Journal of Animal and Veterinary Advances 7 (2): 145-148, 2008
ISSN: 1680-5593

Influence of Fat Titer and Method of Addition on Characteristics of Ruminal and Total Tract Digestion

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Abstract: Twelve Holstein steers (340±7.2 kg) with cannulas in the rumen and proximal duodenum were used to study the influence of fat titer (36 vs. 41°C) and method of fat inclusion (mixed in a portion of steam flaked corn in the proportion 25% fat and 75% corn, prior to adding other ingredients vs. addition of fat to the mixer as the second-to-last step, just before adding molasses) on characteristics of digestion. The basal diet contained 74.4% steam-flaked corn and 5% supplemental fat. There were no treatment effects ($p>0.10$) on site and extent of OM, starch, N, lipid and ADF digestion, nor on ruminal VFA molar concentrations. Post-ruminal lipid digestion averaged 69.3%, in close agreement with expected (71%; where fat digestion, % = 83.18-4.52FI-0.68FI^3) based on level of fat intake (FI, g kg^{-1} of body weight).

Key words: Yellow grease, tallow , steers, metabolism, fat titer, ruminal

INTRODUCTION

Hypothetically, physically coating steam-flaked corn with fat should provide a lipid barrier sufficient to reduce that rate and extent of ruminal starch digestion (Clary *et al*., 1993; García *et al*., 2000). These protection might help prevent subclinical acidosis in cattle fed diets contained high levels of processed grain (Owens *et al*., 1998). However, in a previous study (Zinn *et al*., 1998), saturating grain with 20% yellow grease did not influence starch digestion. Failure to affect a response in this case may have been related to the low melting point of the yellow grease. Titer is a measure of the hardness of fat. It is determined by melting the fat and then measuring the congealing temperature in degrees centigrade. The higher the titer value, the harder the fat is at room temperature. Tallow has a higher titer than yellow grease (41 vs. 36°C). Because the titer of tallow is greater than usually encountered within the rumen, its reactivity (rate of ruminal lipolysis) is substantially lower then that of grease (Elliot *et al*., 1997; Beam *et al*., 2000). Consequently, saturating steam-flaked corn with tallow might afford greater protection for the starch. The objective of this study was to compare the influence of saturating steam-flaked corn with yellow grease versus tallow on starch and lipid digestion.

MATERIALS AND METHODS

Twelve Holstein steers (340±7.2 kg) with cannulas in the rumen and proximal duodenum (Zinn and Plascencia, 1993) were used in a completely random design experiment. Two sources of supplemental fat (yellow grease versus tallow) and two methods of fat supplementation were evaluated in a 2×2 factorial arrangement of treatments. Methods of fat addition were: Fat was mixed in a portion of steam flaked corn in the proportion 25% fat 75% steam-flaked corn and fat was added to the mixer as the penultimate step (just before addition of molasses) in diet preparation. Steers were maintained in individual pens with access to water at all times. Fatty acid profiles of fat sources and composition of the experimental diets are shown in Table 1. Steam-flaked corn which was included at 74% (DMB) into ration was prepared as follows: A chest situated directly above the rollers (46×61cm, corrugated) was filled to capacity (441 kg) with corn and brought to a constant temperature (102°C) at atmospheric pressure using steam (boiler pressure 60 psi). The corn was steamed for 20 min before starting the rollers. Approximately 441 kg of the initial steam-processed grain that exited the rolls during warm-up was not fed to steers on this study. Tension of the rollers was adjusted to provide the indicated flake density (0.31 kg L^{-1}). Retention time of grain in steam chamber

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Table 1: Composition of basal diets fed to steers

	Supplemental fat	
Item	Yellow grease	Tallow
Ingredient composition, % (DM basis)[a]		
Sudangrass hay	6.00	6.00
Alfalfa hay	6.00	6.00
Steam-flaked corn	74.00	74.00
Yellow grease[b]	5.00	
Tallow[c]		5.00
Cane molasses	5.00	5.00
Limestone	1.50	1.50
Urea	1.12	1.12
Trace mineral salt[d]	0.40	0.40
Sodium bicarbonate	0.60	0.60
Chromic oxide	0.38	0.38

