADG (Macit et al., 2003a) and improved feed efficiency of lambs (Macit et al., 2003a,b; Aksu et al., 2004). These studies were conducted using different breeds of sheep (Awassi and Morkaraman) with no statistical analysis of DMI, which could explain differences between their results and ours.

Carcass Characteristics

Final weight and HCW of slaughtered lambs were greater ($P < 0.05$) for lambs fed SAFF compared to NOSAFF; however, there were no differences ($P > 0.16$) in longissimus muscle area measured by acetate traces, cooking loss, or Warner-Bratzler shear force between lambs fed SAFF compared to NOSAFF (Table 3). Final weight, HCW, longissimus muscle area, fat thickness, cooking loss, and Warner-Bratzler shear force of slaughtered lambs did not differ ($P > 0.19$) between lambs fed VITE versus NOVITE. There was an interaction ($P = 0.10$) between safflower-seed and vitamin-E supplementation for dressing percentage. Vitamin E supplementation decreased ($P < 0.10$) dressing percentage of carcasses from lambs fed SAFF (47.6 percent vs 50.4 percent ± .9 percent), but dressing percentage did not differ ($P > 0.10$) between VITE and NOVITE for lambs fed NOSAFF diets (averaging 48.6 percent).

Lambs were slightly under-finished at the termination of the study. Fat thickness was ≤ 0.3 cm and the industry standard is 0.5 cm of fat thickness. Therefore, heavier lambs in each pen were chosen for slaughter, which explains higher final weights and differences in results between Tables 2 and 3. Similar to our results, other researchers reported no differences in carcass characteristics when feedlot lambs were supplemented with safflower oil (Boles et al., 2005), safflower seeds (Bolte et al., 2002; Kott et al., 2003), or vitamin E (Macit et al., 2003a,b). We are not sure why vitamin E appeared to decrease dressing percentage when fed with SAFF in the current study. In contrast to our data, there were no differences in dressing percentage due to safflower (Bolte et al., 2002; Kott et al., 2003; Boles et al., 2005) or vitamin E supplementation (Wulf et al., 1995; Macit et al., 2003b). Similar to our results, supplementation with a combination of soybean and linseed oil had no affect on cooking loss or shear-force values of lamb (Radnz et al., 2009). Although vitamin E supplementation increased cooking loss in beef (Mitsumoto et al., 1995), Macit et al. (2003b) found no affect on cooking loss or shear-force values of lamb.

Muscle fatty acid concentration

There were interactions ($P < 0.10$)

Table 3. Effect of safflower seed and vitamin E supplementation on carcass characteristics of ram lambs selected for slaughter.

	Diets[1]					P-value[2]		
	NOSAFF		SAFF					
Item	NOVITE	VITE	NOVITE	VITE	SE[3]	S	V	S x V
N, lambs	6	5	5	6				
Final weight, kg	59.0	60.3	63.0	64.3	1.39	0.01	0.38	0.99
HCW, kg	28.6	29.4	31.8	30.5	0.89	0.03	0.83	0.27
Dressing percent	48.4	48.7	50.4	47.6	0.93	0.63	0.20	0.10
LMA[4], cm^2	18.0	16.8	17.7	17.8	0.97	0.75	0.59	0.51
Fat thickness, cm	0.23	0.23	0.33	0.34	0.045	0.03	0.96	0.89
Cooking loss, %	13.4	15.0	15.8	16.7	1.47	0.17	0.41	0.81
Shear force[5], kg	5.4	5.0	5.7	6.3	0.76	0.30	0.90	0.53

[1] SAFF = supplemented with safflower seed, NOSAFF = not supplemented with safflower seed, VITE = supplemented with vitamin E, NOVITE = not supplemented with vitamin E.
[2] S = effect of safflower seed supplementation, V = effect of vitamin E supplementation.
[3] SE for the four means.
[4] Longissimus muscle area measured by acetate traces.
[5] Warner-Bratzler shear force.

between safflower and vitamin-E supplementation for concentrations of total-fatty acids, myristic (C14:0), stearic (C18:0), arachidic (C20:0), palmitoleic (C16:1), linoleic (C18:2), and arachidonic (C20:4) acid in lamb muscle tissue (Table 4). Total fatty acid concentration in lamb muscle was lower ($P < 0.10$) in SAFF-fed lambs supplemented with VITE than in lambs fed NOSAFF and supplemented with VITE (7.7 percent vs 12.5 percent ± 1.8 percent). Linoleic-acid concentration was lowest ($P < 0.10$) in muscle from lambs fed NOSAFF diets (5 percent ± .8 percent), intermediate in muscle from lambs fed SAFF with NOVITE (9.7 percent ± .9 percent), and highest in muscle from lambs fed SAFF with VITE (12.3 percent ± .8 percent). Interactions between safflower seed and vitamin E supplementation for the minor fatty acids may not be of any practical importance and will not be detailed here.

