The Effects of High-Oil Corn or Typical Corn with or without Supplemental Fat on Diet Digestibility in Finishing Steers

A.S. Leaflet R1719

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Summary

Two 3 x 3 latin squares were utilized in an 84-day digestion trial with ruminally- and duodenally-cannulated steers. Diets consisted of 73 to 78% whole corn grain, 12.3% corn silage and 2.0% N, with treatment differences being high-oil corn- (HOC), isogenetic typical-corn- (TC), or isogenetic typical-corn + fat- (TC+F) based diets. The HOC and TC+F diets were formulated to provide the same ether extract (EE) content. All diets were fed at 90% of *ad libitum* intake. Chromic oxide was used as a digestibility marker. Total tract dry matter (DM) (P=.08), organic matter (OM) (P=.08) and nitrogen (N) (P=.06) digestibilities tended to be greater for TC than HOC diets, whereas starch neutral detergent fiber (NDF), acid detergent fiber (ADF), and ether extract digestibilities were similar (P>.10). There were no differences (P>.10) in total tract dry matter, organic matter, starch, NDF, ADF, ether extract, or nitrogen digestibilities between TC+F and HOC diets or TC and TC+F diets. Ruminal digestion of dry matter, organic matter, starch, NDF, ADF, and feed nitrogen was similar (P>.10) among treatments. Microbial-nitrogen flow and efficiencies were also similar (P>.10) among treatments. Results indicate finishing steer diets composed of primarily HOC are equally or less digestible than similar diets composed of TC, and adding fat to TC diets did not affect the digestibility of the diet when fed to finishing steers.

Introduction

Fat is sometimes added to finishing cattle diets to increase the caloric density of the feed in hopes of ultimately improving average daily gain and feed efficiency. Recently, high-oil corn, which has approximately twice the oil content of typical corn, has become more popular from an agronomic standpoint due to advancements in plant breeding and improvements in yields and agronomic traits. Because corn is the primary source of energy used in many finishing cattle diets, the use of high-oil corn is an alternative way to increase the dietary energy concentration.

Previous research published in the 1999 A.S. Leaflet R1631 discussed the effects of high-oil corn or supplemental animal/vegetable fat on finishing steer performance and carcass characteristics. In summary, yearling steers fed high-oil corn-based diets numerically had a lower average daily gain and a poorer feed efficiency than steers fed typical-corn- or typical-corn + fat-based diets during the first 56 days of the study. However, during the final 50 days of the feeding trial, steers fed the high-oil corn diet gained faster and were more efficient than steers consuming the typical-corn-based diets with or without added fat.

Therefore, the objectives of this experiment were to compare the nutrient digestibilities of finishing steer diets containing primarily high-oil corn, isogenetic typical-corn, and isogenetic typical-corn with supplemental animal/vegetable fat.

Materials and Methods

Three mature crossbred steers had been fitted with rumen and duodenal cannulaes. The steers were used in two successive 42-day, 3 x 3 latin square digestibility trials. Each latin square consisted of three, 14-day periods, with the initial 8 days of each period being for diet acclimation, followed by a 6-day sampling period on the same diet. The steers were randomly assigned to dietary treatments (Table 1) consisting primarily of typical-corn, typical-corn with an added animal/vegetable fat blend, or high-oil corn. All corn grain was fed as unprocessed, whole kernel corn. Fat was added to the typical-corn-based diet at a level to supply dietary ether extract in an amount (5.6%) equal to that of the high-oil corn diet. The silage was weighed separately and added to the concentrate mix at each feeding to maintain freshness. All diets were formulated to be isonitrogenous (2.0%) and contain the same amount of both protein and non-protein nitrogen. Additional nutrient requirements were met or exceeded according to NRC recommendations. The nutrient compositions of both types of corn are shown in Table 2. The steers were fed monensin throughout the experiment and were housed in individual 3 meter by 3 meter pens with rubber matted flooring. These pens were located in an environmentally controlled room maintained at 25°C with continuous artificial lighting and a fresh supply of clean drinking water.

Table 1. Diet composition (% of dry matter).

	Diet		
Ingredient	**Typical**	**Typical + Fat**	**High-Oil**
Corn	76.78	73.61	78.22
Corn silage (all non-high-oil)	12.28	12.27	12.26
Soybean meal	6.41	6.92	4.93
Molasses	1.72	1.72	1.72
Blended fat	--	2.69	--
Limestone	1.23	1.22	1.24
Urea	.89	.89	.89
Sodium chloride	.30	.30	.30
Potassium chloride	.24	.24	.29
Vitamin A premix[a]	.08	.08	.08
Elemental sulfur	.027	.027	.027
Trace minerals	.024	.024	.024
Monensin premix[b]	.0195	.0195	.0195

[a]Provided 3,080 IU/kg dry matter.
[b]Provided 34.3 mg/kg dry matter.