[a]Diets contained 0.4% chromic oxide as a digesta marker , [b]Fatty acids profile, % of total, myristate, 1.39; myristoleato, 0.24 palmitate; 19.26 palmitoleate, 2.53; stearate, 9.98; oleate, 48.21; linoleate, 16.80; linolenate, 1.25, [c]Fatty acids profile, % of total, myristate, 3.25; myristoleato, 0.93; palmitate; 25.91; palmitoleate, 3.65; stearate,18.04; oleate, 43.91; linoleate, 3.53; linolenate, 0.71, [d]Trace mineral salt conatined: $COSO_4$, 0.068%; $CuSO_4$, 1.04; $FeSO_4$, 3.57%; ZnO, 1.24%; $MnSO_4$, 1.07%; KI, 0.052%; and NaCl, 92.96%

was approximately 18 min. The steam-flaked corn was allowed to air-dry (5 day) before use in diet preparation. Chromic oxide was added to the diets as an inert digesta marker. Steers were fed equal proportions of their experimental diets at 0800 and 2000 daily. Individual feed intake was restricted to 2.2% SBW. Experimental periods were of 14 day duration. Following a 10 day treatment adjustment period, duodenal and fecal samples were taken from each steers twice daily over a period of 4 successive days. The time sequence for sampling steers during the collection periods was 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 500 mL of duodenal chyme and 200 g (wet basis) of fecal material. Fecal samples represented a composite of fecal material which accumulated on the floor slats during a collection interval. Intestinal and fecal samples from each steer, within each period, were composited for analysis. During the final day of each collection period, ruminal samples were obtained from each steer at approximately 4 h postprandial via the ruminal cannula. Ruminal fluid pH was determined and subsequently, 2 mL of freshly prepared 25% (wt/vol) metaphosphoric acid was added to 8 mL of strained ruminal fluid. Samples were then centrifuged (17,000×g for 10 min) and supernatant fluid stored at -20°C for VFA analysis. Upon completion of the trial, ruminal fluid was obtained from all steers and composited for isolation of ruminal bacteria, via differential centrifugation. The microbial isolates were prepared for analysis by oven drying at 70°C and then grinding with mortar and pestle. Feed, duodenal and fecal samples were prepared for analysis by oven drying at 70°C and then grinding in a lab mill (Micro-Mill®, Bell-Arts Products, Pequannock, NJ). Samples were then oven dried at 105°C until no further weight loss and stored in tightly sealed glass jars. Samples were subjected to all or part of the following analyses: ash, Kjeldahl N, ammonia N (AOAC, 1984); starch (Zinn, 1988); purines (Zinn and Owens, 1986); VFA concentrations of ruminal fluid (gas chromatography; Zinn and Plascencia, 1993); GE (adiabatic bomb calorimetry) and chromic oxide (Hill and Anderson, 1958). Microbial Organic Matter (MOM) and N (MN) leaving the abomasum were calculated using purines as a microbial marker (Zinn and Owens, 1986). Organic matter fermented in the rumen was 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 abomasum minus ammonia N and MN and thus, includes any endogenous contributions. Methane production was calculated based on the theoretical fermentation balance for observed molar distribution of VFA and OM fermented in the rumen (Wolin, 1960). Endogenous urinary energy loss was estimated as $0.10W_{kg}^{.50}$ (Brouwer, 1965; NRC, 1984). The trial was analyzed in a completely random design with a 2×2 factorial arrangement treatments (Hicks, 1973).

RESULTS AND DISCUSSION

Treatment effects on characteristics of digestion, ruminal pH and VFA profiles are shown in Table 2 and 3. There were no interactions of fat titer and method of fat inclusion ($p>0.10$). Microbial synthesis, ruminal and postruminal digestion of OM, starch, N, lipid or ADF were very similar for both methods of supplementation. Zinn *et al.* (1998) only detected a slight (2.7%, $p<0.10$) decrease in postruminal digestion of N when saturating a portion of steam-flaked corn with yellow grease.

We hypothesized that if a higher titer fat were adsorbed to grain it might reduce the initial exposure rate of processed grain to the ruminal enzymatic processes. Indeed, numerous studies have noted the depressing effect of added fat on the digestibility of various components of the diet (Zinn and Plascencia, 1993; Elliot *et al*., 1997; Zinn *et al*., 2000). It had been postulated that at least part of the depressing effects of fat on digestion was brought about by physical coating of the feed, producing a lipid barrier and thereby impeding access by hydrophilic enzymes. Nevertheless and notwithstanding, how appealing the concept, physical coating with fat (even to the point of saturation), clearly, has no appreciable effect on ruminal starch digestion.

