2010

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Influence of dietary corn oil on production efficiencies and adipose and muscle accretion in beef cattle[1]

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BEEF 2010-04

SUMMARY

The objective of this research was to determine shifts in metabolism associated with differences in marbling relative to total fatness in beef carcasses. Dietary starch is thought to optimize accumulation of intramuscular adipose (IAT). The two mechanisms used to alter IAT accumulation were to substitute either readily fermentable fiber or corn oil for starch from corn. The model involved yearling steers (n = 144) during a 131 d finishing phase. The control diet contained 8.5% roughage and 81.2% corn. A higher fiber finishing diet included substitution of chopped, high moisture ear corn (43.7%) and dried corn gluten feed (18.2%) for corn. Corn germ was included to provide 0, 2, or 6% corn oil in both the starch and fiber diets. Carbohydrate source (CHO) affected ($P < 0.05$) apparent energy content of the diet. The higher fiber diet resulted in lower ADG, higher DMI, and lower gain/feed. This lowered hot carcass weight (HCW) from 832 to 801 lb ($P < 0.01$) but did not alter other measured carcass traits. The low level germ inclusion caused ($P < 0.05$) higher ADG and heavier HCW but reduced marbling ($P < 0.05$) and the ratio of marbling to total carcass fatness. Qualitative carcass traits were, in general, not affected ($P > 0.10$) by the higher germ inclusion. A sub-population of steers that were highest (n = 12) and lowest (n = 12) in marbling relative to total carcass fatness (M_2Ratio) were scrutinized more closely to understand more about why marbling is or is not accumulated. Differences in M_2Ratio were not associated with HCW or fatness, but were associated with marbling ($P < 0.001$). Serum collected early in the feeding period from high M_2Ratio steers caused higher ($P < 0.05$) satellite cell proliferation and differentiation rates *in vitro* than serum from low M_2Ratio steers. This response diminished with additional days on feed. These results indicate that dietary carbohydrate source has minimal influence on carcass fat distributions, but that dietary oil dramatically alters circulating metabolites and is antagonistic to the production goal of high marbling and high cutability carcasses.

INTRODUCTION

The cattle industry has concerns as to whether corn distiller's grains (CDG) causes relatively lower marbling and cutability in fed cattle carcasses. A cursory review of our data base indicated this may be occurring. Furthermore, we had observed that higher inclusion levels of dry milled corn germ caused a substantial decrease in nitrogen retention in wethers fed high concentrate diets. Reduced N retention would be expected to correspond to lower muscle growth, which in turn could be reflected as lower cutability of the carcass. We had also observed a trend toward smaller LMA and increased fatness in carcasses of cattle fed comparable diets.

[1] This research funded by the NCBA and the South Dakota Agricultural Experiment Station.
[2] Distinguished professor.
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[4] Professor.

Our theory was that the oil fraction of the germ was the causative agent. Corn distiller's grains have relatively lower and more variable corn oil content than corn germ. If corn oil is the causative agent, this would fit the inconsistent observations regarding any relationships between dietary CDG and carcass traits.

This experiment was designed to seek insight into mechanisms that may be involved in lowering quality grades and cutability of carcasses when beef cattle are fed elevated dietary corn oil via feeding corn processing co-products. Cattle performance and carcass traits are discussed here. Metabolic profile responses to diet are described in a companion report included in this issue.

MATERIALS AND METHODS

Cattle Management

Diets for finishing cattle were defined to include no corn milling co-products (CO) or to provide 2% (LO) or 6% (HI) added corn oil from corn germ.

These levels of germ were fed in high starch (S) or high fiber (F) finishing diets. The higher fiber diets included substitution of chopped high moisture earlage and dried corn gluten feed for rolled high moisture corn and dry whole shelled corn. These diets were used as a 3 x 2 factorial arrangement of treatments with main effects of germ level (GERM n = 3) and carbohydrate source (CHO n = 2).

Cattle were fed twice daily. Diets were prepared in a stationary mixer. Diet ingredients were sampled each week, and nutrient composition was determined. True diet formulations were calculated from actual ingredient inclusion in batches of feed and the weekly compositional values for each ingredient. The diets reported in Table 1 depict these true formulations. Energy values reported are based upon tabular (NRC, 1996) values for each ingredient. Diets were fortified to meet or exceed known nutrient requirements (NRC, 2000). Feed records were summarized at 7 d intervals for compiling diet composition data and for calculating DMI.

