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Title: Use of Fibrolytic Enzymes to Augment the Feeding Value of Supplemental Fat in High Forage Growing Diets for Feedlot Cattle

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INDUSTRY SUMMARY

1). Introduction - The negative associative effects of supplemental fat on ruminal fiber digestion are well documented (Brethour et al., 1957; Davidson and Woods., 1960; Devendra and Lewis., 1974; Boggs et al., 1987; Zinn, 1988,1989, 1994; Zinn and Plascencia, 1993, 1996; Zinn et al., 2000). Depression in ruminal fibrolytic capacity with fat supplementation typically ranges between 15 and 40%. The basis for the depression is not due to physical coating of feed particles (Zinn and Plascencia, 1997), but rather to its toxic effect on ruminal fibrolytic organisms, particularly protozoa. In vitro studies (Henderson, 1973; Maczulak et al., 1981) demonstrate that the unsaturated fatty acids, particularly C18:1, play the more active role in inhibiting ruminal cellulolytics. Of primary concern with respect to the depressing effects of supplemental fat on fiber digestion is the consequent effect on energy intake and ADG. The rumen has an upper limit on its physical capacity. As the rate of fiber digestion decreases, the amount of slowly digestible OM in the rumen increases. Zinn and Salinas (1999) observed that the upper limit on ruminal fill-capacity is a predictable function of the initial weight of cattle when first placed in the feedlot, average weight during the feeding trial, dietary NDF, dietary eNDF, and ruminal NDF digestion. With a typical growing diet containing 21% NDF, a 20% reduction in ruminal fiber digestion is expected to depress the ADG of a 220 kg steer by 10% (1.15 vs 1.28 kg/d). Ruminal deficiencies in fibrolytic capacity may be partially overcome by enzyme supplementation. Combinations of cellulase and xylanase enzymes have enhanced in vitro (Feng et al., 1996; Howes et al., 1998) and in vivo NDF digestion (Lewis et al., 1996; Zinn and Salinas, 1999; López-Soto et al., 2000; Murillo et al., 2000), growth performance of steers fed forage-based diets (Beauchemin et al., 1995; Zinn and Salinas, 1999), and milk production (Howes et al., 1998).

2) Objectives - The objective of this study was to evaluate the use of fibrolytic enzymes (combination of cellulase and xylanase) as a tool for overcoming the negative associative effects of supplemental fat on fiber digestion, and hence, energy intake and growth-performance of feedlot cattle.

3) Industry summary - The interaction of fibrolytic enzyme supplementation and fat supplementation characteristics of ruminal and total tract digestion was evaluated in 4 steers with ruminal and intestinal cannulas. Consistent with previous studies, the addition of fat depressed ruminal digestion of OM (14%), and N (10%). The reduction in ruminal OM digestion was due, in part, to the ruminal indigestibility of dietary fat, itself. The decrease in ruminal N digestion was likely due to interactions between the level of dietary fiber, and associated effects of supplemental fat on fiber digestion. There was a supplemental fat by enzyme interaction on ruminal NDF digestion. In the absence of supplemental fat, ruminal NDF digestion was high (51%) and not affected by enzyme supplementation. As expected, fat supplementation depressed (30%, $P < .05$) ruminal NDF digestion. The addition of Fibrozyme to the fat supplemented diet increased (25%) ruminal NDF digestion to a level similar to that of non-fat supplemented diets (47%). Our

