Utilization of Omega-3 Fatty Acids is Improved by Embedding Flaxseed in a Matrix of Dolomitic Lime Hydrate

C. Alvarado Gilis, C.L. Van Bibber-Krueger, K.A. Miller, E. San Vito, G. Feltrin, D. Klamfoth, and J.S. Drouillard

Introduction

Omega-3 fatty acids are essential nutrients for humans, but American diets are often deficient in these important long-chain fats. Incorporating greater proportions of omega-3 fatty acids into beef offers a means of increasing daily consumption of essential fats, while also enhancing the perceived value of beef. In cattle, dietary polyunsaturated fats are extensively hydrogenated into saturated fats by microbes in the rumen. This effectively decreases the efficiency of transfer for fats from the animal's diet into edible beef tissues, because the bacteria convert more than 90% of the polyunsaturated fats into saturated fats before they are absorbed into the animal's blood stream. Preventing this saturation process in the rumen would increase the proportion of dietary omega-3 fatty acids that are available for deposition into beef, thus making the production of omega-3-enriched beef more cost-effective. We have devised a method for improving the stability of fats in the rumen that effectively increases their resistance to the hydrogenating actions of rumen microbes. Sources of polyunsaturated fats are combined with dolomitic lime hydrate, water is added, and the mixture is blended at a high rate of rotation, yielding a densified matrix with improved ruminal stability. Our objective in this study was to evaluate feedlot performance, carcass characteristics, and blood profiles of long-chain fatty acids in cattle fed diets containing varying concentrations of ground flaxseed or ground flaxseed embedded in the dolomitic lime matrix.

Experimental Procedures

Crossbred heifers (454 heifers, 763 ± 44 lb) were blocked by weight, randomly assigned to dietary treatments, and placed into small feedlot pens (11 replicates). This experiment included six treatment groups in a randomized complete block design. Treatments consisted of a control diet without flaxseed; diets with 3 or 6% ground flaxseed, and diets with 2, 4, or 6% of a matrix containing 50% ground flaxseed and 50% dolomitic lime hydrate. Heifers were fed a basal diet containing a combination of steam-flaked corn, wet corn gluten feed, and roughage supplemented with vitamins A and E, macro minerals (calcium, potassium), inorganic trace minerals (Na, Co, Cu, I, Mn, Se, and Zn), Rumensin, and Tylan (Elanco Animal Health, Greenfield, IN) (Table 1). For the treatments containing the flaxseed/lime matrix, ground flaxseed was combined with dolomitic lime hydrate in a 50:50 ratio, then processed to form dense granules. Cattle were fed once daily and had *ad libitum* access to feed and water. Heifers were implanted (Component TE-200; Zoetis, Florham Park, NJ), dewormed (Dectomax; Zoetis), and vaccinated against common viral and clostridial diseases (Ultra-Bac 7 and Bovi-shield Gold 5; Zoetis Inc.).

Blood samples were taken from the jugular vein for analysis of long-chain fatty acids at the beginning of this experiment after 29 days on feed. Blood was collected in heparinized vacuum tubes, which were immediately placed on ice and centrifuged (1200 x *g* for 20 minutes), and plasma was collected and frozen for later analysis by gas chromatography. Starting 23 days before harvest, zilpaterol hydrochloride was added to the diet for 20 days, followed by a 3-day withdrawal. We harvested the six heaviest pens from each treatment on day 140 and the remaining 5 pens from each treatment on day 168 at a commercial abattoir, where we collected slaughter data (hot carcass weight and liver abscesses). Carcasses were chilled for 24 hours, then evaluated for fat thickness over the 12th rib; percentage of kidney, pelvic, and heart fat; ribeye area, marbling score, and USDA yield and quality grades. Data were statistically analyzed using the MIXED procedure of SAS (Version 9.1; SAS Institute, Cary, NC) with treatment as fixed effects, block as the random effect, and pen as the experimental unit.

Results and Discussion

Plasma concentrations of long-chain fatty acids in blood plasma are shown in Table 2. The day-0 values were used as a baseline, as all animals had consumed a similar diet up to this point. As expected, no significant treatment differences were detected in plasma concentrations of long-chain fatty acids on day 0 of the experiment. Feedlot diets, including the one used prior to the start of this trial, normally contain only small amounts of omega-3 fatty acids. Concentrations of alpha-linolenic acid, the principal omega-3 fatty acids found in plants, averaged 40 μg/mL of plasma, which is consistent with low levels of the fatty acid in the diet. When plasma was evaluated after 29 days of feeding the experimental diets, concentrations of alpha-linolenic acid increased sharply for cattle fed diets containing flaxseed, regardless of the form. The greatest concentration of omega-3 fats was achieved by feeding the diet with 6% ground flaxseed. Feeding different levels of ground flaxseed and flaxseed embedded in the lime matrix allowed us to determine the relative efficiencies for assimilation of alpha-linolenic acid from the diet into the blood stream. Based on linear regression slopes, embedding flaxseed in limestone improved transfer efficiency by approximately 42% compared with ground flaxseed.