Muscle from lambs fed SAFF had higher ($P \leq 0.001$) concentrations of the C18:1,trans-10 isomer, CLA, total PUFA, total unsaturated fatty acids, and PUFA:SFA than lambs fed NOSAFF. Muscle from lambs fed SAFF had lower ($P \leq 0.001$) concentrations of palmitic acid, oleic acid (C18:1,cis-9), vaccenic acid (C18:1,cis-11), total SFA, and total monounsaturated fatty acid (MUFA) than lambs fed NOSAFF. Lipid oxidation did not differ (P = 0.75) between SAFF and NOSAFF. Muscle from lambs supplemented fed VITE had higher ($P = 0.02$) concentrations of total SFA than muscle from lambs fed NOVITE (39.7 percent versus 36.7 percent ± .8 percent). Lipid oxidation and PUFA:SFA did not differ ($P > 0.32$) between VITE and NOVITE supplemented lambs.

The effect of safflower supplementation on total fatty acid concentration in lamb muscle has been variable. Bolte et al. (2002) and Boles et al. (2005) reported no difference in total fatty acid concentration from muscle of lambs supplemented with safflower seeds or oil. In contrast, Mir et al. (2000) reported that safflower oil supplementation tended to decrease lipid concentration in lamb muscle (Mir et al., 2000), and Kott et al. (2003) observed an increase in total fatty acid concentration in muscle from lambs fed safflower seeds. In contrast to our results, no difference in total-muscle-lipid concentration was observed, when vitamin E was fed in combination with other PUFA (Demirel et al., 2004; Chen et al., 2008). Differences in results between studies could be due to degree of finish or how closely the cuts were trimmed.

Similar to our research, Boles et al. (2005) reported that concentrations of palmitic and stearic acid in muscle decreased as level of safflower oil in the diet increased; however, Kott et al. (2003) and Mir et al. (2000) reported no differences in palmitic- and stearic-acid concentration in rib muscle of lambs supplemented with safflower. The SAFF diets in our study were lower in palmitic and oleic acids due to a higher concentration of these fatty acids in barley than safflower seed, which may partially explain lower concentrations of these fatty acids

Table 4. Effect of safflower seed and vitamin E supplementation on fatty acid profile of muscle sample extracts in ram lambs.

	Diets[1]							
	NOSAFF		SAFF			P-value[2]		
Item	NOVITE	VITE	NOVITE	VITE	SE	S	V	S x V
N, lambs	6	5	5	6				
Total fat content[3]	9.6^{ab}	12.5^{b}	11.2^{ab}	7.7a	1.79	0.37	0.88	0.09
Myristic (C14:0)[4]	4.7^{b}	3.9^{a}	4.5^{ab}	5.0^{b}	0.33	0.22	0.63	0.07
Palmitic (C16:0)[4]	25.1	27.1	22.5	22.7	0.66	0.0001	0.13	0.19
Stearic (C18:0)[4]	7.3^{a}	11.1^{b}	7.0^{a}	7.5^{a}	0.70	0.01	0.007	0.03
Arachidic (C20:0)[4]	1.2^{b}	0.9^{a}	1.0^{a}	1.2^{b}	0.07	0.68	0.70	0.009
Palmitoleic (C16:1)[4]	3.3^{b}	2.0^{a}	2.5^{a}	2.2^{a}	0.24	0.34	0.004	0.05
Oleic (C18:1, *cis*-9)[4]	36.6	38.6	27.2	26.6	1.23	0.001	0.60	0.30
Oleic (C18:1, *trans*-10)[4]	1.9	2.0	10.0	8.9	0.67	0.001	0.48	0.38
Oleic (C18:1, *cis*-11)[4]	1.4	1.3	1.1	1.1	0.07	0.002	0.59	0.29
Linoleic (C18:2)[4]	5.8^{a}	4.2^{a}	9.7^{b}	12.3^{c}	0.86	0.001	0.54	0.03
CLA (C18:2, *cis*-9,*trans*-11)[4]	0.6	0.6	5.3	4.5	0.34	0.001	0.26	0.33
Arachadonic (C20:4)[4]	2.1^{b}	1.1^{a}	1.7^{ab}	2.1^{b}	0.33	0.33	0.36	0.04
Total SFA[4]	38.3	43.0	35.0	36.3	1.14	0.003	0.02	0.15
Total MUFA[4]	43.2	43.8	40.9	38.9	1.21	0.007	0.57	0.29
Total PUFA[4]	8.5^{a}	5.9^{a}	16.6^{b}	18.9^{b}	1.26	0.0001	0.90	0.07
Total unsaturated fatty acids[4]	51.7	49.7	57.5	57.8	1.48	0.0002	0.57	0.45
PUFA:SFA	0.22	0.14	0.48	0.52	0.043	0.0001	0.59	0.15
Lipid oxidation[5]	0.20	0.32	0.24	0.35	0.111	0.75	0.33	0.97