Table 2. Nutrient composition of corn varieties.

	Corn Variety	
Composition (%)	**Typical[a]**	**High-Oil[a]**
Dry matter	90.6	90.5
Nutrient composition (% of dry matter)		
Ether extract	3.6	7.2
Protein	7.8	8.6
Starch	76.7	72.3

[a]Typical and high-oil corn were sourced by Optimum Quality Grains, Des Moines, IA.

Over 60 days, steers were acclimated to the room and a whole corn-grain-based finishing diet similar to the diets used throughout the experiment to determine *ad libitum* feed intake. Fourteen days prior to the start of the experiment, all steers were poured with the recommended dosage of Ivermectin to control internal and external parasites, although no visual indications of parasitic infestation were apparent. Throughout the experiment, steers were fed at 0900 and 2100 daily, at a level of 10% below *ad libitum* intake.

A timeline depicting the feeding and sampling schedule for each 14-day period is shown in Figure 1. Samples were frozen immediately after collection until the end of the experiment. Upon subsequent thawing, feed and fecal samples were pooled for each steer by period on an equal weight basis and dried. Duodenal samples and rumen bacterial pellets were freeze-dried. After drying, samples of feed, dried duodenal contents, feces and bacterial pellets were ground, and duodenal samples were pooled on an equal weight dry matter basis to form one sample per steer per period. Appropriate laboratory analyses were conducted on feed, rumen fluid, duodenal digesta, and feces to determine ruminal, intestinal, and total tract nutrient digestibilities for the three diets. The ammonia-nitrogen (NH_3-N) concentrations of ruminal fluid and duodenal digesta were measured. Chromium was used as a digestibility marker and purines were used as a marker for microbial flow.

Analysis of variance was used to analyze the data as two 3 x 3 latin squares. Tukey's multiple range comparison was used to test dietary treatments for significance. Data were considered statistically significant at $P<.05$, whereas a trend or tendency was indicated at $P<.10$. P-values greater than .10 were considered not significant (NS). The standard errors of the means (SEM) are also presented.

Results and Discussion

The apparent ruminal digestion of dry matter, organic matter, starch, NDF, ADF, ether extract or feed nitrogen was not significantly different among typical-corn, typical-corn + fat, and high-oil corn diets (Tables 3, 4, and 5). Although the rumen digestibility of dry matter, organic matter, ether extract, and nitrogen fractions of the high-oil corn diet were numerically less than either of the two typical-corn-based diets, statistical significance could not be reached due to a large amount of variation and inconsistency in digestibility coefficients. On the contrary, the rumen digestion of the fibrous fraction of the diet (NDF and ADF) was numerically higher, although not significant, for either of the diets with the added energy source than the unsupplemented typical-corn diet. Prior research indicates supplemental fat will either not change or will decrease fiber digestion in the rumen, due to a decrease in microbial attachment to the fat-coated feed particle. Nonetheless, it seems as though the fat in the present diet did not have a detrimental effect on bacterial attachment to feed fiber. For the high-oil corn diet this could have been due to the fact that the additional dietary oil was within the corn kernel, where it has very little opportunity to interfere with the fibrous fraction of the feed. In the typical-corn + fat diet, the fact that added fat did not affect fiber digestion was probably due to a combination of two things. First, the fat was added to the grain portion of the diet at mixing whereas the silage was mixed with the concentrate immediately prior to feeding. Therefore, the fat never had the opportunity to physically coat the silage, which is the portion of the diet containing the majority of the fiber. Secondly, the fat included in the diet was a relatively small amount that apparently had no effect on the population of fiber digesting bacteria in the rumen. This is further confirmed by very similar bacterial nitrogen flows reaching the duodenum with all three of the diets. Moreover, there was no difference in the amount of ether extract that reached the duodenum beyond that included in the diet, indicating similar microbial fat synthesis. All of this suggests the added fat from either the fat supplemented diet, or the high-oil corn diet had no detrimental effect on the rumen microbial population. However, this is all overshadowed by the fact that the amount of dietary fiber in the ration of finishing cattle is typically very low, which makes small differences in fiber digestion of little importance in the overall efficiency of the animal to convert feed to gain.

Figure 1. Feeding and sampling schedule for each period.

Days 1-6 Feed steers; administer chromium gel-cap in rumen: 0900, 2100.

Days 7-8 Feed steers; administer chromium gel-cap in rumen: 0900, 2100.
Sample fresh feed: 0900, 2100.

Day 9 Feed steers; administer chromium gel-cap in rumen: 0900, 2100.
Sample fresh feed: 0900, 2100.
Duodenal fluid collections: 0900, 1300, 1700.
Fecal sample collections: 0900, 1300, 1700.