Table 3 summarizes feedlot performance. Cattle fed diets without flaxseed, 3 or 6% ground flaxseed, and 2% of the hydrate/flax blend all had comparable dry matter intakes; however, feeding 4 or 6% of the hydrate/flax combination decreased feed intake in a linear manner. The sharp decrease in feed intake for cattle fed these treatments resulted in poorer average daily gain and lighter final weights compared with other treatments, but efficiencies were unchanged. The specific cause of this decrease in feed consumption is unclear, and was not observed in previous studies with cattle fed the hydrate:flaxseed blend in combination with forage-based diets. We have speculated that the higher concentrations of hydrate may disrupt normal cation-anion balance, thus leading to feed intake depression.

Carcass characteristics follow a pattern similar to that observed for live animal performance (Table 4). Compared with their counterparts fed the control, flaxseed, and 2% hydrate:flaxseed treatments, heifers fed diets containing 4 or 6% of the hydrate:flaxseed had lighter carcasses that generally were leaner. This was most evident in the group fed the 6% hydrate:flaxseed blend, and they were further distinguished by having the lowest percentage of carcasses in the USDA Prime and premium Choice categories.

Implications

Flaxseed can be used effectively as a of source alpha-linolenic acid, and it can be protected against rumen biohydrogenation by embedding it in a matrix of dolomitic lime hydrate. Encapsulating ground flaxseed in a matrix of dolomitic lime hydrate increased omega-3 fatty acid assimilation efficiency by 42% compared with ground flaxseed alone, but incorporation of more that 2% of the diet dry matter as the hydrate blend can decrease feed intake and daily gain.

Acknowledgements

Funding for this project was provided by Lhoist North America.

Table 1. Experimental diets

Ingredients, %	Control	3% flax	6% flax	2% flax/ lime	4% flax/ lime	6% flax/ lime
Steam-flaked corn	54.58	52.47	50.49	53.47	52.37	51.26
Corn gluten feed	30.00	30.00	30.00	30.00	30.00	30.00
Corn silage	5.00	5.00	5.00	5.00	5.00	5.00
Wheat straw	3.00	3.00	3.00	3.00	3.00	3.00
Soybean meal	1.66	0.84	--	1.46	1.26	1.06
Flaxseed	--	3.00	6.00	--	--	--
Flaxseed/lime	--	--	--	2.00	4.00	6.00
Supplement[1]	5.76	5.69	5.51	5.07	4.37	3.68

[1] Formulated to provide 300 mg/day Rumensin (Elanco Animal Health, Greenfield, IN), 1,000 IU/lb vitamin A, 0.25% salt, 0.7% calcium, 0.7% potassium, 0.1 ppm cobalt, 10 ppm copper, 0.6 ppm iodine, 60 ppm manganese, 0.25 ppm selenium, and 60 ppm zinc in the total diet on a 100% dry matter basis.

Table 2. Fatty acids concentration in plasma (µg/mL of plasma) in the control diet and supplemented with ground flaxseed or flaxseed encapsulated within a matrix of dolomitic lime hydrate at day 0 and 29[1]

Fatty acid[2]	Control	3% flax	6% flax	2% flax/ lime	4% flax/ lime	6% flax/ lime	SEM	*P*-value
Day 0								
C16:0	324.9	334.9	319.4	298.5	315.3	316.4	11.92	0.179
C18:0	418.2	440.6	423.9	392.8	423.8	423.1	15.80	0.209
C18:1n9c	247.9	245.5	252.3	223.1	241.7	240.7	13.13	0.325
C18:2n6c	1,341.8	1,398.4	1,302.9	1,292.9	1,327.8	1,326.7	62.43	0.648
C18:3n6	10.8	11.5	10.4	9.8	11.5	11.0	1.34	0.934
C18:3n3	41.5	40.2	43.2	36.7	41.8	39.6	2.59	0.370
Day 29								
C16:0	216.6[b]	241.9[a]	243.6[a]	227.2[ab]	221.1[b]	238.3[ab]	7.37	0.012
C18:0	325.2[d]	401.9[ab]	422.6[a]	347.9[cd]	363.1[c]	375.9[bc]	14.22	<0.001
C18:1n9c	116.4[b]	132.9[a]	144.3[a]	135.7[a]	134.8[a]	142.9[a]	5.20	<0.001
C18:2n6c	1,206.7[b]	1,422.9[a]	1,472.8[a]	1,234.4[b]	1,265.9[b]	1,227.9[b]	43.61	<0.001
C18:3n6	8.6[a]	4.5[c]	1.4[d]	7.8[ab]	6.0[bc]	4.7[c]	0.73	<0.001
C18:3n3	21.4[e]	145.9[c]	278.0[a]	72.3[d]	138.7[c]	208.1[b]	5.86	<0.001

[1] Ground flaxseed was encapsulated into a matrix consisting of 50% flaxseed and 50% dolomitic lime hydrate.

