Value of sunflower seed in finishing diets of feedlot cattle[1,2]

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ABSTRACT: The value of sunflower seed (SS) in finishing diets was assessed in two feeding trials. In Exp. 1, 60 yearling steers (479 ± 45 kg) were fed five diets (n = 12). A basal diet (DM basis) of 84.5% steam-rolled barley, 9% barley silage, and 6.5% supplement was fed as is (control), with all the silage replaced (DM basis) with rolled SS, or with grain:silage mix replaced with 9% whole SS, 14% whole SS, or 14% rolled SS. Liver, diaphragm, and brisket samples were obtained from each carcass. In Exp. 2, 120 yearling steers (354 ± 25 kg) were fed corn- or barley-based diets containing no SS, high-linoleic acid SS, or high-oleic acid SS (a 2 × 3 factorial arrangement, n = 20). Whole SS was included at 10.8% in the corn-based and 14% in the barley-based diets (DM basis). In Exp. 1, feeding whole SS linearly increased DMI (P = 0.02), ADG (P = 0.01), and G:F (P = 0.01). Regression of ME against level of whole SS indicated that SS contained 4.4 to 5.9 Mcal ME/kg. Substituting whole for rolled SS did not significantly alter DMI, ADG, or G:F (8.55 vs. 8.30 kg/d; 1.36 vs. 1.31 kg; and 0.157 vs. 0.158, respectively). Replacing the silage with rolled SS had no effect on DMI (P = 0.91) but marginally enhanced ADG (P = 0.10) and improved G:F (P = 0.01). Dressing percent increased linearly (P = 0.08) with level of SS in the diet. Feeding SS decreased (P < 0.05) levels of 16:0 and 18:3 in both diaphragm and subcutaneous fats, and increased (P = 0.05) the prevalence of 18:1, 18:2, *cis*-9,*trans*-11-CLA and *trans*-10,*cis*-12-CLA in subcutaneous fat. In Exp. 2, barley diets supplemented with high-linoleic SS decreased DMI (P = 0.02) and ADG (P = 0.007) by steers throughout the trial, whereas no decrease was noted with corn (interaction P = 0.06 for DMI and P = 0.01 for ADG). With barley, high-linoleic SS decreased final live weight (554 vs. 592 kg; P = 0.01), carcass weight (329 vs. 346 kg; P = 0.06), and dressing percent (58.5 vs. 59.4%; P = 0.04). Steers fed high-linoleic SS plus barley had less (P < 0.05) backfat than those fed other SS diets. No adverse effects of SS on liver abscess incidence or meat quality were detected. Although they provide protein and fiber useful in formulating finishing diets for cattle, and did improve performance in Exp. 1, no benefit from substituting SS for grain and roughage was detected in Exp. 2. Because of unexplained inconsistencies between the two experiments, additional research is warranted to confirm the feeding value of SS in diets for feedlot cattle.

Key Words: Beef, Fat, Feedlots, Oil, Performance, Sunflower Seeds

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Introduction

Most feedlot diets for cattle are grain-based to increase their energy concentration, which typically improves gain efficiency and cost of gain. Although lower in energy than grain, sources of fiber are often included in diets to help maintain ruminal function (Bull et al., 1965) and animal health (Cheng et al., 1998). Lipids are often fed to increase dietary energy density without decreasing fiber. Feeding isolated fats (tallow, yellow grease) can be challenging, however, as specialized equipment for handling, heating, and mixing is required.

Sunflower seed (**SS**) contains over 40% oil, and the majority of its fatty acids are unsaturated. In ruminants, FFA released from consumed fats are partially hydrogenated in the rumen. Microbial hydrogenation of linoleic (18:2) to oleic (18:1) acid gives rise to intermediary CLA, primarily *cis*-9,*trans*-11- and *trans*-10,*cis*-12-octadecanoic acid. This CLA can be absorbed from the small intestine and incorporated into tissue (Ivan

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et al., 2001) or milk fat (Chouinard et al., 2001). Recent studies have shown some dietary CLA to be beneficial for human health (Ha et al., 1989; Parodi, 1997). The prevalence of CLA in deposited fat has been elevated by increasing the intake of linoleic acid by sheep (Mir et al., 2000). High-oil SS typically contains approximately 75% linoleic acid; directed selection has produced SS high in oleic acid. Sunflower seed also contains at least 19% protein and 24% NDF (NRC, 2001).

The feeding value of SS has been studied in dairy diets (Boila et al., 1993) but not in diets for feedlot cattle. This study investigated the suitability of SS as a replacement for forage; the effect of processing the SS before feeding; the effects of dietary SS on growth performance, tissue fatty acid profiles, and organoleptic properties of beef; and whether the response(s) differed with the type of diet (barley vs. corn based) and/or fatty acid profile of the SS (high linoleic vs. oleic acid) fed.

Materials and Methods

Animal Care

All cattle used in this study were cared for in accordance with guidelines set by the Canadian Council on Animal Care (CCAC, 1993).

Experiment 1

Animals, Housing, and Feeding. This study was conducted from November 2000 to February 2001 using 60 yearling steers of mixed breeding (primarily Simmental, Charolais, and Limousin; 479 ± 45 kg initial BW) that had been previously adapted to a barley-based finishing diet. The steers were housed individually in an enclosed shelter comprising six wings of 36 pens (three wings along either side of the central building). Each pen (1.85 m × 6.15 m) featured a feed bunk and water trough at one end and a pen access gate at the other end. Adjacent pens were separated by plank fencing. Livestock housed in this facility have no direct exposure to the weather.

The steers were given ad libitum access to feed and water throughout the study. Fresh feed was mixed and delivered daily using a Calan Data Ranger (American Calan, Northwood, NH). The steers were weighed (without withdrawal of feed or water) on two consecutive days at the beginning and end of the study, for calculation of initial and final weights, and at 28-d intervals throughout the study. To equalize initial BW among treatments, the steers were stratified for assignment to five diets (n = 12) on the basis of weights recorded on d 0. Animals within treatment were assigned to contiguous pens to decrease the potential for feeding errors. The absence of effect of pen location has been confirmed in other studies (Zaman et al., 2002; Ralston et al., 2003; Shah et al., 2004) conducted at this facility, including Exp. 2 of the present trial. At processing on d 1, all steers received a Component TE-S implant containing 140 mg trenbolone acetate and 14 mg estrogen (Elanco Animal Health, Guelph, ON). The steers were monitored daily for health status, including symptoms of acidosis.

Dietary Treatments. Five experimental diets (Table 1) were prepared using the ingredients listed in Table 2. Diets (DM basis) included 1) the control diet, comprising a typical finishing formulation of 84.5% steam-rolled barley, 9% barley silage, and 6.5% supplement; 2) Diet 1 modified by replacing all of the silage (9%) with rolled SS (**9RSS-silage**); 3) Diet 1 with 9% whole SS replacing both silage and barley so that the ratio of silage to barley was the same as in the control diet (**9WSS**); 4) Diet 1 with whole SS replacing both barley and silage to 14% (**14WSS**); and 5) Diet 4 with rolled SS replacing whole SS (**14RSS**). The 14% replacement level was selected to approximately maximal recommended levels of fat in the diet, on the assumption of 40% oil in the SS. A roller mill (Roskamp Manufacturing Inc., Cedar Falls, IA) with rolls 30 cm in diameter and 76 cm wide and 6.3 corrugations/cm was used to process SS for Diets 2 and 5. Rolls were set to ensure all SS were broken apart. These diets allowed evaluation of SS as a roughage source (Diet 1 vs. 2), the linear and quadratic effects of adding SS (Diets 1, 3, 4), and the value of processing SS before feeding (Diet 4 vs. 5).

