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Influence of Method Supplementation of Yellow Grease on Growth Performance, Dietary Energetics, Carcass Characteristics and Nutrient Digestion of Feedlot Steers

Research Article

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ABSTRACT

Two experiments were conducted in order to evaluate two methods of yellow grease (YG) supplementation (5% on a dry matter basis in replaced to the steam-flaked corn in control diet) on cattle growth performance, dietary energetic and site and extent of nutrients digestion. Supplemental methods were as follows: 1) YG added directly on grain (YG was first mixed with the steam-flaked corn in the proportion 50 kg YG to 750 kg corn, prior to adding other dietary ingredients), or 2) YG added on ration (added to the mixer as the next to the last step, prior to adding molasses). A group without YG supplementation was included as controls. Growth-performance trial lasted 151 days (72 crossbred cattle, 273±0.8 kg LW). Method of YG supplementation did not affect growth-performance, dietary energetics or carcass characteristics. Addition of 5% YG in diets increased (P≤0.04) feed efficiency (4.7%) and dietary net energy (NE, 5.7%). Based on performance data, the estimated NE_m value of YG was 4.38 Mcal/kg. In trial 2, six Holstein steers (313±5.5 kg) with cannulas in the rumen and proximal duodenum were used in a replicated 3 × 3 latin square design experiment to evaluate treatment effects on digestive function and ruminal fermentation. Yellow grease added directly to the grain decreased (2.6%, P<0.05) postruminal digestion of N without effected the site and extent of digestion of organic matter (OM), starch and fiber. Supplemental YG did not affect ruminal proportion of volatile fatty acids nor ruminal pH, but decreased (P≤0.04) ruminal digestion of OM (10.4%) and acid detergent fiber (ADF, 36.7%). Supplemental YG tended (P=0.06) to decreased total tract digestion of OM (1.8%) and ADF (13.9%). It is concluded that there are no positive associative effects of adding YG directly to steam-flaked corn on growth-performance or digestive function.

KEY WORDS digestion, feedlot, performance, ruminal fermentation, supplementation method, yellow grease.

INTRODUCTION

Control of the ruminal digestion rate of carbohydrates is an important step for the optimization of the energy intake. In this sense, it's desirable a lower digestion rate for starch and greater digestion rate for fiber (Krebiel, 2014). The first limiting step toward degradation of feed particles within the rumen is exposure of the substrate to the enzymatic process. This forms the basis for the various processing techniques applied to grains and forages (Deckart *et al*. 2013). For example, steam flaking corn disrupts the seed coat and protein matrix surrounding the starch granules, thereby enhancing ruminal (extent and rate of digestion) and total tract starch digestion (Zinn *et al*. 2002). However, at high levels of

processed grain inclusion in diet the possibility of associative negative impacts (i.e. lower ruminal pH) are present (Owens *et al*. 1998).

In opposite, the detrimental effects of supplemental fats on fiber ruminal digestibility can be partially attributed to physical effect of fat on fiber in the rumen; fats coated the fiber particles, decreasing the hydration retarding to microbial attack (Garnsworthy, 1997). The same effect on starch of particles of processed grain can be expected; however, in a previous report (Zinn and Plascencia, 2004), no effect was detected of method of supplementation (fat on grain or on last) of tallow fatty acids on growth performance and dietary energetic. However, earlier studies demonstrate that the degree of saturation of fat play an important role on its solubility and in their dispersion in the ruminal fluid (Jenkins, 1993).

With a lower degree of saturation, fats become more soluble in the rumen fluid. Yellow grease is a more commonly source of fat used in feedlot diets and has a lower degree of saturation (greater iodine value, 82 *vs*. 50) than tallow fatty acids (Zinn and Jorquera, 2007). For that reason, different response with method of supplementation with YG can be expected. Considering that the finishing diets containing around 70 to 80% of grain, starch is a major component of diets to finishing cattle (Plascencia *et al*. 2012).

For that reason, our hypothesis is that coating corn grain with supplemental YG prior to be mixed with the rest of ingredients may reduce the exposure rate of starch to ruminal fermentation, increasing escape of starch to the small intestine improving the energy efficiency of starch utilization in feedlot cattle. The objective of the present study was to investigate this strategy with respect to feedlot cattle growth performance, dietary energetics and site and extent of starch digestion.