findings show that when the ruminal environment is favourable for optimal NDF digestion (ruminal NDF digestion accounts for 80% or more of what is considered maximal - usually, when ruminal NDF digestion exceeds 45%), limitations on NDF digestion are primarily associated with the nature of the fiber, itself, and its accessibility to the fibrolytic process. The addition of enzymes in this case would be expected to have little or no benefit. On the other hand, when the ruminal environment is not favourable for optimal NDF digestion, limitations on fiber digestion are largely a function of fibrolytic capacity, supplementation with fibrolytic enzymes will be beneficial. Hence, the supplemental Fibrozyme supplanted ruminal fibrolytic capacity that had been depressed by the supplemental fat. Fibrozyme supplementation increased (6%) ruminal degradation of feed protein. This effect was likely due to increased protein exposure to ruminal proteolytic processes in association with concomitant increases in fiber digestion. There were no treatment interactions on total tract digestion of OM, NDF, and N. Supplemental fat depressed total tract digestion of OM (5%), NDF (17%), and N (4%). Fibrozyme supplementation increased (8%) total tract digestion of NDF. Post-ruminal fatty acid digestion averaged 85 and 75%, respectively, for 0 and 4% fat supplemented diets.
The interaction of supplemental fat and fibrozyme on growth performance was evaluated in 96 crossbred steer calves. Steers were fed a conventional 12% forage finishing diet. Consistent with previous studies, fat addition increased ADG. However, enzyme addition to the non-fat supplemented diet increased ADG to a level that was numerically similar (99%) to that of the fat supplemented diets. There were no treatment effects on dry matter intake. Hence, changes in growth performance are attributable to improved dietary net energy. Fibrozyme supplementation increased the NE_m and NE_g value of the non-fat supplemented diet by 6.7 and 5.1%, respectively, but did not affect the NE values of the fat supplemented diet. Fat supplementation increased the NEm and NEg value of the diet by 6.7 and 8.7%. The NE_m and NE_g ($NE_g = .877NE_m - .41$) values for the yellow grease used in this trial were 6.25 and 5.07 Mcal/kg, respectively. Based on level of fat intake the expected NE_m and NE_g values for supplemental fat are 6.11 and 4.95 Mcal/kg, respectively, in close agreement with observed. We conclude that Fat supplementation increases the NE value of growing-finishing diets for feedlot cattle in a manner consistent with level of total fat intake. The negative associative effects of supplemental fat on ruminal fiber digestion can be largely overcome by the addition of fibrolytic enzymes to the diet. However, the practical significance of this, in terms of growth-performance may depend largely on total forage fiber intake. Fibrolytic enzyme supplementation may improve performance of feedlot cattle in a manner independent of its effects on total tract OM digestion.

Scientific Abstract: Four Holstein steers (522 kg) with cannulas in the rumen and duodenum were used in a 4 □ 4 Latin square design to evaluate the interaction of supplemental fat (0 vs 4%) and fibrolytic enzymes (0 vs 15 g/d Fibrozyme) on characteristics of digestion. Fibrozyme was incorporated into the diet at the time of feeding. Feed intake was restricted to 2% of BW. Fat supplementation depressed ruminal digestion of OM (14%, $P < .01$) and N (10%, $P < .05$). There was a supplemental fat by enzyme interaction ($P < .10$) on ruminal NDF digestion. In the absence of supplemental fat, ruminal NDF digestion was high (51%) and not affected by enzyme supplementation. In the absence of supplemental enzyme, fat supplementation depressed ruminal NDF digestion (30%, $P < .05$). Fibrozyme addition to the fat supplemented diet increased (25%, $P < .05$) ruminal NDF digestion to a level similar to that of non-fat supplemented diets (47%). Fibrozyme supplementation tended (6%, $P < .10$) to increase ruminal degradation of feed N. There were no treatment effects ($P = .45$) ruminal microbial efficiency. There were no treatment interactions ($P > .10$) on total tract digestion. Fat supplementation depressed total tract digestion of OM (5%, $P < .01$), NDF (17%, $P < .01$), and N (4%, $P < .05$). Fibrozyme supplementation increased (8%, $P < .10$) total tract digestion of NDF. We conclude that Fibrozyme supplementation can overcome the negative associative effects of supplemental fat on ruminal fiber digestion of growing-finishing diets fed to feedlot cattle.