Sample Collection and Analyses. Ingredient and diet samples were collected twice each month. Composite samples were analyzed for DM by drying in a forced-air oven at 55°C for 48 h. Orts were collected weekly (before weighing the steers, when on weigh days) and dried for determining DM content as described for diet samples. Dry matter disappearance was calculated weekly as (feed delivered × $\%DM_{feed}$) – (orts collected × $\%DM_{orts}$) and considered as DMI. Average daily gain, DMI, and G:F were determined for each period that animal weights were obtained.

Fecal samples were collected from eight steers in each of control, 14WSS, and 14RSS diet groups by rectal extraction during weighing on d 84 and again on d 85. The samples were air-dried for 6 d and oven-dried at 55°C for 24 h for DM determination. Fat content of dried fecal samples was determined by extraction with ether (AOAC, 1990).

Dried feed samples were ground to pass a 1-mm screen and analyzed for ADF and NDF (Van Soest et al., 1991) after extraction of the oil with ether (AOAC, 1990). Mineral contents (Ca and P) were determined at an accredited commercial laboratory. Crude protein was estimated from N content determined from Kjeldahl analysis (AOAC, 1990). Fatty acid composition was determined after direct transmethylation as described by Park and Goins (1994). Fatty acid methyl esters were analyzed using a model HP68890 gas chromatograph (Hewlett-Packard, San Fernando, CA) equipped with an automatic sampler (HP7673A).

At slaughter, livers were scored for severity of abscess using a 4-point numeric scale (Brown et al., 1975), in which 0 indicates no visible abscess and 3 indicates

Table 1. Formulas and calculated composition (DM basis) of diets fed in Exp. 1

	Treatment				
Item	Control	9RSS-silage	9WSS	14WSS	14RSS
Ingredients, %					
Steam-rolled barley	84.5	84.5	76.4	71.8	71.8
Barley silage	9.0	—	8.1	7.7	7.7
Rolled sunflower seed	—	9.0	—	—	14.0
Whole sunflower seed	—	—	9.0	14.0	0.0
Supplement[b]	6.5	6.5	6.5	6.5	6.5
Composition, %					
DM	81.9	86.9	82.8	83.2	83.2
CP	13.9	14.5	14.5	14.9	14.9
NDF	25.1	23.8	25.5	25.7	25.7
Oil	2.0	5.6	5.8	8.0	8.0
Fatty acids, % of total fatty acids[c]					
16:0	26.6	17.7	15.9	14.1	16.4
18:0	1.6	3.6	5.0	5.8	6.5
18:1	29.8	25.5	19.7	19.5	15.6
18:2	36.3	49.9	56.8	58.3	58.7
18:3	2.5	1.2	0.8	0.6	0.8

[a]9RSS-silage: all of the silage (9%) replaced with rolled sunflower seed (SS); 9WSS = whole SS replacing silage:grain mix to 9% of diet; 14WSS = whole SS replacing silage:grain mix to 14% of diet; and 14RSS = rolled SS replacing silage:grain mix to 14% of diet.
[b]Supplement contained 27% CP (from canola meal), 10.5% Ca, 1.2% Na, 320 ppm Cu, 1,270 ppm Zn, 560 ppm Mn, 14.5 ppm I, 4.2 ppm Co, 6.4 ppm Se, 107,000 IU/kg vitamin A, 10,000 IU/kg vitamin D, 290 IU/kg vitamin E, and 431 ppm monensin sodium.
[c]Values determined from analysis.

severe abscess, defined as more than four small abscesses or one or more abscesses greater than 2.5 cm in diameter. At slaughter, warm carcass weight (with kidneys removed), dressing percent, backfat thickness, LM area, and quality grade were recorded for each carcass. Samples of pars costalis diaphragmatis muscle (diaphragm), liver, and subcutaneous fat (brisket) were also collected from each carcass and frozen immediately on dry ice. Following extraction of tissue lipids with hexane (Hara and Radin, 1978), the triglyceride fraction was isolated from total lipid and the fatty acid content of the triglyceride fraction was determined as described by Kazala et al. (1999).

Experiment 2

Animals, Housing, and Feeding. In September 2001, 127 British cross (primarily Angus and Hereford) yearling steers (initial BW = 354 ± 25 kg) were housed in individual pens within the facility described above and

Table 2. Analysis (DM basis) of ingredients used to prepare the barley-based finishing diet for steers in Exp. 1 and the transition and final finishing diets for steers in Exp. 2

Item[a]	Barley grain	Corn grain	Barley silage	High-linoleic SS	High-oleic SS
DM, %	88.1	88.8	40.4	92.6	87.8
CP, %	14.5	10.3	10.7	22.0	19.3
ADF, %	7.8	1.6	28.7	19.8	14.6
NDF, %	25.4	8.0	45.9	29.9	22.6
Ca, %[b]	0.06	0.01	0.19	0.25	0.22
P, %[b]	0.49	0.28	0.12	0.54	0.75
Ash, %[b]	2.5	1.6	6.5	3.60	4.0
Ether extract, %	1.9	3.2	1.7	41.3	44.5
Individual fatty acids, % of total fatty acids					
16:0	26.9	13.0	21.7	6.8	0.07
18:0	3.4	1.6	3.3	2.4	4.39
18:1	17.3	22.8	18.5	13.8	87.3
18:2	33.6	58.1	28.1	72.9	2.1
18:3	2.5	1.6	6.4	0.2	0.06

[a]For barley grain, barley silage and high linoleic sunflower seed (SS), values shown are the means of triplicate determinations conducted during Exp. 1 and Exp. 2. Corn grain and high-oleic acid SS were used only in Exp. 2.
[b]Determined in Exp. 2 only.

Table 3. Composition and calculated analysis (% DM basis) of final diets fed to steers in Exp. 2

Item	Barley-based diets[a]			Corn-based diets		
	No SS (control)	High-linoleic SS	High-oleic SS	No SS (control)	High-linoleic SS	High-oleic SS
Ingredients						
Steam-rolled barley	83.5	73.3	73.3	—	—	—
Steam-rolled corn	—	—	—	79.2	72.0	72.0
Barley silage	9.0	7.7	7.7	0.0	8.0	8.0
High-linoleic acid SS	—	14.0	—	—	10.4	—
High-oleic acid SS	—	—	14.0	—	—	10.4
Soybean meal	2.5	—	—	6.8	4.6	4.6
Supplement[b]	5.0	5.0	5.0	5.0	5.0	5.0
Composition, DM basis						
DM, % as fed	79.3	79.3	79.3	76.5	77.8	77.8
CP, %	13.4	13.4	13.4	13.4	13.4	13.4
Oil, %[c]	2.0	7.4	7.4	3.7	7.5	7.5
NDF, %	23.4	24.6	23.5	8.9	11.4	10.6
Ca, %	0.63	0.62	0.62	0.62	0.61	0.61
Vitamin E, IU/kg	115.0	115.0	115.0	115.0	115.0	115.0

[a]SS = whole sunflower seed.
[b]Supplement contained 20% CP (from canola meal), 10.5% Ca, 1.2% Na, 320 ppm Cu, 1,270 ppm Zn, 560 ppm Mn, 14.5 ppm I, 4.2 ppm Co, 6.4 ppm Se, 107,000 IU/kg vitamin A, 10,000 IU/kg vitamin D, and 2,300 IU/kg vitamin E, 562 mg/kg monensin sodium, and 220 mg/kg tylosin phosphate.
[c]Based on assumed oil contents of 2% for barley, 4% for corn, 4% for silage, and 40% for SS.

fed a diet consisting of 59% silage, 33.1% barley, 5.0% supplement, and 2.9% soybean meal (DM basis). After a 2-wk adaptation period, initial weights were determined as the average of unshrunk weights recorded on two consecutive days (d 0 and 1). On the basis of d-0 weights, the seven steers with the lowest rates of gain during the adaptation period were culled, and the remaining 120 were stratified by weight and assigned to six dietary treatments (n = 20). The steers in each diet group were placed in two separate blocks of 10 adjacent pens to allow testing for location effects. No anabolic implants were administered in this experiment.