MATERIALS AND METHODS

All procedures involving animal care and management were in accordance with and approved by the University of California, Davis, Animal Use and Care Committee.

Growth performance trial

Animals, treatments, and sampling

Seventy-two Holstein steers (273±0.8 kg initial shrunk weight) were blocked by weight and randomly assigned, within weight groupings, to 12 pens (6 steers/pen). Pens were 43 m^2 with 22 m^2 overhead shade, automatic waterers and 2.4 m fence-line feed bunks. Average daily minimum and maximum air temperatures during the trial were 13 and 31˚C, respectively.

There was 2.6 cm precipitation; average daily relative humidity was 41%. Steers were vaccinated against infectious bovine rhinotracheitis (IBR), bovine virus diarrhea (BVD) (type 1 and 2), parainfluenza type 3 (PI3), bovine respiratory syncytial virus (BRSV) (Cattle Master Gold FP 5 L5, Zoetis, New York, NY), clostridia (Ultrabac 8, Zoetis, New York, NY), treated against internal and external parasites (Dectomax, Zoetis, New York, NY), injected with 1500 IU vitamin E (as d-alpha-tocopherol), 500000 IU vitamin A (as retinyl-palmitate) and 50000 IU vitamin D_3 (Vital E-AD, Stuart Products, Bedford, TX), Steers were implanted with Synovex-S® (Syntex Corp., Des Moines, IA) upon initiation of the trial and reimplanted with Revalor® (Hoechst-RousselAgri-Vet, Somerville, NJ) on d 56. The maximal total fat (from basal ingredients plus added fat) content recommended for feedlot diets is 8.0% (Vasconcelos and Galyean, 2007). In these sense, the limit fat inclusion in finishing diets are commonly 5% (Zinn and Plascencia, 2007). Therefore, we decide used the maximal recommended level of supplementation to test our hypothesis. Dietary treatments (Table 1) consisted of a diet without supplemental YG (control), and two methods of YG supplementation (5% on a dry matter basis) as follows: 1) supplemental YG added directly on grain (for each prepared ton of diet, 50 kg of YG was first mixed with 750 kg of steam-flaked corn, prior to adding the rest of dietary ingredients), or 2) YG added on ration (YG was added to the mixer as the next to the last step, prior to adding molasses). Yellow grease replaced the corn in control diet. Composition of the yellow grease (YG) used in this study (described in footnote Table 1) is similar to the standards set by American fats and oils association (AFOA, 1988), and was very similar to with those used in other experiments conducted at this center (Zinn, 1988; Zinn, 1989; Zinn, 1992). Diets were prepared at approximately weekly intervals and stored in plywood boxes located in front of each pen. Fresh feed was provided twice daily at 06:00 and 14:00 h, offering approximately 30% of daily consumption in the morning feeding and the remainder in the afternoon feeding. Feed and refusal samples were collected daily for DM analysis, which involved oven drying the samples at 105 ˚C until no further weight loss occurred (method 930.15; AOAC, 2000).

Carcass evaluation

Hot carcass weights (HCW) were obtained at time of slaughter. After carcasses chilled for 24 h, the following measurements were obtained: longissimus muscle (LM) area (cm^2) by direct grid reading of the muscle at the 12^{th} rib; subcutaneous fat (cm) over the LM at the 12^{th} rib taken at a location 3/4 the lateral length from the chine bone end

(adjusted by eye for unusual fat distribution); kidney, pelvic and heart fat (KPH) as a percentage of HCW; marbling score [using 3.0 as minimum slight, 4.0 as minimum small, 5.0 as minimum modest, 6.0 as minimum moderate, etc. (USDA, 1997)], and estimated retail yield of boneless, closely trimmed retail cuts from the round, loin, rib and chuck (% of HCW)= 52.56 - 1.95 × subcutaneous fat - 1.06 × KPH + 0.106 × LM area - 0.018 × HCW.