Key Words: Fat, Cattle, Digestion, Xylanase, Cellulase

Introduction: The negative associative effects of supplemental fat on ruminal fiber digestion are well documented (Brethour et al., 1957; Davidson and Woods., 1960; Devendra and Lewis., 1974; Boggs et al., 1987; Zinn, 1988,1989, 1994; Zinn and Plascencia, 1993, 1996; Zinn et al., 2000). Depression in ruminal fibrolytic capacity with fat supplementation typically ranges between 15 and 40%. The basis for the depression is not due to physical coating of feed particles (Zinn and Plascencia, 1997), but rather to its toxic effect on ruminal fibrolytic organisms, particularly protozoa. In vitro studies (Henderson, 1973; Maczulak et al., 1981) demonstrate that the unsaturated fatty acids, particularly C18:1, play the more active role in inhibiting ruminal cellulolytics. Of primary concern with respect to the depressing effects of supplemental fat on fiber digestion is the consequent effect on energy intake and ADG. The rumen has an upper limit on its physical capacity. As the rate of fiber digestion decreases, the amount of slowly digestible OM in the rumen increases. Zinn and Salinas (1999) observed that the upper limit on ruminal fill-capacity is a predictable function of the initial weight of cattle when first placed in the feedlot, average weight during the feeding trial, dietary NDF, dietary eNDF, and ruminal NDF digestion. With a typical growing diet containing 21% NDF, a 20% reduction in ruminal fiber digestion is expected to depress the ADG of a 220 kg steer by 10% (1.15 vs 1.28 kg/d). Ruminal deficiencies in fibrolytic capacity may be partially overcome by enzyme supplementation. Combinations of cellulase and xylanase enzymes have enhanced in vitro (Feng et al., 1996; Howes et al., 1998) and in vivo NDF digestion (Lewis et al., 1996; Zinn and Salinas, 1999; López-Soto et al., 2000; Murillo et al., 2000), growth performance of steers fed forage-based diets (Beauchemin et al., 1995; Zinn and Salinas, 1999), and milk production (Howes et al., 1998). The objective of this study was to evaluate the use of fibrolytic enzymes (combination of cellulase and xylanase) as a

tool for overcoming the negative associative effects of supplemental fat on fiber digestion.

Experimental procedures: *Trial 1.* Four Holstein steers (522 kg) with cannulas in the rumen and proximal duodenum (Zinn and Plascencia, 1992) were used in a 4 □ 4 Latin square experiment. Composition of the experimental diets is shown in Table 1. Chromic oxide was added to the diets as a digesta marker. Dry matter intake was restricted to 2% of live weight. Diets were fed at 0800 and 2000 daily. Experimental periods consisted of a 10-d diet adjustment period followed by a 4-d collection period. During the collection period duodenal and fecal samples were taken from all steers, twice daily as follows: d 1, 0750 and 1350; d 2, 0900 and 1500; d 3, 1050 and 1650; and d 4, 1200 and 1800. Individual samples consisted of approximately 700 mL duodenal chyme and 200 g (wet basis) fecal material. Samples from each steer and within each collection period were composited for analysis. During the final day of each collection period, ruminal samples were obtained from each steer 4 h after feeding via the ruminal cannula. Ruminal fluid pH was determined on fresh samples. Samples were then strained through 4 layers of cheese cloth. Upon completion of the trial, ruminal fluid was obtained from all steers and composited for isolation of ruminal bacteria via differential centrifugation (Bergen et al., 1968). Samples were subjected to all or part of the following analysis: DM (oven drying at 105 C until no further weight loss); ash, Kjeldahl N, ammonia N (AOAC, 1984); NDF (Weizhong and Uden, 1998); purines (Zinn and Owens, 1986); fatty acids (Sukhhija and Palmquist, 1988); chromic oxide (Hill and Anderson, 1958) and starch (Zinn, 1990). Microbial organic matter (MOM) and N (MN) leaving the abomasum is calculated using purines as a microbial marker (Zinn and Owens, 1986). Organic matter fermented in the rumen (OMF) is considered equal to OM intake minus the difference between the amount of total OM reaching the duodenum and MOM reaching the duodenum. Feed N escape to the small intestine is considered equal to total N leaving the abomasurn minus ammonia-N and MN and, thus, includes any endogenous contributions. The trial was analyzed as a 4 □ 4 Latin square experiment with a 2 □ 2 factorial arrangement of treatments (Hicks, 1973).