The six diets were studied in a 2×3 factorial arrangement of grain type (barley- or corn-based diets) and SS supplementation (no SS, high–linoleic acid SS, or high–oleic acid SS). In the diets containing SS, both grain and silage were replaced, so that the grain:silage ratios of the control diets were maintained. The ingredients used and the compositions of the final finishing diets are presented in Tables 2 and 3, respectively. The level of SS included in the corn-based diets was adjusted to provide an equal amount of total oil as in the barley-based diets, with calculations based on assumed oil contents of 4, 2, 4, and 40% for corn, barley, silage, and SS, respectively. To ensure the diets were isonitrogenous, soybean meal was included as needed (the highest level was 6.8%). In an attempt to minimize the potential for oxidation of dietary and carcass unsaturated fatty acids, 2,300 IU/kg vitamin E was included in the supplement targeted to provide each steer 1,000 IU/d. Transition from the common initial diet (33.1% barley grain) to the six final experimental diets shown in Table 3 was accomplished over 20 d using five step-up diets specific to each experimental treatment (i.e., corn vs. barley; no SS vs. linoleic or oleic SS). The final diets (Table 3) were fed for 152 d.

Sample Collection and Analyses. Sampling and analysis of feeds and orts were as described for Exp. 1. Animal weights were obtained at 28-d intervals throughout the 172-d feeding period. Initial and final weights were the average of unshrunk weights recorded on two consecutive days. A 4% shrink was assumed when calculating interim weights. At slaughter, the presence and severity of liver abscess was recorded as described for Exp. 1. Carcass characteristics measured at slaughter included warm carcass weight, dressing percent, backfat thickness, LM area, and quality grade.

On the day after slaughter, LM steaks cut from the 13th rib were shipped on ice to the University of Georgia and subjected to sensory analysis by an eight-person panel following the guidelines of the AMSA (1995). Panelists evaluated each sample for juiciness, tenderness, and flavor intensity on an 8-point scale in which 1 is least desirable and 8 is most desirable. Panelists also assessed the presence of off-flavors in each sample from 0 (no off-flavor) to 8 (maximal off-flavor).

Statistical Analyses

Data from steers considered to have exhibited atypical performance (gaining more than 3.2 kg/d or less than 0.68 kg/d) were excluded from the analyses of performance and carcass data. Gain efficiency was analyzed as gain/feed. In Exp. 1, ME and NE_g content of each diet were calculated based on DMI and ADG. To more accurately account for carcass gain and retained

energy in these calculations, final weight was calculated from carcass weight using an assumed dressing percent of 62. The NE_m and NE_g contents of the diets were numerically iterated (Hays et al., 1987) using the relationships $NE_g = 0.877 \times NE_m - 0.41$, and retained energy (Mcal/d) = $0.0635 \times$ equivalent empty $BW^{0.75} \times ADG^{1.097}$ (NRC, 1996).

Measurements were subjected to analysis of variance using SAS (SAS Institute Inc., Cary, NC) with animal as the experimental unit and diet as the only class variable. Experiment 1 was arranged as a completely randomized design with nonorthogonal contrasts used to assess 1) the roughage value of RSS (control vs. 9RSS-silage); 2) the value of rolling SS (14WSS vs. 14RSS); and 3) the linear and quadratic effects of including 0, 9, or 14% whole SS. The linear regression of diet ME against SS level was calculated so that the ME of the basal diet and of pure SS could be estimated.

The PDIFF option of the GLM procedure of SAS was used to separate least squares means of individual fatty acids from tissues of cattle fed the control diet, 14WSS, or 14RSS for Exp. 1. Orthogonal contrasts were used to compare fatty acid concentrations in tissues of steers fed the control diet against the average for tissues from steers fed diets containing 14% SS.

Experiment 2 was also a completely randomized design with a factorial arrangement of treatments (diets based on two grain types with or without two types of SS). The GLM procedure (SAS Institute Inc.) was used to statistically compare treatments. Animal was the experimental unit with location (each treatment was fed in two locations), grain source (barley or corn), and sunflower seed type (high linoleic vs. high oleic) considered in the statistical model. The LSMEANS and PDIFF options were used for generating LSMEANS and comparison of treatments. Contrasts were used for analysis of taste panel data with covariance adjustment for difference among panelists. In both Exp. 1 and Exp. 2, significance was declared at $P \leq 0.05$, with trends declared where $P \leq 0.10$.

Results and Discussion

Experiment 1

Six steers gained less than 0.68 kg/d during this trial. Three of these were from the control group, two from 9RSS-silage, and one from 9WSS. One steer (on 14WSS) gained more than 3.2 kg/d. The plot of ADG against mean DMI for the experiment detected no additional outliers.

Level of Sunflower Seed. Increasing the amount of whole SS in the diet linearly ($P = 0.06$) increased DMI during the initial 28 d of the experiment (Table 4). This trend became clearer ($P = 0.01$) during the second 28-d period (d 29 to 56) so that for the whole experiment, DMI was linearly increased ($P = 0.02$) by added SS. Quadratic effects of SS were not observed for any of the variables measured.

The positive effects of SS on DMI suggest that SS may provide some of the nutritional value of a forage in finishing diets. Adding whole SS increased the concentration of NDF compared with the control diet (Table 1). Because both barley and silage were decreased when SS was included, in order to maintain barley:silage ratios, the SS-associated increase in NDF is small when expressed as a percentage of the total diet. However, if SS is considered as a forage component, NDF from forages increased from 4.0% in the control diet to 6.3 with 9% SS, and to 7.6% with 14% SS. Intake of finishing diets typically increases with increasing levels of NDF provided by forage (Galyean and Defoor, 2002). This response often is attributed to decreased energy density of the diet (NRC, 1996); however, in the current experiment, the linear improvement ($P = 0.01$) in G:F suggests that dietary energy supply increased with the addition of SS. Suppression in DMI of finishing diets in association with increased energy density has been attributed to a decreased ruminal pH (Fulton et al., 1979) or an increased concentration of specific VFA (Baile, 1971; Baile and Forbes, 1974). In the present study, however, most of the energy from SS came from lipid, which is minimally fermented in the rumen (Jenkins, 1993); thus, it seems that the DMI may have been increased because the stimulatory effect on DMI of the increased supply of NDF with SS supplementation exceeded any suppression of DMI resulting from the increased energy supply or possible toxic or inhibitory effects of the added fat on ruminal microbial populations (Jenkins, 1993). Zinn and Plascencia (1996) found that supplemental fat enhanced intake only when forage levels were increased in high-grain diets. Moderate levels of lipid (i.e., <4%) have often (Krehbiel et al., 1995; Zinn and Shen, 1996; Ramirez and Zinn, 2000), although not always (Duckett et al., 2002), decreased DMI when added to corn-based finishing diets, but their effect on DMI of finishing diets containing barley is minimal (Zinn, 1989; Engstrom et al., 1994). Including 3.5 to 4% fat in wheat-based finishing diets was found to increase intake (Brethour et al., 1986; Brandt et al., 1988; Bock et al., 1991). Neutral or positive effects on DMI from fat supplementation might be expected with grains that contain less oil (barley and wheat) rather than with grains that are less rapidly fermented and contain more oil (corn).