Calculations

For calculation of growth performance, initial live weight is the off-truck arrival weight. Final live weight was reduced 4% to adjust for digestive tract fill. Average daily gain (ADG) was computed by subtracting the initial weight from the final adjusted weight and dividing the result by the number of days on feed. Gain to feed ratio (gain efficiency) was determined by dividing ADG by the daily dry matter intake (DMI).

Energy gain (EG, Mcal/d) was calculated by the equation: $EG= 0.0557SBW^{0.75} \times ADG^{1.097}$; where EG is the daily deposited energy and SBW is the equivalent of live weight × 0.96 (NRC, 1984). Maintenance energy (EM, Mcal/d) was calculated by the equation: $EM= 0.084SBW^{0.75}$ (Garrett, 1971). From the derived estimates of energy required for maintenance and gain, the NE_m and NE_g values of the diet were obtained using the quadratic formula (Zinn *et al*. 2008):

$$x= (-b-\sqrt{b^2-4ac}) / 2\ c$$

Where:
x: diet NE_m, Mcal/kg,
a= −0.41 EM.
b= 0.877 EM + 0.41 DMI + EG.
c= −0.877 DMI.
$NE_g= 0.877\ NE_m - 0.41$.

Statistical analyses

The trial was analyzed as a randomized complete block design using the pen as experimental unit (SAS, 2007) according to the following statistical model:

$$Y_{ij}= \mu + B_i + T_j + \varepsilon_{ij}$$

Where:
μ: common experimental effect.
B_i: initial weight block effect.
T_j: dietary treatment effect.
ε_{ij}: residual error.

Performance data were determined reducing 4% the initials and final weights to account for digestive tract fill.

Treatments effects were tested by means of orthogonal contrasts according to SAS (2007) as follows: 1) no YG *vs*. supplemental YG, and 2) YG on grain *vs*. YG on total mixed ration. The analysis was carried out with the MIXED procedure of SAS (2007).

In all cases, least squares means and standard error are reported and contrasts were considered significantly when the P-value was ≤ 0.05, and tendencies are identified when the P-value was > 0.05 and ≤ 0.10.

Digestion trial

Animals, treatments, and sampling

Six Holstein steer (313±5.5 kg) with cannulas in the rumen and proximal duodenum (Zinn and Plascencia, 1993) were used in a replicated 3 × 3 latin square experiment to study treatment effects on characteristics of ruminal and total tract digestion. Treatments were the same as those used in trial 1 (Table 1), with 0.30% chromic oxide added as a digesta marker. Steers were maintained in individual pens (3.9 m^2) with access to water at all times. 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 500 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 the morning feeding via the ruminal cannula. Ruminal fluid pH was determined (Digi-Sense LCD pH Meter, Cole-Parmer, Chicago, IL) on fresh samples, and samples were strained through four layers of cheesecloth. Two milliters of freshly prepared 25% (w/v) meta-phosphoric acid was added to 8 mL of strained ruminal fluid. Samples were then centrifuged (17000×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 (Bergen *et al*. 1968).

Sample analysis and calculations

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, 2000); acid detergent fiber (ADF) (Goering and Van Soest, 1970); purines (Zinn and Owens, 1986); lipids (Zinn, 1994); volatile fatty acid (VFA) concentrations of ruminal fluid (gas chromatography; Zinn, 1988); chromic oxide (Hill and Anderson, 1958) and starch (Zinn, 1990).

Table 1 Composition of experimental diets fed to steers (trials 1 and 2)[1]

Item	Control	Method of supplementation[2]	
		On ration	On grain
Ingredient composition, % DM basis			
Alfalfa hay	8.00	8.00	8.00
Sudangrass hay	4.00	4.00	4.00
Steam-flaked corn	80.29	75.29	75.29
Yellow grease[3]			
On ration	---	5.00	---
On grain	---	---	5.00
Cane molasses	4.00	4.00	4.00
Limestone	1.77	1.77	1.77
Urea	1.19	1.19	1.19
Dicalcium phosphate	0.25	0.25	0.25
Trace mineral salt[4]	0.50	0.50	0.50
Nutrient composition, % DM basis[5]			
Crude protein	12.24	11.63	11.96
Starch	50.41	48.55	48.30
Acid detergent fiber	8.99	7.54	8.01
Lipids	3.07	8.44	8.67
Ash	5.25	5.30	5.33
Calculated NE, Mcal/kg[6]			
Maintenance	2.15	2.33	2.33
Gain	1.47	1.63	1.63