Table 2: Influence of type and method of fat supplementation on characteristics digestion

	Treatment				
	On grain		On last		
	YG	TL	YG	TL	SD
Steers	3	3	3	3	
Intake (g d^{-1})					
DM	7.541	6.997	8.004	6.544	
OM	7.132	6.618	7.571	6.190	
Starch	3.469	3.218	3.682	3.010	
ADF	597	554	634	518	
N	127	117	134	110	
Lipid	616	572	654	535	
GE (Mcal d^{-1})	34.8	32.3	37.0	30.3	
Ruminal digestion, % intake					
OM	67.1	62.3	63.3	64.9	6.3
Starch	87.8	85.9	84.0	88.7	5.9
ADF	32.1	20.6	31.1	16.7	13.0
Feed N	53.6	41.6	48.8	43.9	9.3
N efficiency[a]	1.01	1.15	1.09	1.10	0.08
Post-ruminal digestion, % leaving abomasum					
OM	63.3	63.5	64.9	65.9	4.3
Starch	94.4	94.5	94.3	95.7	1.8
ADF	13.0	19.6	16.2	30.0	14.6
N	74.4	73.6	74.3	76.7	4.2
Lipid	68.0	72.5	66.0	70.6	4.7
Total tract digestion (%)					
OM	84.1	82.9	83.5	84.7	2.8
Starch	99.3	99.3	99.0	99.5	3.8
ADF	40.8	38.4	42.5	41.7	9.6
N	73.1	68.9	70.9	73.4	4.7
DE (Mcal kg^{-1})	3.74	3.70	3.68	3.75	0.12
DE (%)	80.9	80.1	79.5	81.0	2.6

[a] Duodenal non-ammonia N/N intake

Table 3: Main effects of influence of source and method of fat supplementation on ruminal pH, VFA and methane production 4 h after feeding

	Treatment				
	On grain		On last		
	YG	TL	YG	TL	SD
Ruminal pH	5.74	6.23	5.73	5.80	0.40
Ruminal VFA, mol 100 mL^{-1}					
Acetate	47.8	46.5	48.0	52.8	6.8
Propionate	38.4	46.1	38.7	35.4	7.5
Butyrate[a]	13.7	7.4	13.3	11.7	3.3
Methane production[b]	0.30	0.29	0.37	0.42	0.09

[a]Source of fat effect, $p<0.10$, [b]Methane, mol mol^{-1} of glucose equivalent fermented

Consistent with previous trials with steers fed a high-energy (Zinn, 1989; Zinn and Plascencia, 1992; Plascencia *et al*., 1999) and high-forage diets (Moore *et al*., 1986; Palmquist, 1991), there were no effects ($p>0.10$) of fat source (yellow grease vs. tallow) on site and extent of OM, starch, N and ADF digestion, ruminal pH and VFA molar proportions. Fat source and method of substitution did not affect post-ruminal lipid digestion. Intestinal digestion averaged 69.3%, in close agreement with expected (71%; where fat digestion, % = 83.18 - 4.52FI - .68FI[3]; Zinn, 1994) based on level of fat intake (FI, g kg^{-1} of body weight).

Recently a controversy has risen about the potential of the unsaturated: saturated proportion contents in fat on the nutrimental value for feedlot cattle. In general, when degree of saturation is increased in a fat source (for example by hydrogenation) the negative effects on ruminal fermentation are reduced, but also intestinal digestibility of fatty acids is reduced. In relation to this, it has been shown that fatty acid digestibility is reduced from 74% for tallow to 37% for high hydrogenated tallow (Macleod and Buchanan-Smith, 1972; Elliott *et al*., 1999) and reduction of 23% in lipid digestibility was observed when yellow grease was offered in hydrogenated form (Jenkins and Jenny, 1989). However, the latter should not be generalized for different fat sources with different saturation degrees. For example, Bock *et al*. (1991) did not detect differences in fatty acid intestinal digestibility (average 75%) of soy oil soapstock with a proportion of unsaturated: saturated of 3.7 as compared with tallow (proportion of unsaturated: saturated of 1.65) added to a finishing-wheat ground diet. Likewise, Palmquist (1991) compared 5 different fat sources with different proportions of unsaturated:saturated fat and did not report differences in fatty acid digestibility. Attenuation of effects caused by unsaturated: saturated proportion contained in fat that is commonly added to ruminant diets is due to the high degree of biohydrogenation of unsaturated FA that occurs in rumen (Zinn and Plascencia, 2007). For the latter, differences between FA proportions that exist among the different sources of supplemental fat are slightest when they reach the small intestine, in such a manner that the proportion of unsaturated: saturated content in the feed has less relevance for ruminants as compared with non-ruminant species (Vila and Esteve-García, 1996; Hamilton, 2002).

IMPLICATIONS

Method of fat supplementation does not influence the feeding value of supplemental fat. Differences in titer between fat sources does not modify the characteristics of ruminal starch digestion when fats are coated onto a portion of steam-flaked corn.

CONCLUSION

We conclude that method of fat supplementation does not influence the feeding value of supplemental fat. Differences in titer between fat sources do not modify the characteristics of ruminal starch digestion when fats are coated onto a portion of steam-flaked corn.

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