Differences in protein levels between treatments also may have affected DMI. Dietary protein levels averaged 13.9, 14.5, and 14.9% for 0, 9, and 14% SS, respectively. DiCostanzo and Zehnder (1997) concluded that much of the gain response to protein supplementation can be attributed to an increase in DMI. When protein was increased from 11.2 to 13.2% using canola meal in barley-based finishing diets, intake increased (Engstrom et al., 1994). However, increasing protein content further, from 13 to 15% (McKinnon et al., 1993a) or to 17 or 19% (McKinnon et al., 1993b) failed to increase DMI of barley-based diets. With corn-based diets, protein supplementation often increased DMI when protein lev-

Table 4. Effect of supplemental sunflower seed (SS) on performance of finishing steers fed barley grain-based diets in Exp. 1

	Treatment[a]					*P*-values[b]		
Item	Control	9RSS-silage	9WSS	14WSS	14RSS	LIN	PROC	RGH
No. of observations	7	8	9	9	10			
Initial BW, kg	483 ± 13	485 ± 13	489 ± 12	481 ± 12	482 ± 12	0.94	0.95	0.96
Final BW, kg	579 ± 17	600 ± 16	611 ± 15	617 ± 15	613 ± 15	0.08	0.85	0.37
Days 1 to 28								
DMI, kg/d	7.38 ± 0.39	7.72 ± 0.37	8.08 ± 0.35	8.25 ± 0.35	8.26 ± 0.34	0.06	0.98	0.53
ADG, kg	0.69 ± 0.69	0.92 ± 0.66	1.61 ± 0.63	1.62 ± 0.63	1.79 ± 0.60	0.21	0.83	0.82
G:F	0.154 ± 0.10	0.137 ± 0.09	0.209 ± 0.09	0.191 ± 0.09	0.218 ± 0.08	0.64	0.81	0.89
Days 29 to 56								
DMI, kg/d	7.47 ± 0.37	7.38 ± 0.35	8.43 ± 0.32	9.00 ± 0.33	8.79 ± 0.32	0.01	0.66	0.88
ADG, kg	0.81 ± 0.22	1.32 ± 0.20	1.14 ± 0.20	1.66 ± 0.20	1.74 ± 0.19	0.01	0.75	0.10
G:F	0.108 ± 0.03	0.182 ± 0.03	0.138 ± 0.02	0.189 ± 0.02	0.202 ± 0.02	0.02	0.70	0.06
Days 57 to 100								
DMI, kg/d	7.43 ± 0.35	7.13 ± 0.33	8.11 ± 0.31	8.45 ± 0.31	8.12 ± 0.30	0.05	0.47	0.55
ADG, kg	1.22 ± 0.51	1.21 ± 0.49	1.02 ± 0.47	1.01 ± 0.47	0.74 ± 0.45	0.58	0.68	0.96
G:F	0.145 ± 0.06	0.158 ± 0.06	0.114 ± 0.06	0.112 ± 0.06	0.087 ± 0.06	0.54	0.78	0.92
Days 1 to 100								
DMI, kg/d	7.42 ± 0.35	7.37 ± 0.34	8.19 ± 0.32	8.55 ± 0.32	8.30 ± 0.31	0.02	0.65	0.91
ADG, kg	0.96 ± 0.09	1.16 ± 0.08	1.22 ± 0.08	1.36 ± 0.08	1.31 ± 0.08	0.01	0.64	0.10
G:F	0.129 ± 0.01	0.153 ± 0.01	0.149 ± 0.01	0.160 ± 0.01	0.156 ± 0.01	0.01	0.85	0.01
Dietary energy[c]								
ME, Mcal/kg	2.63 ± 0.09	2.90 ± 0.08	2.85 ± 0.08	3.02 ± 0.08	2.93 ± 0.08	0.01	0.43	0.05
NE_g, Mcal/kg	1.1 ± 0.06	1.29 ± 0.06	1.27 ± 0.06	1.38 ± 0.06	1.32 ± 0.05	0.01	0.47	0.04

[a]Control diet contained 9% silage (no SS); 9RSS-silage =rolled SS replaced all of the silage; 9WSS = whole SS replaced 9% of grain + silage; 14WSS = whole SS replaced 14% of grain + silage; 14RSS = rolled SS replaced 14% of grain + silage. Diets 9WSS, 14WSS, and 14RSS contained 8.1, 7.7, and 7.7% silage, respectively.

[b]LIN = linear effect of including whole SS in the diet; PROC = effect of processing SS (i.e., 14WSS vs. 14RSS); RGH = effect of roughage source (i.e., control diet vs. 9RSS-silage). Quadratic effects were not observed.

[c]Energy levels calculated iteratively from mean BW, DMI, and ADG as described by Hays et al. (1987) using NRC (1996) equations.

els were low (i.e., <12%) but rarely increased intake when protein was above this level (Anderson et al., 1988; Milton et al., 1997; Shain et al., 1998). Hence, it seems doubtful that the small increase in protein content above 13.9% with SS supplementation was responsible for the increased DMI seen with an increased amount of dietary SS in this experiment.

Consistent with the increased DMI, added SS linearly increased ADG from d 29 to 56 ($P = 0.01$), which contributed to an overall positive effect ($P = 0.02$) over the course of the 100-d trial. Engstrom et al. (1994) also reported a positive response of ADG only during the first 56 d of a 102-d finishing trial in which 4% canola oil was added to a barley-based finishing diet. Inconsistent growth rates throughout feeding periods are not uncommon, likely reflecting compensatory growth patterns that are known to occur in cattle (Berg and Butterfield, 1976). McKinnon et al. (1993a) observed increased daily gain by large-framed cattle when protein was increased from 13 to 15% in one trial in which high-energy barley-based diets were fed. However, this response is not always consistent and seems to be more prevalent with moderate- than with high-energy diets (McKinnon et al., 1993b). Thus, the ADG response to SS in Exp. 1 likely was the result of greater DMI and not an increase in protein concentration in the diet.

A linear improvement in G:F with increasing levels of SS was observed from d 29 to 56 ($P = 0.02$) as well as averaged over the total experiment ($P = 0.01$). Greater DMI contributes to improved G:F by increasing the amount of net energy above maintenance that is available for gain. However, very high intakes of feedlot diets containing grains that are not extensively processed are often associated with decreased G:F, presumably owing to decreased digestibility (Owens et al., 1995b). The improvement in G:F from replacing barley and silage with SS likely reflects greater intake of DE from the diet. Fat supplementation has improved the G:F of feedlot cattle fed barley-based finishing diets in most (Zinn, 1988; Zinn, 1989) but not all (Engstrom et al., 1994) experiments. Similarly, with corn-based diets, fat supplementation has improved G:F in some (Brandt et al., 1992; Zinn, 1992; Krehbiel et al., 1995) but not all (Johnson and McClure, 1973; Buchanan-Smith et al., 1974; Huffman et al., 1992) feeding experiments. Supplemental fat should be of greater benefit with diets based on barley or wheat than with diets based on corn (Brandt, 1995) owing to the lower fat content of barley and wheat (Brandt, 1995; Zinn and Plascencia, 2002); however, efficiency is not always improved by adding fat even with wheat-based diets (Zinn, 1992).