[1] Diets in trail 2 contained an additional 0.30% chromic oxide as a digesta marker.
[2] On ration=YG was added to the mixer as the next to the last step, prior to adding molasses; On grain= YG was first mixed with a portion of the steam-flaked corn in the proportion of 50 kg YG in 750 kg of steam-flaked corn prior to adding other dietary ingredients.
[3] Fatty acid profile, %: C12:0, 0.30; C14:0, 0.76; C16:0, 14.54; C16:11.38; C18:0, 8.61; C18:1, 48.30; C18:2, 22.42; C18:3, 2.26.
[4] Trace mineral salt contained: $CoSO_4$: 0.068%; $CuSO_4$: 1.04%; $FeSO_4$: 3.57%; ZnO: 1.24%; $MnSO_4$: 1.07%; KI: 0.052% and NaCl: 92.96%.
[5] Dietary chemical composition for crude protein (CP), neutral detergent fiber (NDF), lipids, ash, and acid detergent fiber were determined by analyzing subsamples collected and composited throughout the experiment.
[6] Net energy was calculated based on tabular net energy (NE) values for individual feed ingredients (NASEM, 2016).

Composition of supplemental yellow grease was analyzed according to AOCS (2017) procedures as follows: moisture (method Ca 2a-45), impurities (method Ca 3-46), unsaponifiables (method Ca 6a-40), iodine value (method Tg 1a-64). Microbial organic matter (MOM) and N (MN) leaving the abomasum was calculated using purines as a microbial marker (Zinn and Owens, 1986). Organic matter fermented in the rumen (OMF) 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 was 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) and ruminal OM digestion.

Statistical analyses

The trial was analyzed (SAS, 2007) as a replicated 3 × 3 Latin square according to the following statistical model:

$$Y_{ijkl} = m + B_i + A_{j(i)} + P_k + T_l + E_{ijkl}$$

Where:

B_i: block.
$A_{j(i)}$: steer within block.
P_k: period.
T_l: treatment.
E_{ijkl}: residual error.

Treatment effects were tested by means of the following orthogonal contrasts: 1) control *vs*. supplemental YG, 2) YG on grain *vs*. YG on total mixed ration. In all cases, least squares means and standard error are reported and contrasts were considered significantly when the P-value was ≤ 0.05, and tendencies are identified when the P-value was > 0.05 and ≤ 0.10.

RESULTS AND DISCUSSION

Growth performance and carcass characteristics

Treatment effects on growth-performance and dietary NE (Trial 1) are shown in Table 2. Method of fat supplementation did not affect growth-performance, dietary energetics nor carcass characteristics. In a previous report (Zinn and Plascencia, 2004), no effect was detected of method of supplementation (fat on grain or on last) of tallow fatty acids on growth performance and dietary energetic in cattle fed a combined steam-flaked wheat and steam-flaked corn diet.

Table 2 Influence of method of fat supplementation on feedlot growth performance of Holstein steers (trial 1)

Item	Control	Method of supplementation[1]		SEM	Method	P-value
		On ration	On grain			Control *vs.* YG
Pen replicates	5	5	5			
Days on test	151	151	151			
Shrunk body weight, kg [2]						
Initial	270.4	270.4	269.6	0.35		
Final	508.4	500.0	501.7	2.90	0.53	0.06
Daily gain, kg	1.54	1.48	1.51	0.017	0.39	0.06
Dry matter intake, kg/d	8.23	7.68	7.74	0.04	0.38	< 0.01
Gain to feed, kg/kg	0.187	0.193	0.194	0.002	0.65	0.04
Diet NE, Mcal/kg						
Maintenance	2.26	2.34	2.34	0.019	0.81	0.02
Gain	1.58	1.64	1.64	0.017	0.81	0.02
NE of yellow grease, Mcal/kg						
Maintenance	--	4.38	4.38			
Gain	--	3.43	3.43			

[1] On ration= YG was added to the mixer as the next to the last step, prior to adding molasses; On grain= YG was first mixed with a portion of the steam-flaked corn in the proportion of 50 kg YG in 750 kg of steam-flaked corn prior to adding other dietary ingredients.
[2] Initial and final full body weights were shrunk 4% to account for digestive tract fill.
SEM: standard error of the means.