Trial 2. Ninety-six crossbreed steer calves (262 kg) were used in a 173-d randomized complete block experiment, to evaluate the interaction of dietary fat and fibrolytic enzyme supplementation on growth performance. Steers were blocked by weight and randomly allotted within weight groupings to 16 pens (6 steers/pen). Experimental diets are shown in Table 2. Diets were prepared weekly stored in plywood boxes located in front of each pen. Pens were 50 m^2, with 33 m^2 overhead shade, automatic waters, and 4.3 m fence-line feed bunks. Cattle were allowed ad libitum access to experimental diets and water. Fresh feed was provided twice daily. Steers were implanted with Synovex-S[7] (Forte Dodge Animal Health, Forte Dodge, IA) upon initiation of the trial, and reimplanted with Revalor-S[7] (Intervet Inc., Millsboro, DE) on d 84. Energy gain (**EG**) was calculated by the equation: $EG = ADG^{1.097}.0557W^{.75}$, where EG is the daily energy deposited (Mcal/d), and W is the mean shrunk body weight (kg; NRC, 1984). Maintenance energy (Mcal/d, **EM**) was calculated by the equation: $EM = .077W^{.75}$ (Lofgreen and Garret, 1968). The NE_m and NE_g values of the diet were obtained by means of the quadratic formula: Install Equation Editor and double-click here to view equation. ( ), where $a = -.41EM$, $b = .877EM + .41DMI + EG$, and $c = -.877DMI$, and $NE_g = .877NE_m - .41$. This trial was analyzed as a randomized complete block experiment with a 2 x 2 factorial arrangement of treatments (Hicks,

1973), using pen as the experimental unit.

Results and Discussion: Treatment effects on characteristics of ruminal and total tract digestion (Trial 1) are shown in Table 3. Consistent with other studies (Zinn, 1988; Zinn, 1994; Plascencia et al., 1999; Zinn and Plascencia, 1993, 1996; Zinn et al., 2000), the addition of fat depressed ruminal digestion of OM (14%, $P < .01$), and N (10%, $P < .05$). The reduction in ruminal OM digestion can be ascribed, in part, to the ruminal indigestibility of dietary fat, itself. The decrease in ruminal N digestion is most likely due to interactions between the level of dietary fiber, and associated effects of supplemental fat on fiber digestion. With diets containing less than 15%s forage, supplemental fat has had very little effect on ruminal degradation of feed N (Zinn, 1988, 1989, 1992). However, when rations contained greater amounts of forage, the effects of supplemental fat on ruminal degradation of feed N were appreciable, declining as much as 24% (Zinn and Plascencia, 1993, 1996).

There was a supplemental fat by enzyme interaction ($P < .10$) on ruminal NDF digestion. In the absence of supplemental fat, ruminal NDF digestion was high (51%) and not affected by enzyme supplementation. As expected, fat supplementation depressed (30%, $P < .05$) ruminal NDF digestion. The magnitude of the depression was within the range of 15 to 40% previously reported (Brethour et al., 1957; Davidson and Woods., 1960; Devendra and Lewis., 1974; Boggs et al., 1987; Zinn, 1988,1989, 1994; Zinn and Plascencia, 1993, 1996; Zinn et al., 2000).

The addition of Fibrozyme to the fat supplemented diet increased (25%, $P < .05$) ruminal NDF digestion to a level similar to that of non-fat supplemented diets (47%). The surmounting effects of enzyme supplementation on negative associative effects of supplemental fat on ruminal fiber digestion lend support to the contention that the depressing effects of fat are not due to a physical coating of the feed particles (Pfander and Verma, 1957), but rather to the toxic effect which fat has on the growth of protozoa (Czerkawski, 1973; Czerkawski et al., 1975) and fibrolytic bacteria (Henderson, 1973; Maczulak et al., 1981).

Consistent with basic concepts of enzyme kinetics, our results show that when the ruminal environment is favourable for optimal NDF digestion (ruminal NDF digestion accounts for 80% or more of what is considered maximal - usually, when ruminal NDF digestion exceeds 45%), limitations on NDF digestion are primarily associated with the nature of the fiber, itself, and its accessibility to the fibrolytic process (0-order kinetics). The addition of enzymes in this case would be expected to have little or no benefit. On the other hand, when the ruminal environment is not favourable for optimal NDF digestion, limitations on fiber digestion are largely a function of fibrolytic capacity (enzyme levels and velocity; 1^{st}-order kinetics). In which case, supplementation with fibrolytic enzymes will be beneficial. Hence, the supplemental Fibrozyme supplanted ruminal fibrolytic capacity that had been depressed by the supplemental fat.