These diets were evaluated in 144 steers (initial BW 770 lb S_d 33 lb). Steers were approximately 10 mo of age and had been on site for >65 d. They were selected based upon uniformity of body weight from a group of 168 steers that had remained healthy since arrival at the feedlot. To allot steers to treatments, 2d prior to initiating the study, steers were weighed, ranked by BW, and then sequentially assigned to CHO diets S or F. Steers were then sorted by CHO diet, ranked by BW, and then randomly assigned to GERM level. The process was repeated to assign steers to pen replicates (n = 3). At each step in the process, data were tested to confirm that mean BW and variance were similar across main effects. The combination criteria of CHO, GERM, and replicate constituted a pen. The allotment process resulted in a representative stratification of initial BW in each pen. Steers were physically sorted to test pens 2 d prior to starting the experiment.

Individual BW were determined starting at 0800 initially and at 28-d intervals during the study except the last period (25 d). Revalor-S implants were administered to all steers during the day 28 weighing process. The feeding study duration was 137 d.

Ultrasound measurements of ribeye area, ribfat depth, and percent intramuscular fat were acquired 77 and 6 d prior to harvest, corresponding to 60 and 131 d on feed.

Table 1. True diet formulations and compositions.[1]

	High starch						Low starch					
Germ Level	Control		Low		High		Control		Low		High	
Item	$\bar{x}$	S_d	$\bar{x}$	S_d	$\bar{x}$	S_d	$\bar{x}$	S_d	$\bar{x}$	S_d	$\bar{x}$	S_d
Sorghum silage, %	8.64	0.75	8.64	0.75	8.64	0.76	8.39	0.83	8.39	0.83	8.39	0.83
Whole shelled corn, %	41.26	0.55	37.08	0.61	28.98	0.68	25.51	0.80	21.09	0.65	12.16	0.37
High moisture corn, %	39.94	0.38	39.94	0.38	39.93	0.37	-	-	-	-	-	-
High moisture earcorn, %	-	-	-	-	-	-	43.69	1.45	43.69	1.46	43.68	1.49
Soybean meal, %	5.84	0.45	5.47	0.60	4.39	0.73	-	-	-	-	-	-
Germ, %	-	-	4.55	0.08	13.75	0.24	-	-	4.42	0.17	13.37	0.50
Corn gluten feed, %							18.21	0.29	18.21	0.28	18.21	0.27
Supplement[2], %	4.32	0.05	4.32	0.05	4.32	0.05	4.20	0.15	4.20	0.15	4.19	0.14
Monensin, g/T	29.4	0.37	29.4	0.36	29.3	0.34	28.5	1.00	28.5	1.00	28.5	0.98
Dry matter, %	71.97	0.98	72.19	0.96	72.65	0.92	69.99	1.07	70.21	1.05	70.66	1.02
Crude protein, %	12.98	0.60	13.05	0.62	13.03	0.59	12.04	0.13	12.25	0.13	12.69	0.13
NDF, %	13.33	0.44	14.00	0.43	15.32	0.42	20.29	1.02	20.95	1.03	22.29	1.04
ADF, %	6.26	0.31	6.55	0.31	7.11	0.30	8.88	0.63	9.19	0.64	9.81	0.64
Ash, %	3.18	0.12	3.16	0.11	3.09	0.11	4.20	0.15	4.20	0.14	4.20	0.14
Germ EE, %[3]	0		2.09	0.04	6.32	0.11	0		2.04	0.08	6.15	0.23
NE_M, Mcal/cwt[4]	93.11	0.28	95.45	0.32	100.18	0.39	88.01	0.27	90.26	0.27	94.83	0.36
NE_G, Mcal/cwt[4]	61.79	0.28	63.73	0.31	67.68	0.37	57.03	0.28	58.89	0.28	62.65	0.33

[1] All values except DM on a dry matter basis.

[2] Supplement provided vitamins and trace minerals to meet or exceed nutrient requirements. One common supplement was used in all diets and contained monensin and tylosin.

[3] Ether extract contributed from germ.

[4] Based on tabular NE values for ingredients fed.

Termination of the feeding phase was targeted for an overall average ribfat depth of 0.5 in. On the final day in the feedlot, only the morning feed delivery was made. Beginning at 1600 h steers were loaded on trucks and shipped to Tyson Fresh Meats, Dakota City, NE (145 mi). Slaughter began at 0700 the following day.