Apparently, the level of YG supplementation (50 kg YG/750 kg grain) directly to the grain did not coat the grain particles sufficiently so that the rate of ruminal digestion was retarded. Even though supplemental YG tended (P=0.06) to decrease 2.9% average daily gain, decreases of 6.3% (P<0.01) on dry matter intake as well; therefore, supplemental YG increased (P<0.04) feed efficiency (4.7%) and diet NE (5.7%, P=0.02). The tendency of decrease on ADG in YG supplemented cattle is not commonly expected. Generally, due to difference on energy density between YG and replaced corn (5.6 *vs.* 2.38 Mcal NE_m/kg; NASEM, 2016), YG supplementation generally increases ADG, feed efficiency or both (Zinn and Jorquera, 2007). Using the replacement technique, the NE_m and NE_g values of YG were 4.38 and 3.45 Mcal/kg, respectively. In previous trials conducted at this Center (Zinn, 1988; Plascencia *et al*. 2003; Zinn and Plascencia, 2004) the NE_m value of supplemental yellow grease ranged from 6.02 to 6.35 Mcal/kg when total lipid intake did not exceed 1.60 g/kg BW. Therefore, initially, the NE value observed here for YG was 27% lower than those determined in previous trials at this center. It is well recognized that at higher lipid intakes the NE_m value of the supplemental fat declines in a linear fashion (Zinn and Jorquera, 2007). Lipid intake in this trial averaged 1.71 g/kg BW (Table 3). Thus, based on the partial efficiency of utilization of ME from dietary fat for BW gain (Plascencia *et al*. 2003), the expected NE_m value of yellow grease is 5.50 Mcal NE_m/kg, very similar to 5.60 expressed in current standards (NASEM, 2016); therefore, the expected NE value related to the lipid intake is 20% greater with the observed value of 4.38 Mcal NE_m/kg in Trial 1. However, similarly, low NE for supplemental fat values have been reported by other workers (Brandt Jr and Anderson, 1990; Clary *et al*. 1993).

As will be discussed later, the low NE values of YG observed in Trial 1 were the consequence of low intestinal lipid digestibility observed in Trial 2.

Treatment effects on carcass characteristics are shown in Table 3. There were no treatments effect on carcass characteristics. The absence of effects of YG supplementation on carcass is surprising since several studies had shown that supplemental fat increased KPH (Zinn, 1988; Zinn, 1992; Zinn and Plascencia, 1996) and / or dressing percentage (Bock *et al*. 1991; Plascencia *et al*. 1999).

Site and extent of digestion

Treatments effects on characteristics of ruminal and total tract digestion (Trial 2) are shown in Table 4. Due to the replace of grain by YG, method of fat supplementation increased almost three-fold (2.81) lipid intake, and slightly decreased ADF (12.4%) and starch intake (4.3%). Method of fat supplementation did not affect (P>0.10) flow of non-ammonia N, microbial N and feed N, averaging 122, 63.9, and 58.9 g/d, respectively.

Addition of 5% YG in diets increased 28% lipid flow to duodenum (P<0.01), this increase reflecting the indigestibility of YG itself plus de novo microbial fatty acid synthesis commonly observed at the moderated levels of fat supplementation (Ramirez and Zinn, 2000; Plascencia *et al*. 2003).

Method of fat supplementation did not affect (P>0.10) ruminal and total tract digestion of OM, ADF, or N. Contrary to our hypothesis, method of fat supplementation did not affect (P>0.10) ruminal, post-ruminal and total tract digestion of starch.

This finding confirms the results observed in Trial 1 in which method of supplementation did not affect gain efficiency nor dietary energetics.