[2] Expressed as ug/mL of blood plasma. C16:0 is palmitic acid; C18:0 is stearic acid; C18:1n9 is oleic acid; C18:2n6 is linoleic acid (an omega-6 fatty acid); C18:3n6 is gamma linolenic acid (an omega-6 fatty acid); and C18:3n3 is alpha-linolenic acid (an omega-3 fatty acid).

[a,b,c,d,e] Means in the same row without a common superscript letter are different, $P < 0.05$.

Table 3. Feedlot performance of heifers supplemented with flaxseed or flaxseed encapsulated in a dolomitic lime matrix[1]

Item	Control	3% flax	6% flax	2% flax/ lime	4% flax/ lime	6% flax/ lime	SEM	*P*-value
Initial weight, lb	764.7	762.1	754.6	763.3	765.5	764.6	13.74	0.261
Final weight, lb	1217.5[a]	1234.1[a]	1223.4[a]	1223.7[a]	1185.6[b]	1116.9[c]	14.15	<0.001
Daily gain, lb	2.97[a]	3.11[a]	3.09[a]	3.03[a]	2.77[b]	2.32[c]	0.076	<0.001
Feed intake, lb/day (dry basis)	19.7[a]	19.4[a]	19.4[a]	19.6[a]	18.6[b]	16.4[c]	0.353	<0.001
Feed:gain	6.80	6.62	6.67	6.85	6.80	6.80	0.137	0.717

[1] Ground flaxseed was encapsulated into a matrix consisting of 50% flaxseed and 50% dolomitic lime hydrate.

[a,b,c] Means in the same row without a common superscript letter are different, $P < 0.05$.

Table 4. Carcass traits of heifers supplemented with flaxseed or flaxseed encapsulated in a dolomitic lime matrix[1]

Item	Control	3% flax	6% flax	2% flax/ lime	4% flax/ lime	6% flax/ lime	SEM	*P*-value
Carcass weight, lb	773.1[a]	781.5[a]	776.8[a]	775.9[a]	751.7[b]	709.2[c]	9.02	<0.001
Ribeye area, sq. in.	13.52[b]	13.65[ab]	13.95[a]	13.92[a]	13.19[bc]	13.11[c]	0.161	<0.001
12th-rib fat, in.	0.61[a]	0.63[a]	0.61[a]	0.60[a]	0.59[a]	0.48[b]	0.021	<0.001
Kidney, pelvic, and heart fat, %	2.63	2.59	2.88	2.87	2.56	2.69	2.08	0.440
Marbling score	493[a]	499[a]	491[a]	490[a]	497[a]	449[b]	12.4	0.040
USDA yield grade	2.73[a]	2.76[a]	2.62[a]	2.57[ab]	2.76[a]	2.32[b]	0.101	0.012
Yield grade 1, %	5.33	5.33	9.09	9.33	8.00	18.18	3.40	0.104
Yield grade 2, %	30.67	28.00	29.87	36.00	30.67	35.06	5.42	0.854
Yield grade 3, %	50.67	52.00	50.65	42.67	40.00	42.86	5.81	0.506
Yield grade 4, %	12.00	14.67	10.39	12.00	20.00	3.90	3.90	0.078
Yield grade 5, %	1.33	0.00	0.00	0.00	1.33	0.00	0.77	0.505
Liver abscesses, %	14.67	16.00	7.79	14.67	12.00	10.39	3.92	0.631
Prime, %	4.00	1.33	9.09	5.33	2.67	1.30	2.26	0.119
Premium Choice, %	24.00[bc]	40.00[a]	29.87[ab]	37.33[ab]	32.00[ab]	15.58[c]	5.26	0.010
Choice, %	86.67[ab]	90.67[a]	76.62[b]	74.67[b]	80.00[ab]	75.32[b]	4.69	0.036
Select, %	8.00	6.67	14.29	16.00	13.33	18.18	4.12	0.136
No roll, %	1.33	1.33	0.00	4.00	4.00	5.20	0.95	0.690

[1] Ground flaxseed was encapsulated into a matrix consisting of 50% flaxseed and 50% dolomitic lime hydrate.
[a,b,c] Means in the same row without a common superscript letter are different, $P < 0.05$.