Individual steer identity was tracked through the slaughter and grading processes. For carcass composition comparisons, 3 steers from each pen had been previously identified as nearest to the mean initial BW. Carcasses from these steers were isolated and anatomical reference points for 9-10-11 rib sections (Hankins and Howe, 1946) were marked on the left side of each carcass. These reference points were used to recover rib sections during fabrication 24 h after grading was completed.

The 9-10-11 rib sections were taken to the SDSU Meat Lab. Soft tissue and bone were separated and weighed. Soft tissue was then processed through a sausage chopper and homogenized for subsequent water, fat, and protein determinations. Water content was considered weight loss during 72 h freeze drying. These dehydrated samples were then used to determine fat content by ether extraction using a Soxhlet apparatus (AOAC, 1990). Crude protein of the dry, fat-free residue was determined by the Kjeldahl procedure (AOAC, 1990). Ash (650^{o} C, 12 h) was determined on dehydrated samples. Each assay was conducted in triplicate, and composite totals for water, protein, fat, and ash within sample ranged from 98.7% to 100.1%.

The MRatio is a method that normalizes dissimilar units for comparing marbling with carcass fatness. The following equation was used:

$$\left[\frac{(\text{Obs Var}_1 - \text{Var}_1\ \overline{\text{x}})}{\text{Var}_1\ S_d} \right] - \left[\frac{(\text{Obs Var}_2 - \text{Var}_2\ \overline{\text{x}})}{\text{Var}_2\ S_d} \right]$$

Means and standard deviations used were from the whole population. When both variables deviate normally, the resulting value = 0. The MRatio reported used marbling and ribfat depth as variables 1 & 2, respectively. For M_2Ratio calculations, percent carcass fat derived from 9-10-11 rib sections was used as variable 2.

Statistical Analysis

Statistical analysis of cattle performance and carcass variables were conducted using procedures appropriate for a 2 x 3 factorial arrangement of treatments for a completely randomized design. Pen was considered the experimental unit. Statistical analyses were conducted using the GLM module of SAS (SAS institute, Raleigh, NC).

RESULTS AND DISCUSSION

Dietary targets were achieved (Table 1), cattle performance was good (Table 2), and the harvest target of 0.5 in. ribfat was reached (Table 3). There were no indications that the production aspect of the project would compromise affects on the targeted dependent carcass trait variables. The main effects of CHO and GERM level are presented independently as there were no CHO x GERM level interactions detected for any production or carcass traits.

Level of CHO affected cattle performance in a manner that was predictable. The higher fiber content diet had a lower energy density, which should result in increased DMI, lower gain efficiency, and possibly lower ADG (Table 2). Each of these responses occurred ($P < 0.05$) for the 137-d feeding period.

This resulted in lower ($P < 0.01$) final BW and HCW on the higher fiber diet. We should expect cattle of similar mature size to have a similar body composition at a common body weight. Current growth models also assume that at a common body composition, the intramuscular fat (IMF) content of the longissimus is similar, regardless of body weight. Finally, there is a prevailing dogma that diets of higher starch content promote IMF deposits. Cumulatively, these factors should result in lower carcass fatness and disproportionately lower IMF or marbling steers fed the high fiber diet. In contrast to these principles, there were no differences in ribfat depth, marbling scores, MRatio, carcass fat content, or M_2Ratio.

Table 2. Cumulative 137 d steer performance by main effects

	Diet		Germ			
	Starch	Fiber	Control	Low	High	EMS
n	9	9	6	6	6	
Initial BW, lb	770	770	762	768	770	5.7
Final Live BW, lb[1]	1310[a]	1275[b]	1288	1303	1286	166.7
Adjusted [2]						
Final BW, lb	1331[d]	1282[e]	1307[b]	1317[a]	1296[c]	12.72
ADG, lb	4.10[a]	3.74[b]	3.90[ab]	4.01[a]	3.84[b]	0.006
DMI, lb	23.25[a]	24.32[b]	23.85	24.10	23.40	0.128
F/G	5.69[a]	6.51[b]	6.13	6.04	6.12	0.036
Gain/Feed, g/kg	176	154	164	167	164	16

[1] Include 3% shrink.
[2] Final BW = hot carcass weight/0.625.
[a,b,c] Means within main effect without common superscripts differ ($P < 0.05$).
[d,e] Means within main effect without common superscripts differ ($P < 0.01$).