Table 3 Influence of method of fat supplementation on carcass characteristics of Holstein steers (trial 1)

Item	Control	Method of supplementation[1]		SEM	Method	P-value
		On ration	On grain			Control *vs*. YG
Carcass weight, kg	313	305	310	3.29	0.34	0.18
Dressing percentage	61.7	61.2	61.8	0.33	0.23	0.64
Longissimus area, cm^2	80.3	77.1	78.8	1.15	0.35	0.14
Fat thickness, cm	0.50	0.42	0.48	0.04	0.27	0.28
Kidney, pelvic and heart fat (KPH), %	1.33	1.65	1.72	0.16	0.78	0.11
Marbling score[2]	3.6	3.8	3.7	0.09	0.50	0.66
Retail yield[3]	52.4	52.2	52.1	0.20	0.78	0.46

[1] On ration= YG was added to the mixer as the next to the last step, prior to adding molasses and On grain= YG was first mixed with a portion of the steam-flaked corn in the proportion of 50 kg YG in 750 kg of steam-flaked corn prior to adding other dietary ingredients.
[2] Coded: minimum slight= 3 and minimum small= 4.
[3] Percentage of closely trimmed, mostly boneless, retail product from the round, loin, rib, and chuck.
SEM: standard error of the means.

Table 4 Influence of method of YG supplementation on characteristics of digestion incannulated Holstein steers (trial 2)

Item	Control	Method of supplementation[1]		SEM	Method	P-value
		On ration	On grain			Control *vs*. YG
Steer replicates	6	6	6			
Intake, g/d						
Dry matter	6074	6125	6112			
Organic matter	5755	5800	5786			
Starch	3062	2974	2891			
Acid detergent fiber	546	462	495			
Nitrogen	119	114	117			
Lipids	187	517	530			
Flow to duodenum, g/d						
Organic matter	2110	2582	2526	48.7	0.45	< 0.01
Starch	241	281	273	18.7	0.75	0.17
Acid detergent fiber	323	360	349	23.1	0.73	0.30
Non-ammonia N	124	123	120	3.3	0.56	0.55
$N\text{-}NH_3$	5.34	5.13	5.15	0.30	0.98	0.61
Microbial N	65.0	63.2	63.5	3.47	0.96	0.71
Feed N	44.4	45.0	41.9	3.43	0.53	0.83
Lipids	419	579	589	33.5	0.83	< 0.01
Ruminal digestion, %						
Organic matter	74.6	66.4	67.2	1.19	0.63	< 0.01
Starch	92.1	90.5	90.3	0.68	0.87	0.08
Acid detergent fiber	40.3	21.1	29.9	4.85	0.24	0.04
Feed N	62.4	60.5	64.4	2.89	0.37	0.98
Microbial efficiency[2]	15.1	16.5	16.6	0.68	0.95	0.13
Protein efficiency[3]	1.05	1.08	1.02	0.031	0.23	0.94
Fecal excretion, g/d						
Dry matter	931	997	1046	38.5	0.40	0.09
Organic matter	762	834	886	34.6	0.32	0.05
Starch	9.2	8.6	11.4	1.11	0.11	0.57
Acid detergent fiber	251	252	257	13.2	0.77	0.86
Nitrogen	29.3	28.8	30.6	0.52	0.05	0.57
Lipids	139	194	213	22.2	0.56	0.04
Postruminal digestion (as % of entering to duodenum)						
Organic matter	63.1	67.5	64.9	0.02	0.37	0.22
Starch	95.8	96.6	95.6	0.56	0.26	0.67
Acid detergent fiber	18.3	30.0	24.2	7.96	0.62	0.40
Nitrogen	77.5	77.6	75.5	0.62	0.05	0.25
Lipids	67.2	66.5	64.0	2.12	0.43	0.49
Total tract digestion, %						
Dry matter	84.7	83.7	82.9	0.62	0.38	0.12
Organic matter	86.7	85.6	84.7	0.58	0.30	0.06
Starch	99.7	99.7	99.6	0.03	0.15	0.39
Acid detergent fiber	53.9	44.9	47.9	2.71	0.46	0.06
Nitrogen	75.4	74.8	73.9	0.57	0.36	0.20

[1] On ration= YG was added to the mixer as the next to the last step, prior to adding molasses and On grain= YG was first mixed with a portion of the steam-flaked corn in the proportion of 50 kg YG in 750 kg of steam-flaked corn prior to adding other dietary ingredients.
[2] Microbial efficiency was expressed as: Duodenal microbial N, g/ kg of OM fermented in the rumen.
[3] Protein efficiency was estimated as: Duodenal non-ammonia N, g/g of N intake.
SEM: standard error of the means.