Unsaturated fats at high concentrations are toxic to cellulolytic bacteria (Palmquist and Jenkins, 1980), and, consequently, fat supplementation often reduces fiber digestibility (Palmquist and Jenkins, 1980; Zinn and Shen, 1996). No decrease in fiber digestibility was

Table 5. Effect of supplemental sunflower seed (SS) on carcass characteristics and liver abscess of cattle fed barley-based diets in Exp. 1

	Treatment[a]					*P*-values[b]		
Item	Control	9RSS-silage	9WSS	14WSS	14RSS	LIN	PROC	RGH
No. of observations	7	8	9	9	10			
Carcass weight, kg	338.2 ± 10.3	349.8 ± 9.8	360.4 ± 9.3	368.0 ± 9.3	362.0 ± 8.9	0.03	0.65	0.42
Dressing percent	58.3 ± 0.5	58.3 ± 0.5	59.0 ± 0.4	59.7 ± 0.4	59.1 ± 0.4	0.08	0.36	0.90
Backfat, mm	10.7 ± 1.4	11.7 ± 1.3	11.3 ± 1.3	13.7 ± 1.3	13.7 ± 1.2	0.11	0.98	0.59
LM area, cm^2	84.8 ± 3.2	87.0 ± 3.0	87.3 ± 2.9	93.7 ± 2.9	84.2 ± 2.7	0.29	0.02	0.61
Quality grade[c]	2.4 ± 0.2	2.2 ± 0.2	2.5 ± 0.2	2.4 ± 0.2	2.8 ± 0.2	0.76	0.15	0.44
Abscessed livers, %	33.3 ± 16.3	30.0 ± 15.5	27.3 ± 14.8	36.4 ± 14.8	33.3 ± 14.1	0.94	0.88	0.88
Severely abscessed, %[d]	22.2 ± 10.6	0.0 ± 10.0	0.0 ± 9.6	18.2 ± 9.6	16.7 ± 9.2	0.59	0.91	0.14

[a]Control diet contained 9% silage (no SS); 9RSS-silage =rolled SS replaced all of the silage; 9WSS = whole SS replaced 9% of grain + silage; 14WSS = whole SS replaced 14% of grain + silage; 14RSS = rolled SS replaced 14% of grain + silage. Diets 9WSS, 14WSS, and 14RSS contained 8.1, 7.7, and 7.7% silage, respectively.

[b]LIN = linear effect of including whole SS in the diet (0, 9, or 14%); PROC = effect of processing SS included at 14% (i.e., 14WSS vs. 14RSS); RGH = effect of roughage source (i.e., control diet vs. 9RSS-silage).

[c]1 = Canada Grade A (approximately equivalent to USDA Standard); 2 = AA (approximately equivalent to USDA Select); and 3 = AAA (approximately equivalent to USDA Choice).

[d]Exhibiting more than four small abscesses or at least one abscess >2.5 cm in diameter.

evident from growth performance in this experiment, but NDF concentrations in these diets were reasonably low (<26%). As well, negative effects of added fat can be attenuated by providing the oil as intact seeds (Larson and Schultz, 1970; Steele et al., 1971; Aldrich et al., 1997), because biohydrogenation can proceed as rapidly as oil is released. As a result, toxicity to cellulolytic microorganisms is mitigated (Palmquist, 1995); however, gain and efficiency responses were no better for whole than for rolled SS in this study.

Processing

Equal performance with 14WSS and 14RSS indicates little if any advantage from rolling SS before feeding. Steers fed 14RSS diets exhibited DMI, ADG, and G:F only 2.9, 3.7, and 0.6% lower, respectively, than those fed 14WSS ($P = 0.65$, 0.64, and 0.85, respectively). Using recorded performance data (Table 4) with NRC (1996) equations to calculate energy content revealed that diets containing whole SS surprisingly had slightly higher ME values than diets containing rolled SS (3.02 vs. 2.93 Mcal/kg; Table 4). In addition, an unexplainable increase ($P < 0.05$) in LM area was detected when whole rather than rolled SS was fed (Table 5).

Fecal Fat

Concentrations of ether extract in feces were higher ($P < 0.001$) when 14WSS (8%) or 14RSS (7.5%) were fed than when the control diet (4%) was fed (data not shown). If DM digestibility of these diets was assumed to be 80%, as is typical of barley-based finishing diets, digestibilities of fat in these diets would be 80, 81%, and 60%, respectively. Although these estimates do not allow precise determination of fat digestibility, these values indicate that the fat from SS may not have been completely digested. White et al. (1987) reported 86% digestibility for oil from whole SS included at 20% of the diet. When partially crushed, high-oleic acid SS was included at 20% of the diet, 95% of the fatty acids from the SS were absorbed (Chang et al., 1992). Digestibilities of saturated fatty acids (18:0 and 16:0) from SS, however, have been reported to be as low as 69 and 78%, respectively (Hogan and Hogan, 1976). Similarities ($P = 0.33$) in ether extract content of feces from steers fed diets containing 14% whole vs. 14% rolled SS, combined with similarities in intake and performance, indicate that processing the seed did not enhance digestibility of the oil. Whole SS must have been adequately masticated and/or ruminated to maximize digestibility of the lipid because whole SS is resistant to microbial fermentation (White et al., 1987; Palmquist, 1995). Increased fecal ether extract with supplementation of 14% whole SS would be expected as the dietary concentration of fat increased (Brandt, 1995; Zinn and Plascencia, 2002).

Sunflower Seed as a Roughage Source

Replacing silage with SS resulted in an improvement ($P < 0.01$) in G:F (0.157 vs. 0.129). This improved G:F reflects superior ($P = 0.10$) ADG with no effect ($P = 0.50$) on DMI. Improved efficiencies frequently are observed (Stock et al., 1990; Bartle et al., 1994; Traxler et al., 1995) when higher energy ingredients (i.e., SS) replace lower energy feeds (i.e., silage) in the diet unless fiber levels are inadequate for ruminal function (Bull et al., 1965; Hinders and Owen, 1965; Thorlacius and Lodge, 1973). Replacing silage with SS did not ($P = 0.88$) increase the incidence of liver abscesses (Table 5), indicating that despite its small particle size, effectiveness of roughage from SS may equal that of barley silage. The linear increase in DMI with increasing levels of whole SS supports this theory; however, steers penned and fed individually consume feed less aggressively (Kidwell et al., 1954; Coppock et al., 1972; Phipps et al., 1983) than

when fed as a group, so this experiment may lack the sensitivity needed to detect digestive challenges associated with low fiber levels. With no negative control treatment (0% roughage) to determine the necessity of including roughage in these diets, one cannot draw firm conclusions about the roughage value of SS. However, results indicate that SS could fully replace barley silage in diets of individually fed steers without negative effects on intake, performance, or liver abscess incidence or severity.

Energy Value of Sunflower Seed

Energy contents of the diets were calculated using DMI, ADG, and average animal weight (Table 4). Metabolizable energy and NE_g of diets increased linearly ($P = 0.01$) with SS content. Regression of ME against the percentage of SS in the diet yielded the following equation ($R^2 = 0.23$; $P < 0.01$):

$$\text{ME (Mcal/kg)} = 2.63 + 0.025 \times (\%\ \text{SS in diet})$$

with SE of 0.079 and 0.0071 for the y-intercept and slope, respectively. According to this formula, a diet with 100% SS would have an ME content of 5.13 Mcal/kg, almost 9% higher than the 4.71 Mcal/kg cited ME content of high-oil SS for dairy cows fed at 3× maintenance (NRC, 2001).

Effects of Sunflower Seed on Carcass Traits

Feeding whole SS tended to linearly increase ($P = 0.08$) final live weight and dressing percent and increased ($P = 0.03$) carcass weights (Tables 4 and 5). Backfat thickness tended ($P = 0.11$) to increase with SS content of the diet. At modest rates of gain (<1.3 kg/d), carcass fat usually increases with increases in growth rates (Owens et al., 1995a). Supplemental lipid often results in increased carcass fat that is in turn associated with an increased dressing percent (Owens et al., 1993). The higher dressing percent observed with feeding SS in the present study would not reflect increases in kidney, pelvic, and heart fat alone, as is often observed with fat supplementation in the United States (Cameron and Hogue, 1968; Zinn, 1989; Clary et al., 1993) because these deposits are removed from the carcasses in Canadian slaughter plants.