Fibrozyme supplementation increased (6%, $P < .10$) ruminal degradation of feed N. This effect was likely due to increased protein exposure to ruminal proteolytic processes in association with concomitant increases in fiber digestion. There were no treatment effects ($P = .45$) on ruminal microbial efficiency.

There were no treatment interactions ($P > .10$) on total tract digestion of OM, NDF, and N. Supplemental fat depressed total tract digestion of OM (5%, $P < .01$), NDF (17%, $P < .01$), and N (4%, $P < .05$). Fibrozyme supplementation increased (8%, $P < .10$) total tract digestion of NDF.

Post-ruminal fatty acid digestion was 12% lower ($P < .01$) for fat supplemented than for

non-fat supplemented diets, averaging 85 and 75%, respectively. Based on fatty acid intakes (**FI**, g/kg BW), observed postruminal fatty acid digestion was 104 and 96% of expected (fat digestion, % = 83.18 - 4.52FI - .68FI^3; Zinn, 1994) for non-fat and fat supplemented diets, respectively.

Treatment effects on growth-performance of feedlot steers (Trial 2) is shown in Table 4. With this 12% forage finishing diet, there was an interaction ($P < .05$) between enzyme and fat supplementation. Consistent with previous studies, fat addition to the non-enzyme supplemented diet increased (14%) ADG. However, enzyme addition to the non-fat supplemented diet increased ADG to a level that was numerically similar (99%) to that of the fat supplemented diets. There were no treatment effects ($P > .10$) on DMI. Hence, changes in growth performance are attributable to improved dietary NE.

As with ADG, there were treatment interactions ($P < .10$) on dietary NE. Fibrozyme supplementation increased ($P < .05$) the NE_m and NE_g value of the non-fat supplemented diet by 6.7 and 5.1%, respectively, but did not affect ($P > .10$) the NE values of the fat supplemented diet. In like manner, Pereira and Zinn (2001) observed a 6.3 increase in dietary NE_m and a 5.0% increase in dietary NEg due to Fibrozyme supplementation. Incontrast, in other studies (Zinn and Ware, 2002) most of the improvements in ADG due to fibrozyme supplementation could be attributed to increased DMI, with little of no changes in dietarty NE, per se.

Fat supplementation increased (main effect, $P < .01$) the NEm and NEg value of the diet by 6.7 and 8.7%. Given that the NE_g value of steam-flaked corn is 2.38 Mcal/kg (NRC, 1984), then the NEm replacement value of the supplemental fat can be estimated as follows: Fat NE_m = [(NE_m fat supplemented diet - NE_m unsupplemented diet)/.04] + 2.38. The constant (.04) represents the amount of supplemental fat that replaced steam-flaked corn in the diet. Accordingly, the NE_m and NE_g ($NE_g = .877NE_m - .41$) values for the yellow grease used in this trial were 6.25 and 5.07 Mcal/kg, respectively. Based on level of fat intake (**FI**; 1.03 g/kg BW), the expected NE_m and NE_g values for supplemental fat ($NE_g = 5.24 - .285FI - .0428FI^3$; Zinn, 1994) are 6.11 and 4.95 Mcal/kg, respectively, in close agreement with observed.

Treatment effects on carcass characteristics are shown in Table 5. There treatment interactions ($P < .05$) on carcass weight and dressing percentage. Fat thickness tended to be lower for cattle receiving fat supplemented diets ($P < .10$). There were no treatment effects on Ribeye area, KPH, or yield of boneless closely-trimmed retail cuts.

Conclusions: Fat supplementation increases the NE value of growing-finishing diets for feedlot cattle in a manner consistent with level of total fat intake. The negative associative effects of supplemental fat on ruminal fiber digestion can be largely overcome by the addition of fibrolytic enzymes to the diet. However, the practical significance of this, in terms of growth-performance may depend largely on total forage fiber intake. Fibrolytic enzyme supplementation may improve performance of feedlot cattle in a manner independent of its effects on total tract OM digestion.