Day 10 Feed steers; administer chromium gel-cap in rumen: 0900, 2100.
Sample fresh feed: 0900, 2100.
Duodenal fluid collections: 1000, 1400, 1800.
Fecal sample collections: 1000, 1400, 1800.

Day 11 Feed steers; administer chromium gel-cap in rumen: 0900, 2100.
Sample fresh feed: 0900, 2100.
Duodenal fluid collections: 1100, 1500, 1900.
Fecal sample collections: 1100, 1500, 1900.

Day 12 Feed steers; administer chromium gel-cap in rumen: 0900, 2100.
Sample fresh feed: 0900, 2100.
Duodenal fluid collections: 1200, 1600, 2000.
Fecal sample collections: 1200, 1600, 2000.

Day 13 Feed steers; administer chromium gel-cap in rumen: 0900, 2100.
Ruminal fluid collections: 0900, 1000, 1100, 1200, 1300, 1500, 1700, 1900.

Day 14 Feed steers; administer chromium gel-cap in rumen: 0900, 2100.
Ruminal fluid collections: 1200, 1700.

Table 3. Effects of typical-corn-, typical-corn + fat-, and high-oil corn-based diets on ruminal, intestinal, and total tract nutrient digestion in steers.

	Diet				P-Value		
	Typical	Typical + Fat	High-Oil	SEM	TC vs. TC+F	TC vs. HOC	TC+F vs. HOC
Intake (g/d)							
DM	8692	8620	8602	20	--	--	--
OM	8423	8331	8293	25	--	--	--
Starch	5678	5231	5173	82	--	--	--
NDF	870	879	852	12	--	--	--
ADF	351	371	360	7	--	--	--
Apparent Ruminal Digestion (%)							
DM	39.7	38.9	35.2	2.7	NS[a]	NS	NS
OM	47.4	46.9	43.3	2.6	NS	NS	NS
Feed OM	74.2	73.4	69.8	2.1	NS	NS	NS
Starch	78.2	78.5	77.6	1.5	NS	NS	NS
NDF	30.8	36.1	33.4	6	NS	NS	NS
ADF	23.2	29.5	26.5	7	NS	NS	NS
Apparent Intestinal Digestion (%)							
DM	54.6	54.4	45.1	3.4	NS	NS	NS
OM	50.6	50.3	39.6	3.9	NS	NS	NS
Starch	26.8	34.2	3.7	10	NS	NS	NS
NDF	4.0	1.3	2.0	6	NS	NS	NS
ADF	5.0	0.3	3.7	6	NS	NS	NS
Apparent Total Tract Digestion (%)							
DM	73.3	72.1	64.3	2.5	NS	.08	NS
OM	74.7	73.5	65.7	2.5	NS	.08	NS
Starch	86.0	85.5	78.6	2.7	NS	NS	NS
NDF	39.7	37.8	36.8	5	NS	NS	NS
ADF	33.9	31.1	31.2	4	NS	NS	NS

[a]Not significant at P>.10.

No difference was observed in the intestinal or total tract digestion of dry matter or organic matter between typical-corn and typical-corn + fat diets. However, the high-oil corn diet tended to have a lower total tract dry matter and organic matter digestibility than the typical corn diet, and was numerically less digestible (64.3 and 65.7% versus 72.1 and 73.5%), although not significantly, than the typical-corn + fat diet. It is difficult to assess why the high-oil corn diet was less digestible in this study than either of the two typical-corn-based diets. Possibly the oil within the high-oil corn kernel was inhibiting the enzymatic digestion of the feed in the small intestine, because no significant difference in ruminal digestion of these nutrients was observed. For the same contrast, statistical significance was not reached for intestinal digestibility, however, there did appear to be a difference just by interpreting the raw numbers. In looking more specifically at what nutrient within the organic matter of the feed was more poorly digested in the high-oil corn diet, nitrogen is the only nutrient that showed a definite trend towards a lower intestinal and total tract digestibility. Both starch and ether extract, however, were numerically less digestible, although not significantly, for the high-oil corn diet than either of the two typical-corn diets. With this in mind, both of the typical-corn diets contained a higher proportion of soybean meal in the diet in order to balance the diets isonitrogenously. Because soybean meal composed a large part of the nitrogen constituent in the diets, it is possible, and quite logical, that the nitrogen from the soybean meal was more digestible than the nitrogen contained within the corn kernel. Most of the nitrogen within the kernel is found in the germ, which is the innermost part of the kernel. Because the corn was not processed, thorough physical mastication of the feed would be necessary to expose the inner germ to microbial or enzymatic activity needed for nitrogen digestion. Similarly, the difference in ether extract digestion can be looked at the same way. Simply put, fat on the outside of the feed is more accessible to digestion than fat imbedded deep within the kernel.