Tissue Fatty Acid Profiles

Despite the fact that unsaturated fatty acids are extensively biohydrogenated in the rumen (Palmquist and Jenkins, 1980), alterations in fatty acid profiles of liver, diaphragm, and brisket fat were observed when SS was fed (Table 6). Differences between diets, however, were not consistent across these tissues. Fatty acid profiles differ among tissues (Dryden and Marchello, 1973; Garrett et al., 1976; Hogan and Hogan, 1976) presumably as a result of differences in their accretion of specific fatty acids (Hood and Thornton, 1976) and desaturase activity (Chang et al., 1992). The effects of dietary SS on carcass subcutaneous and diaphragm fat were similar, but effects on liver lipids often opposed those observed in subcutaneous and diaphragm fat.

Including rolled SS in the diet increased ($P = 0.02$) 17:0 in the liver, but decreased ($P = 0.07$) prevalence of 18:2. Whole SS decreased ($P = 0.03$) prevalence of 18:1 compared with the control diet and also reduced ($P < 0.05$) levels of 20:4. Both SS treatments increased ($P < 0.05$) saturation of fatty acids in the liver. In contrast, SS decreased the prevalence of 16:0 ($P < 0.001$), 16:1 ($P = 0.01$), 17:0 ($P < 0.001$), 18:3 ($P = 0.001$), and 20:4 ($P = 0.06$) in the diaphragm, but increased ($P = 0.05$) prevalence of *cis*-9,*trans*-11-CLA. Similarly, SS increased prevalence of 18:1 ($P < 0.001$), 18:2 ($P = 0.002$), *cis*-9,*trans* 11-CLA ($P = 0.05$), *trans*-10,*cis*-12-CLA ($P < 0.001$), and total unsaturated fatty acids ($P = 0.06$) in subcutaneous fat. These observations are consistent with the proposal by Beaulieu et al. (2002) that CLA may be deposited preferentially in subcutaneous fat. Contrast comparisons also indicated that the prevalence of 18:3 and saturation of fatty acids were decreased (both at $P = 0.05$) by including 14% SS in the diet.

Surprisingly, changes in fatty acid profiles with SS supplementation were not consistent between whole and rolled SS. For example, decreases in 14:1 ($P = 0.03$) and 16:0 ($P = 0.02$) in subcutaneous fat were seen only with whole SS, whereas only rolled SS decreased concentrations of 17:0 ($P = 0.02$) and 18:3 ($P = 0.005$) in subcutaneous fat. Processing the SS probably increased both the rate and extent of fatty acid exposure and hydrogenation in the rumen, which could influence both the microbial populations in the rumen and the type of fatty acids available for absorption. Consistent with this theory, only whole SS increased ($P = 0.01$) the prevalence of 18:2 in diaphragm tissue. The reason why whole SS increased ($P < 0.001$) the prevalence of 18:2 in subcutaneous fat, however, is not clear. Decreased hydrogenation of oil from whole compared with processed oilseeds, which has been suggested previously (Baldwin and Allison, 1983; Aldrich et al., 1997), may have led to greater deposition of unsaturated fatty acids in target tissues with whole than with rolled SS.

Including 14% SS in the diet reduced ($P < 0.05$) the prevalence of 16:0 in both diaphragm and subcutaneous fat, more so with whole than with rolled seeds. This is consistent with reported milk fat responses to supplemental SS (McGuffey and Schingoethe, 1982; Rafalowski and Park, 1982; Markus et al., 1996). Increased dietary fat reduces the rate of de novo fatty acid synthesis in ruminants (Vernon, 1976) by inhibiting acetyl-CoA carboxylase activity (Palmquist and Jenkins, 1980). Thus, the SS-mediated decreases in 16:0 concentrations observed in the present study could presumably have arisen from depressed de novo synthesis as a result of the increased dietary supply of lipid from SS.

Table 6. Fatty acid profiles of liver, diaphragm, and s.c. (brisket) fat from cattle fed diets with and without sunflower seed (SS) in Exp. 1[a]

	Liver					Diaphragm					Subcutaneous				
Fatty acid[b]	Cont	14WSS	14RSS	SE[c]	Cont vs. SS[d]	Cont	14WSS	14RSS	SE	Cont vs. SS	Cont	14WSS	14RSS	SE	Cont vs. SS
14:0	1.56	1.77	1.74	0.22	0.44	2.55	2.41	2.48	0.15	0.47	3.67	3.73	3.66	0.15	0.90
14:1	0.17	0.25	0.24	0.78	0.10	0.30	0.27	0.31	0.55	0.63	3.45^{y}	1.69^{z}	2.18^{yz}	0.55	0.16
16:0	24.53	26.68	27.09	1.26	0.31	26.92^{y}	23.07^{z}	24.91^{yz}	0.89	0.0001	28.96^{y}	25.95^{z}	26.47^{yz}	0.89	0.03
16:1	1.15	1.33	1.55	0.54	0.13	1.15	0.95	1.02	0.38	0.01	4.67	4.21	4.20	0.38	0.53
17:0	0.92^{y}	1.01^{yz}	1.19^{z}	0.07	0.06	1.45^{y}	1.24^{z}	1.15^{z}	0.05	0.0001	0.97^{y}	1.01^{y}	0.80^{z}	0.05	0.39
18:0	11.34	14.58	15.05	2.11	0.48	9.10	12.62	9.33	1.49	0.30	2.81	3.25	2.79	1.49	0.54
18:1	42.52^{y}	36.76^{z}	37.68^{yz}	1.83	0.17	55.60	54.83	57.66	1.30	0.67	52.80^{z}	56.62^{y}	56.92^{y}	1.30	0.0006
18:2	7.22^{y}	7.64^{y}	4.86^{z}	0.74	0.35	1.44^{z}	3.29^{y}	1.86^{z}	0.52	0.20	1.15^{z}	1.84^{y}	1.40^{z}	0.52	0.002
18:3	0.39	0.39	0.41	0.03	0.82	0.40^{y}	0.32^{z}	0.30^{z}	0.02	0.001	0.39^{y}	0.34^{y}	0.29^{z}	0.02	0.05
20:0	0.09	0.07	0.09	0.01	0.65	0.19	0.18	0.17	0.01	0.08	0.10	0.12	0.08	0.01	0.65
20:1	0.11	0.09	0.12	0.02	0.93	0.21	0.20	0.21	0.02	0.60	0.20	0.24	0.23	0.02	0.12
20:4	9.40^{y}	8.87^{z}	9.35^{y}	0.12	0.53	0.28	0.15	0.14	0.12	0.06	0.01	0.02	0.01	0.12	0.46
C9-T11	0.58	0.56	0.64	0.06	0.80	0.38	0.45	0.42	0.04	0.05	0.78^{z}	0.92^{y}	0.91^{y}	0.04	0.05
T10-C12	0.03	0.02	0.02	0.01	0.37	0.02	0.03	0.03	0.01	0.28	0.03^{z}	0.08^{y}	0.07^{y}	0.01	0.0002
Saturated	38.44^{z}	44.10^{y}	45.15^{y}	2.01	0.13	40.21	39.51	38.05	1.42	0.37	36.51	34.05	33.79	1.42	0.06
Unsaturated	61.56^{y}	55.90^{z}	54.85^{z}	2.01	0.13	59.79	60.49	61.95	1.42	0.37	63.49	65.96	66.21	1.42	0.06

[a]Cont = control diet (0% SS); 14WSS = diet contained 14% whole SS; 14RSS = diet contained 14% rolled SS.
[b]Expressed as % of total fatty acids. C9-T11 = *cis*-9,*trans*-11-conjugated linoleic acid (CLA); T10-C12 = *trans*-10,*cis*-12-CLA.
[c]Standard error of treatment means, n = 10.
[d]*P*-value for the contrast comparing the control diet to both sunflower seed diets.
[y,z]Within a row and tissue type, values without a common superscript differ, $P < 0.05$.