[1] SAFF = supplemented with safflower seed, NOSAFF = not supplemented with safflower seed, VITE = supplemented with vitamin E, NOVITE = not supplemented with vitamin E.
[2] S = effect of safflower seed supplementation, V = effect of vitamin E supplementation.
[3] % on dry weight basis.
[4] % of total fatty acids.
[5] mg malonaldehyde/kg fresh meat.

in the muscle of lambs fed SAFF diets. Most previous researchers concluded that supplementation with safflower oil or seeds increased the concentration of linoleic acid, CLA, and C18:1 isomers in lamb muscle, while concentrations of oleic acid were decreased (Mir et al., 2000; Bolte et al., 2002; Kott et al., 2003; Boles et al., 2005). The primary product of fatty acid metabolism in growing sheep is palmitic acid, which can be further elongated to stearic acid and then desaturated to oleic acid by stearoyl-CoA desaturase (Sinclair, 2007). Starch diets promote greater activity of stearoyl-CoA desaturase (Daniel et al., 2004), and PUFA (including linoleic acid) also inhibited stearoyl-CoA desaturase gene 1 expression in mouse liver (Ntambi, 1992) and adipocytes (Sessler et al., 1996). These observations could explain why lambs supplemented with safflower seed had lower concentrations of MUFA and oleic acid in muscle compared to lambs fed NOSAFF (higher starch) diets. Our values for CLA in muscle of safflower supplemented lambs (4.9 percent) were higher than the concentrations reported by others (0.84 percent to 1.45 percent; Mir et al., 2000; Bolte et al., 2002; Kott et al., 2003; Boles et al., 2005); however, the concentrations of linoleic acid in our study (11 percent) were within the range reported by these authors (4.5 percent to 16 percent) and were similar to concentrations found in olive oil (10 percent; Enig, 2000).

In agreement with our data, Bolte et al. (2002) observed a decrease in total MUFA concentration in muscle of lambs supplemented with safflower seeds; however in contrast to our data, Bolte et al. (2002) and Kott et al. (2003) reported no difference in total SFA concentrations in lamb muscle due to safflower-seed supplementation. Differences in results between studies could be due to differences in the number and type of individual fatty acids used to calculate total fatty acid content or differences in biohydrogenation due to the composition of the basal diet. Lamb is generally considered a high-fat food (>5 percent) with a low PUFA:SFA (Wood and Enser, 1997; Sinclair, 2007). In the current experiment, total fatty acid concentration of muscle was 7.7 percent to 12.5 percent and the PUFA:SFA of safflower supplemented lamb meat was 0.48 and 0.52, which is higher than the recommended PUFA:SFA of 0.45 (Wood and Enser, 1997).

Few researchers have supplemented vitamin E in combination with different oils, and our study may be the first to report the effects of feeding safflower seed (oil) in conjunction with vitamin E in feedlot diets. Unsal et al. (2004) and Aksu et al. (2004) did not include a source of oil in the diet of lambs, but reported almost no differences in fatty acid composition of intra- or intermuscular fat due to Vitamin E supplementation. Chen et al. (2008) reported that lambs receiving vitamin E in addition to soybean oil had higher concentrations of PUFA and decreased concentrations of total SFA in lamb muscle than lambs supplemented with only soybean meal; however, vitamin E had no effect on concentrations of linoleic, palmitic, stearic, CLA, or total MUFA in lamb muscle. Demirel et al. (2004) reported no effects of supplemental vitamin E on total fat, CLA, or trans18:1 in muscle tissue, when fed with three different fat sources (Megalac, linseed oil, and fish oil) and observed no interactions between fat source and vitamin E.

Wulf et al. (1995) reported that supplemental vitamin E reduced the effect of storage time on lipid oxidation. We observed no difference in lipid oxidation among diets in the current study; however, we only estimated lipid oxidation at one time point: 24 h after thawing frozen muscle samples. In agreement with our data, Kerry et al (2000) and Yaprak et al. (2002) reported no differences in lipid oxidation on d 0 or d 2 to d4, respectively, between lambs supplemented or not supplemented with vitamin E with values ranging from 0.2 to 0.5. However, in agreement with Wulf et al. (1995) most researchers observed decreased lipid oxidation with vitamin-E supplementation as time progressed (Kerry et al., 2000; Yaprak et al., 2002).

Implications

This may be the first study to evaluate the effects of feeding safflower seeds in combination with Vitamin E on feedlot performance, carcass characteristics, and fatty acid concentration of lamb muscle. Muscle from lambs fed safflower seeds had higher percentages of linoleic acid, CLA, PUFA, total unsaturated fatty acids, and PUFA:SFA. Vitamin E supplementation decreased total fatty acid concentration of muscle from lambs fed safflower seeds and increased total SFA in lamb muscle. Our data suggests that lambs fed safflower seeds produced muscle with a fatty acid composition that may be more desirable to the modern consumer and more beneficial to human health.

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