In relating these data to those previously reported, in the feeding trial, during the first period, the increase in gain and feed efficiency in steers fed both the supplemented and unsupplemented typical-corn-based diets coincides with the higher total tract nitrogen digestibility observed in the digestion trial. Therefore, more nitrogen was being digested in the typical-corn-based diets, allowing for greater nitrogen retention, thereby increasing lean tissue gain. Sometime within the final 50 days of the feeding trial, these steers reached the point in their growth curve where lean tissue deposition slows, and fat deposition is increased. At this time, average daily gain and feed efficiency typically declines. The steers consuming the high-oil corn diet, however, grew less rapidly during the initial 56 days of the trial; thus, they were lighter. They also experienced more days of growth under which a high proportion of lean, and little fat, was being deposited. This explains the advantage the high-oil corn fed steers had in daily gain and efficiency during the second phase of the feeding trial. It is possible that the high-oil corn fed steers were responding to the additional energy during the final days of the trial, resulting in more rapid gains. However, the observation that the steers fed the fat-supplemented typical-corn diet did not have an advantage from the standpoint of daily gain or efficiency suggests additional energy is not the major factor influencing gain during this period. Results from the digestion trial, although not statistically significant, suggest ether extract from both of the typical-corn diets to be more digestible than that from the high-oil corn diet. Therefore, the steers fed typical-corn + fat were probably digesting more ether extract than steers fed high-oil corn, yet this did not affect feedlot performance.

Implications

This study suggests that finishing steer diets composed of whole high-oil corn grain tend to be less digestible than similar diets composed of traditional corn without an added fat source. Additionally, blended fat added to traditional corn-based finishing diets does not significantly differ from typical-corn-based finishing diets or high-oil corn-based finishing diets from the standpoint of nutrient digestion. However, digestion coefficients for typical-corn-based diets with added fat seem to more closely resemble those of typical-corn diets without added fat as opposed to high-oil corn diets.

Acknowledgments

This work was supported in part by grants from Optimum Quality Grains, L.L.C., and the Iowa Corn Promotion Board, both of Des Moines, Iowa.

Table 4. Effects of typical-corn-, typical-corn + fat-, and high-oil corn-based diets on ether extract flow and the site and extent of ether extract digestion in steers.

	Diet				P-Value		
	Typical	Typical + Fat	High-Oil	SEM	TC vs. T+F	TC vs. HOC	TC+F vs. HOC
Intake (g/d)							
EE	285	451	515	9	--	--	--
Flow to Duodenum Above Intake EE (g/d)							
EE	200	226	191	49	NS[a]	NS	NS
Apparent Intestinal Digestion (%)							
EE	75.6	75.5	63.3	4	NS	NS	NS
Apparent Total Tract Digestion (%)							
EE	58.9	63.5	51.7	4	NS	NS	NS

[a]Not significant at P>.10.

Table 5. Effects of typical-corn-, typical-corn + fat-, and high-oil corn-based diets on the site and extent of nitrogen digestion and microbial efficiency in steers.

	Diet				P-Value		
	Typical	Typical + Fat	High-Oil	SEM	TC vs. TC+F	TC vs. HOC	TC+F vs. HOC
Intake (g/d)							
Total N[a]	178	176	175	.5	--	--	--
Protein N[b]	142	141	140	.3	--	--	--
Rumen Degradation (% of intake)							
Total N	89.5	90.2	85.0	3.4	NS[c]	NS	NS
Protein N	86.9	87.7	81.2	4.3	NS	NS	NS
Flow to Duodenum (g/d)							
Total N	206	201	209	8.3	NS	NS	NS
Feed N	19	17	26	6.0	NS	NS	NS
Bacterial N	178	174	173	6.3	NS	NS	NS
NH_3-N	10.1	10.1	10.4	.6	NS	NS	NS
Flow to Duodenum (% of total N flow)							
Feed N	8.5	8.5	13.1	2.6	NS	NS	NS
Bacterial N	86.4	86.5	81.8	2.7	NS	NS	NS
NH_3-N	5.1	5.0	5.1	.3	NS	NS	NS
Microbial Efficiency							
OM[d]	28.9	28.4	30.0	1.6	NS	NS	NS
Starch[e]	40.8	42.4	43.7	2.6	NS	NS	NS
Apparent Intestinal Digestion (%)							
Total N	75.0	72.1	69.4	1.6	NS	.08	NS
Apparent Total Tract Digestion (% of intake)							
Total N	71.3	68.5	63.7	2.0	NS	.06	NS

[a]Includes urea N.
[b]Does not include urea N.
[c]Not significant at P>.10.
[d]g bacterial N/kg OM truly digested in the rumen.
[e]g bacterial N/kg starch digested in the rumen.