Table 7. Performance of steers fed barley- or corn-based finishing diets containing high-linoleic acid or high-oleic acid sunflower seed (SS) in Exp. 2

	Barley-based diets[a]			Corn-based diets[a]				
Item	No SS (control)	High-linoleic SS	High-oleic SS	No SS (control)	High-linoleic SS	High oleic SS	SE[b]	Grain[c]
Initial BW, kg	356.5	351.1	354.8	354.2	353.9	354.0	5.6	0.98
Final BW, kg	592.0^{x}	554.1^{y}	590.3^{x}	585.6^{x}	597.4^{x}	585.9^{x}	10.8	0.22[d]
Days 1 to 28								
DMI, kg/d	9.11^{x}	8.69^{y}	9.21^{x}	9.37^{x}	9.49^{x}	9.58^{x}	0.24	0.02
ADG, kg	1.73^{x}	1.50^{xy}	1.44^{y}	1.60^{xy}	1.59^{xy}	1.60^{xy}	0.10	0.59
G:F	0.189^{x}	0.172^{xy}	0.156^{y}	0.170^{xy}	0.169^{xy}	0.167^{xy}	0.010	0.64
Days 29 to 56								
DMI, kg/d	9.46^{xy}	8.90^{y}	9.84^{x}	9.40^{xy}	9.85^{x}	9.63^{xy}	0.28	0.31[e]
ADG, kg	1.83	1.59	1.86	1.89	1.89	1.75	0.12	0.40
G:F	0.193	0.177	0.190	0.200	0.191	0.186	0.01	0.57
Days 57 to 172								
DMI, kg/d	9.36^{x}	8.35^{y}	9.50^{x}	8.81^{xy}	9.08^{xy}	9.19^{x}	0.27	0.85[d]
ADG, kg	1.17^{x}	1.00^{y}	1.23^{x}	1.15^{x}	1.26^{x}	1.19^{x}	0.05	0.12[d]
G:F	0.125^{xy}	0.120^{z}	0.130^{xyz}	0.131^{xy}	0.139^{x}	0.128^{xyz}	0.003	0.02[d]
Days 1 to 172								
DMI, kg/d	9.33^{x}	8.49^{y}	9.50^{x}	9.00^{xy}	9.27^{x}	9.32^{x}	0.25	0.67e
ADG, kg	1.37^{x}	1.18^{y}	1.37^{x}	1.35^{x}	1.42^{x}	1.35^{x}	0.05	0.11[d]
G:F	0.146^{xy}	0.139^{y}	0.144^{xy}	0.150^{x}	0.153^{x}	0.144^{xy}	0.004	0.05[e]

[a]Whole SS high in linoleic acid or high in oleic acid were included in diets at 14%.
[b]Standard error of treatment means, n = 20.
[c]Probability of effect of grain type.
[d,e]Interactive effect (grain type × SS type) significant at $P < 0.05$ or $P < 0.10$, respectively.
[x,y,z]Within a row, values without a common superscript differ, $P < 0.05$.

The effects of dietary vegetable oils on duodenal flow of the *cis*-9,*trans*-11-CLA isomer (Duckett et al., 2002) or its incorporation into carcass fat (McGuire et al., 1998; Beaulieu et al., 2002) in cattle have been minimal. In contrast, the effect of supplementary oil in diets for lambs on the CLA content of tissues has been dramatic. Feeding 6% sunflower seed oil to lambs increased total CLA content by 33 to 55% in diaphragm, leg, rib, heart, liver, kidney, and subcutaneous fat (Ivan et al., 2001). Similarly, 6% safflower oil in the diet increased CLA content more than 200% in each of these tissues (Mir et al., 2000). The *cis*-9,*trans*-11 isomer, which was increased in diaphragm and subcutaneous fat by feeding SS in the present study, is thought to provide the greater anticancer benefits for humans (MacDonald, 2000), although other isomers may offer benefits in animal production by altering energy retention through modulation of fat synthesis or catabolism.

Experiment 2

Interactive effects of location of pen within the barn and dietary treatment were not detected ($P > 0.20$) during any period of the experiment for any of the variables considered. Consequently, location was removed from the statistical model. Initial full weight averaged 354 kg with no differences among treatments ($P = 0.89$). As in Exp. 1, the performance indicators were analyzed for the first two 28-d periods, for the remainder of the experiment (d 57 to 172), and over the entire 172-d experiment (Table 7).

No interactive effects ($P > 0.28$) of grain source and SS variety (high linoleic vs. high oleic acid) on DMI, ADG, or G:F were detected for the first 28 d of the feeding trial (Table 7). However, DMI by steers fed barley with high-linoleic SS was lower ($P < 0.05$) than DMI by those fed the other diets. Averaged across grain types, SS did not affect DMI ($P = 0.46$), ADG ($P = 0.29$), or G:F ($P = 0.20$). Cattle fed corn-based diets ate more DM (9.48 vs. 9.00 kg/d; $P = 0.02$) than cattle fed barley, but their ADG (1.60 vs. 1.55 kg; $P = 0.59$) and G:F (0.169 vs. 0.173; $P = 0.64$) were similar between grain types. During this initial period, the steers fed high-oleic SS tended ($P = 0.07$) to be less efficient than those fed no SS (0.162 vs. 0.180).

During the second 4 wk of the experiment (d 29 to 56), a trend toward an interaction of grain type and SS type on DMI was observed ($P = 0.08$). When the diets were barley-based, DMI was lower ($P = 0.02$) when high-linoleic SS was fed than when high-oleic SS was fed, whereas, with corn-based diets, the steers receiving high-linoleic SS had the numerically highest DMI. No other differences in performance were detected during this period.

Over the remainder of the feeding trial (d 57 to 172), the effects of SS on performance indicators were inconsistent across grain types, and SS × grain type interactions ($P < 0.05$) were detected for DMI, ADG, and G:F. Feeding high-linoleic SS negatively affected ($P < 0.05$) DMI and ADG with barley-based diets but not ($P = 0.19$) with those based on corn.