The LO level inclusion of germ improved ($P < 0.05$) ADG over the HI germ inclusion but ADG on both LO and HI treatments were similar to the Control. Unlike previous work at South Dakota State University, the HI germ level did not cause lower ADG or G/F compared to CO (Table 2). Carcass weight was highest for LO germ and was lowest for HI germ ($P < 0.05$), but differences were small (Table 3). The contrast of CO versus pooled GERM levels indicated that GERM caused ($P < 0.05$) lower marbling and lower MRatio (Table 3) at a constant ribfat depth and lower M_2Ratio ($P < 0.05$) without altering carcass fatness (Table 4).

Table 3. Influence of main effects on carcass traits

	Diet		Germ			
	Starch	Fiber	Control	Low	High	EMS
HCW, lb	832[d]	801[e]	816[b]	823[a]	810[c]	36.5
LMA, in[2]	12.41	12.19	12.42	12.33	12.15	0.619
Ribfat, in.	0.50	0.48	0.48	0.49	0.47	0.007
Marbling[1]	597	584	607[a]	579[b]	584[ab]	0.080
KPH, %	2.54	2.71	2.57	2.66	2.63	0.330
MRatio[2]	-0.102	-0.001	0.120[a]	-0.292[b]	0.018[a]	0.0632

[1] 500 = Small^{o}; 400 = Slight^{o}.
[2] Difference as marbling-ribfat divergence from population means.
[a,b,c] Means within main effect without common superscripts differ ($P < 0.05$).
[d,e] Means within main effect without common superscripts differ ($P < 0.01$).

Table 4. Carcass composition estimates from 9-10-11 rib sections

	Diet		Germ			
	Starch	Fiber	Control	Low	High	EMS
Edible Carcass						
Fat, %	31.42	30.76	30.78	31.49	31.01	2.372
Protein, %	15.09	15.28	15.26	15.07	15.22	0.338
Water, %	52.17	52.60	52.61	52.06	52.50	2.281
M_2Ratio[1]	-0.089	0.081	0.280[x]	-0.163[y]	-0.128[y]	0.1157

[1] M_2Ratio based on marbling and carcass fat content.
[x,y] Means within main effect without common superscripts differ ($P < 0.10$).

Ultrasound data (US) at 60 d on feed was obtained on 149 head (Table 5). No differences were found for LMA due to CHO or GERM. Steers consuming S diets had greater ($P < 0.05$) US ribfat measurements than steers fed F. No differences were found for GERM. Marbling development quantified by the percentage of intramuscular fat content was greater ($P < 0.05$) for S than F (4.64 vs. 4.44). Steers consuming the CO germ had greater ($P < 0.05$) US IMF than the LO or HI germ treatments (4.71 vs. 4.40 vs 4.49, respectively). The MRatio was lower ($P < 0.05$) for S cattle because of greater ribfat depth. MRatio was lower for LO germ ($P < 0.05$) compared to CO, but was not different from HI.

Ultrasound data at 131 d on feed was obtained on 138 head. Again, there were no treatment effects ($P > 0.10$) on LMA. Between CHO, higher ribfat was maintained by steers fed the S diets (0.52 vs. 0.47 cm; $P < 0.05$). No diet effects were observed for percent IMF or MRatio at this latter (131 d) point in growth.

These results indicated that increased fiber in the finishing diet from corn gluten feed and high moisture corn cobs had a predictable effect on cattle performance (lower efficiency) but did not alter the rate of accumulation of intramuscular fat. In contrast, inclusion of increasing levels of corn germ oil affected performance differently from performance predictions based upon dietary NE content. Supplemental corn germ oil also altered the distribution of adipose in the carcass.

Table 5. Influence of main effects on interim measures of carcass ultrasound traits

	Diet		Germ			
	Starch	Fiber	Control	Low	High	EMS
60 d						
LMA, in^2	11.07	11.10	11.01	11.24	11.01	1.214
Ribfat, in	0.34^a	0.32^b	0.33	0.33	0.33	0.004
IMF, %[1]	4.64^a	4.44^b	4.71^a	4.40^b	4.49^c	1.077
MRatio[2]	-0.04	0.10	0.159^a	-0.118^b	0.037^{ab}	1.607
131 d						
LMA, in^2	13.08	12.96	13.11	13.17	12.77	1.336
Ribfat, in	0.52^a	0.47^b	0.50	0.50	0.48	0.009
IMF, %[1]	5.60	5.32	5.47	5.47	5.44	1.667
MRatio[2]	-0.16	0.16	-0.040	-0.017	0.059	1.655

[1] Intramuscular fat, %.

[2] MRatio based on marbling and ribfat depth.

[a,b,c] Means within main effect without common superscripts differ ($P < 0.05$).