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Table 1. Composition of experimental diets fed to steers in

	Supplemental Fat, %			
	0		4	
	Fibrozyme[7], g/d			
Item	0	15	0	15
Ingredient Composition, % (DMB)				
Sudangrass hay	20.00	20.00	20.00	20.00
Steam-flaked Corn	68.20	68.20	64.20	64.20
Limestone	1.70	1.70	1.70	1.70
Magnesium oxide	0.15	0.15	0.15	0.15
Trace-mineralized salt[b]	0.40	0.40	0.40	0.40
Urea	1.15	1.15	1.15	1.15
Chromic oxide	0.40	0.40 .4	0.40	0.40
Laidlomycin propionate, mg/kg	12.00	12.00	12.00	12.00
Fibrozyme, g/d[c]		15.00		15.00
Yellow Grease[d]			4.00	4.00
Cane molasses	8.00	8.00	8.00	8.00
Nutrient composition (DMB)				
NE, Mcal/kg				
Maintenance	1.87	1.87	2.02	2.02
Gain	1.24	1.24	1.37	1.37
CP, %	13.5	13.5	13.1	13.1
NDF, %	24.2	24.2	23.6	23.6
Ether Extract, %	2.49	2.49	6.33	6.33
Ca, %	0.80	0.80	0.82	0.82
P, %	0.30	0.30	0.29	0.29
Mg, %	0.32	0.32	0.32	0.32
K, %	0.98	0.98	0.98	0.98
S, %	0.14	0.14	0.13	0.13

[a]Chromic oxide (0.40% DMB) was added to experimental diets as an inert digesta marker in Trial 1 .

[b]Contains (%): $CoSO_4$, 0.68; $CuSO_4$, 1.04; $FeSO_4$, 3.57; ZnO, 0.75; $MnSO_4$, 1.07; KI, 0.052; and NaCl, 93.4.

[c]Enzymes were added to complete mixed diets at time of feeding.

[d]Composition: MIU, 1.7%; IV, 83; C16:0, 16.0%; C16:1, 1.7%; C18:0, 11.0%; C18:1; 54.4%; C18:2, 13.6%; C18:3, .2%; other; 3.1%.

Table 2. Composition of experimental diets fed to steers in

	Supplemental Fat, %			
	0		4	
	Fibrozyme[7], g/d			
Item	0	15	0	15
Ingredient Composition, % (DMB)				
Sudangrass hay	8.00	8.00	8.00	8.00
Alfalfa hay	4.00	4.00	4.00	4.00
Steam-flaked Corn	80.70	80.70	76.70	76.70
Limestone	1.80	1.80	1.80	1.80
Trace-mineralized salt[a]	0.40	0.40	0.40	0.40
Urea	1.10	1.10	1.10	1.10
Laidlomycin propionate, mg/kg	12.00	12.00	12.00	12.00
Fibrozyme, g/kg[b]	0.00	2.10	0.00	2.10
Yellow Grease[c]	0.00	0.00	4.00	4.00
Cane molasses	4.00	4.00	4.00	4.00
Nutrient composition (DMB)				
NE, Mcal/kg				
Maintenance	2.14	2.14	2.28	2.28
Gain	1.48	1.48	1.61	1.61
CP, %	12.4	12.4	12.0	12.0
NDF, %	14.2	14.2	13.9	13.9
Ether Extract, %	3.73	3.73	7.53	7.53
Ca, %	0.78	0.78	0.80	0.80
P, %	0.29	0.29	0.28	0.28
Mg, %	0.18	0.18	0.19	0.19
K, %	0.70	0.70	0.70	0.70
S, %	0.16	0.16	0.15	0.15

[a]Contains (%): $CoSO_4$, 0.68; $CuSO_4$, 1.04; $FeSO_4$, 3.57; ZnO, 0.75; $MnSO_4$, 1.07; KI, 0.052; and NaCl, 93.4.