Table 5 Influence of method of fat supplementation on ruminal pH, VFA molar proportions and estimated methane production 4h after feeding (trial 2)

Item	Control	Method of supplementation[1]		SEM	P-value	
		On ration	On grain		Method	Control *vs.* YG
Steer replicates	6	6	6			
Ruminal pH	5.77	5.91	5.94	0.09	0.81	0.15
Ruminal VFA, mol/100 mol						
Acetate	53.3	56.0	56.1	3.44	0.99	0.53
Propionate	33.7	32.4	34.5	2.77	0.60	0.94
Butyrate	13.0	11.6	9.4	1.48	0.33	0.21
Methane production[2]	0.43	0.46	0.44	0.038	0.71	0.81

[1] On ration= YG was added to the mixer as the next to the last step, prior to adding molasses and On grain= YG was first mixed with a portion of the steam-flaked corn in the proportion of 50 kg YG in 750 kg of steam-flaked corn prior to adding other dietary ingredients.
[2] Mol/mol of glucose equivalent fermented.
SEM: standard error of the means.

Thus, it can be concluded that saturating steam-flaked corn with yellow grease (at proportion used here) not increase the proportion of starch digestion in the small intestine.

Consistent with previous studies (Zinn and Plascencia, 1993; Zinn, 1989; Zinn, 1994), supplemental YG depressed ruminal digestion of OM (10.4%, P<0.01) and ADF (36.7%, P=0.04). The depression in OM digestion can be largely (55%) attributed to the ruminal indigestibility of fat itself (Zinn, 1994) and the negative effects of supplemental fat on ruminal ADF digestion.

There were no treatment effects (P>0.10) on post-ruminal digestion of OM, ADF and lipid. However, saturating a portion of steam-flaked corn with YG decreased slightly (2.7%, P<0.05) postruminal digestion of N.

Postruminal digestion of supplemental fat (LD, %) is largely a function of total lipid intake (LI, g/kg BW): LD= 83.18 - 4.07LI - 0.61LI^3 (Zinn, 1994). Accordingly, expected intestinal lipid digestibility of the YG supplemented diets is 73.5%. Thus, observed intestinal lipid digestibility was 88% of expected. In a previous report (Plascencia and Zinn, 2019) in which YG was tested at 5% supplementation level, fatty acid post-ruminal digestibility was 76%. The low digestion value observed here is uncertain, but as mentioned above, the low dietary NE values of YG observed in Trial 1 provide confirmatory evidence that the measures obtained in digestion trial are not aberrant.

Method of fat supplementation did not affect (P>0.10) total tract digestion, but consistent with the most of reports (Hess *et al*. 2008), supplemental YG decreased (P=0.06) total tract digestion of OM (1.8%) and ADF (13.9%).

Treatment effects on ruminal pH, VFA molar proportions and estimated methane production are shown in Table 5. Method of fat supplementation did not influence (P>0.10) ruminal pH or VFA molar proportions. From this it may be surmised that in addition to the lack of effect of method of fat supplementation on extent of ruminal OM and starch digestion, rate of digestion was also unaffected. Yellow grease supplementation did not affect ruminal pH.

This is consistent with previous reports which indicate no effects of YG on ruminal pH when YG replace corn grain (Plascencia and Zinn, 2002; Corona *et al*. 2005). Supplemental YG did not influence (P>0.10) ruminal VFA molar proportions. These results are consistent with previous reports (Zinn and Plascencia, 1993; Zinn and Plascencia, 1996). Although more frequently, fat supplementation has increased relative proportions of propionate (Toprak, 2015).

CONCLUSION

Method of fat supplementation does not influence the feeding value of yellow grease for feedlot cattle. Saturation of a portion of the dietary steam-flaked corn with yellow grease does not reduce its negative effects on ruminal fiber digestion, nor does it enhance the proportion of dietary starch that escapes ruminal degradation.

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