Table 8. Carcass traits of steers fed barley- or corn-based finishing diets containing sunflower seed (SS) high in linoleic or oleic acids in Exp. 2

	Barley-based diets[a]			Corn-based diets[a]				
Item	No SS (control)	High-linoleic SS	High-oleic SS	No SS (control)	High-linoleic SS	High-oleic SS	SE[b]	Grain[c]
Carcass wt, kg	345.9^{xy}	329.1^{y}	346.5^{xy}	350.0^{x}	350.8^{x}	350.4^{x}	6.3	0.06
Dressing percent	58.5^{z}	59.4^{xy}	58.7^{yz}	59.7^{x}	58.8^{yz}	59.9^{x}	0.32	0.03[f]
Backfat, mm	17.7^{yz}	16.7^{z}	20.6^{xy}	19.1^{xyz}	21.6^{x}	20.0^{xy}	1.23	0.04[g]
Quality grade[d]	2.30	2.05	2.20	1.95	2.05	2.05	0.14	0.14
LM area, cm^2	76.3^{xy}	76.8^{xy}	77.5^{xy}	79.1^{x}	74.7^{y}	79.7^{x}	1.45	0.43
Saleable meat, %	51.6^{xy}	52.8^{x}	49.8^{y}	51.1^{xy}	48.4^{y}	50.5^{xy}	0.94	0.07[f]
Abscessed livers, %	15.0	5.0	20.0	5.0	20.0	10.0	7.45	0.78
Severely abscessed livers, %[e]	0.0	5.0	5.0	5.0	10.0	0.0	4.51	0.65

[a]Whole SS high in linoleic acid or high in oleic acid were included in diets at 14%.
[b]Standard error of treatment means, n = 20.
[c]Probability of effect of grain type.
[d]1 = Canadian quality grade A (approximately equivalent to USDA Standard); 2 = AA (approximately equivalent to USDA Select); and 3 = AAA (approximately equivalent to USDA Choice).
[e]Exhibiting more than four small abscesses or at least one abscess >2.5 cm in diameter.
[f,g]Interactive effect (grain type × SS type) significant at $P < 0.05$ or $P < 0.10$, respectively.
[x,y,z]Within a row, values without a common superscript differ, $P < 0.05$.

Similar to the latter portion of the study, the effects of SS on DMI over the entire feeding period (d 1 to 172) were inconsistent, and grain type × SS source interactions were detected for G:F and DMI (trends at $P = 0.11$ and $P = 0.06$, respectively) and ADG ($P = 0.01$). When diets were barley based, including high-linoleic SS decreased DMI ($P = 0.02$) and ADG ($P = 0.007$) compared with no SS supplementation. In contrast, when diets were corn based, SS did not affect ($P > 0.55$) DMI, ADG, or G:F. Final live weights (Table 7) and carcass weights (Table 8) were lower ($P < 0.05$ and $P < 0.06$, respectively) for steers fed high-linoleic SS with barley than for steers fed any of the other diets.

Incorporating high-linoleic SS increased ($P = 0.04$) carcass dressing percent when the barley-based diets were fed but reduced it ($P = 0.03$) when diets were corn based (Table 8; interactive effect at $P = 0.005$). Longissimus muscle area was lower ($P < 0.05$) with the high-linoleic SS, corn-based diet than with the other corn-based diets. Among steers fed barley, those fed high-linoleic SS had less backfat compared with those receiving no SS ($P = 0.02$), which is reflective of the slower gain rate, but LM area was not altered ($P = 0.75$). The decreased backfat thickness contributed to a greater saleable meat ($P = 0.02$) for steers fed high-linoleic SS compared with those fed high-oleic SS. No differences were observed in quality grade among treatments. The incidence of abscessed livers ranged from 5 to 20% across treatments, whereas the incidence of severe abscess ranged from 0 to 10%. Statistically significant differences in liver abscess rates among treatments were not detected.

Sunflower seed did not affect organoleptic properties of meat from barley-fed cattle, but minor differences were detected when diets were corn based (Table 9). When corn diets were fed, added high-oleic acid SS increased ($P = 0.02$) juiciness (6.0 vs. 4.7 on a hedonistic scale, where 1 is least desirable and 8 is most desirable), whereas linoleic SS increased initial and overall tenderness (6.4 vs. 5.4; $P = 0.02$). Level or source of SS did not affect warmed-over flavor of meat. On the basis of observed DMI, the additional vitamin E that was incorporated into the diets in Exp. 2 to mitigate the tendency of supplemental dietary oil to increase carcass fat oxidation provided an average of approximately 900 IU daily to each steer.

Differences in response to SS between these two experiments are difficult to explain. Nutrient levels and fatty acid profiles of SS used in Exp. 1 were similar to those of the high-linoleic SS used in Exp. 2. The 14% SS diet containing whole SS in Exp. 1 was quite similar to the barley-based diet supplemented with linoleic SS of Exp. 2, but responses in growth and intake to added SS differed substantially. Compared with Exp. 1, cattle in Exp. 2 weighed less (354 vs. 484 kg initial weight) and were therefore fed longer (172 vs. 100 d). Cattle in Exp. 1 were preadapted to their finishing diets before the initiation of the experiment, whereas SS was included in transition diets in Exp. 2. Cattle in Exp. 1 were implanted, but implants were not used in Exp. 2. Diets were not isonitrogenous between treatments in Exp. 1 (13.9 to 14.9%), but diets were isonitrogenous in Exp. 2 (13.4%). Differences in carcass trends noted between experiments may be due to the anabolic implants used or to the fact that the cattle in Exp. 1 had a higher percentage of exotic (Charolais × Simmental) breeding and a larger frame size compared with the British cattle used in Exp. 2. On average, cattle in Exp. 1 had considerably less backfat and larger LM areas than cattle in Exp. 2. Several trials (Byers and Parker, 1979; Tatum et al., 1988; McKinnon et al., 1993a) have found that cattle with larger frame size are more responsive to increased energy levels than are medium-framed animals. Decreased genetic potential to utilize

Table 9. Organoleptic properties of steaks from steers fed barley- or corn-based finishing diets containing high-linoleic acid or high-oleic acid sunflower seed (SS) in Exp. 2

	Barley-based diets[a]			Corn-based diets[a]			
Property[b]	No SS (control)	High-linoleic SS	High-oleic S	No SS (control)	High-linoleic SS	High-oleic SS	Grain[c]
Juiciness	5.6 ± 0.40^{yz}	5.5 ± 0.26^{yz}	5.4 ± 0.24^{yz}	4.7 ± 0.36^{z}	5.6 ± 0.23^{yz}	6.0 ± 0.21^{y}	0.92
TD initial	5.7 ± 0.28^{yz}	5.8 ± 0.22^{yz}	6.3 ± 0.20^{y}	5.4 ± 0.39^{z}	6.4 ± 0.16^{y}	6.0 ± 0.31^{yz}	0.71
TD overall	6.1 ± 0.33^{yz}	5.8 ± 0.20^{yz}	6.2 ± 0.16^{yz}	5.4 ± 0.43^{z}	6.4 ± 0.19^{y}	6.1 ± 0.35^{yz}	0.81
Flavor	4.2 ± 0.22	4.8 ± 0.33	4.5 ± 0.17	4.7 ± 0.29	4.6 ± 0.24	4.4 ± 0.20	0.67
Off-flavor[d]	1.5 ± 0.23	1.3 ± 0.45	1.2 ± 0.45	0.8 ± 0.32	0.7 ± 0.28	1.2 ± 0.41	0.19

[a]Whole SS high in linoleic acid or high in oleic acid were included in diets at 14%.
[b]Properties (n = 20) were scored on an 8-point scale (1= least desirable; 8 = most desirable). TD initial = initial tenderness; TD overall = overall tenderness.
[c]P value for effect of grain type.
[d]Off-flavors were scored on a 9-point scale (0 = no off-flavors; 8 = intense off-flavor).
[y,z]Within a row, values without a common superscript differ, $P < 0.05$.

increased energy as well as increased carcass fat might be responsible for the lack of response to SS supplementation in Exp. 2.

Implications

Sunflower seed provides energy-dense oil, does not require processing, and can provide some of the required dietary fiber in finishing diets. Inconsistencies in performance across these two experiments make it difficult to establish an energy value of sunflower seed. The optimum sunflower seed type for finishing diets may differ with grain source. Linoleic acid sunflower seed fed at 14% of dietary dry matter favorably altered fatty acid profiles and conjugated linoleic acid concentrations of tissues but may decrease cattle performance with barley-based diets. In taste panel comparisons, including sunflower seed at 14% of dietary dry matter

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