[b]Enzymes were premixed with minerals and ionophore just prior to inclusion into the diet during the feedmixing process.

[c]Composition: MIU, 1.7%; IV, 83; C16:0, 16.0%; C16:1, 1.7%; C18:0, 11.0%; C18:1; 54.4%; C18:2, 13.6%; C18:3, .2%; other; 3.1%.

Table 3. Influence of Fibrozyme[7] and supplemental fat on characteristics of ruminal and total tract digestion.

	Supplemental Fat, %				
	0		4		
	Fibrozyme[7], g/d				
Item	0	15	0	15	SD
Steer Wt, kg	522	522	522	522	
Intake, g/d					
DM	8,782	8,782	8,692	8,692	
OM	8,223	8,223	8,125	8,125	
NDF	1,547	1,547	1,515	1,515	
N	160	160	155	155	
Fatty Acid	209	209	489	489	
Ruminal digestion, %					
OM[a]	66.2	64.9	56.7	54.8	4.3
NDF[bc]	51.3	50.5	35.8	47.4	6.4
Feed-N[cd]	59.5	56.0	53.6	42.2	6.4
Microbial efficiency[f]	23.4	23.3	23.6	27.9	4.9
N efficiency[g]	1.19	1.17	1.16	1.38	0.14
Total tract digestion, %					
OM[a]	82.3	83.4	78.7	79.5	1.5
NDF[ad]	54.3	57.5	44.3	48.4	3.6
N[c]	70.7	71.7	67.4	69.3	2.1
Intestinal Fatty	86.1	84.6	74.1	75.7	2.7

[a]Supplemental Fat effect, $P < .01$

[b]Supplemental Fat x Fibrozyme[7] interaction, $P < .10$

[c]Supplemental Fat effect, $P < .05$

[d]Fibrozyme[7] effect, $P < .10$

[f]Microbial N, g/kg OM fermented.

[g]Duodenal Nonammonia N leaving the abomasum / Duodenal N intake.

Table 4. Influence of Fibrozyme[7] and supplemental fat on growth performance of feedlot steers.

	Supplemental Fat, %				
	0		4		
	Fibrozyme[7], g/d				
Item	0	15	0	15	SD
Pen Replicates					
Live weight[a], kg					
Initial	262.6	261.2	259.0	261.6	5.1
Final (carcass adjusted)[b]	496.5	518.8	525.5	510.5	14.8
ADG, kg	1.35	1.49	1.54	1.47	0.05
DM intake, kg/d	7.34	7.39	7.34	6.97	0.15
DM intake/gain[bc]	5.44	4.96	4.76	4.76	0.22
Diet net energy,					
Maintenance[cde]	2.22	2.37	2.44	2.46	0.08
Gain[cde]	1.56	1.64	1.72	1.76	0.04

[a]Initial and final weights were reduced 4% to account for digestive tract fill. [b]Supplemental Fat x Fibrozyme[7] interaction, $P < .05$.

[c]Supplemental Fat effect, $P < .01$.

[d]Fibrozyme[7] effect, $P < .10$.

[e]Supplemental Fat x Fibrozyme[7] interaction, $P = .10$.

Table 5. Influence of Fibrozyme[7] and supplemental fat on carcass characteristics of feedlot steers. digestion.

	Supplemental Fat, %				
	0		4		
	Fibrozyme[7], g/d				
Item	0	15	0	15	SD
Retail Yield, %	50.9	50.7	50.6	51.2	0.5
Quality grade	5.26	5.29	5.58	5.04	0.55
KPH fat, %[a]	1.92	2.11	2.00	2.09	0.19
Fat thickness, cm[b]	1.48	1.47	1.44	1.28	0.17
RIb eye area, cm^2	82.4	84.7	82	82.4	1.2
Dressing Percentage[c]	63.6	64.7	64.4	63.7	0.5
Carcass weight, kg[c]	318.2	332.5	336.8	327.2	9.5

[a]Kidney, pelvic and heart fat as a percentage of carcass weight.

[b]Supplemental Fat effect, $P < .10$.

[c]Supplemental Fat x Fibrozyme[7] interaction, $P < .05$.