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Influence of Kaolinite Clay Supplementation on Growth Performance and Digestive Function in Finishing Calf-fed Holstein Steers

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ABSTRACT: Two experiments were conducted to examine the influence of kaolinite clay supplementation (0%, 1%, or 2% diet dry matter [DM] basis) on characteristics of digestion (Trial 1) and growth performance (Trial 2) in calf-fed Holstein steers fed a finishing diet. In Trial 1, 6 Holstein steers (539±15 kg) with ruminal and duodenal cannulas were used to evaluate treatment effects on characteristics of digestion. Kaolinite clay supplementation decreased total tract DM digestion (linear effect, $p<0.01$) without effects ($p\geq 0.10$) on site and extent of digestion of organic matter, neutral detergent fiber, starch and N, or ruminal microbial efficiency. There were no treatment effects on ruminal pH, volatile fatty acids molar proportions or estimated methane production. In Trial 2, 108 Holstein steers (132.4±5.6 kg) were used in a 308-d study to evaluate growth performance and carcass characteristics. There were no treatment effects ($p>0.10$) on average daily gain (ADG) and gain efficiency (ADG/dry matter intake). Kaolinite supplementation tended (linear effect, $p = 0.08$) to increase dietary net energy (NE) during the initial 112-d period. However, the overall (308-d) effect of supplementation dietary NE was not appreciable ($p>0.20$). However, due to the inertness of kaolinite, itself, the ratio of observed-to-expected dietary NE increased with kaolinite supplementation. This effect was more pronounced (linear effect, $p\leq 0.03$) during the initial 224 d of the study. Overall (308 d), kaolinite supplementation tended to increase (linear effect, $p = 0.07$) dietary NE by 3% over expected. Kaolinite supplementation did not affect carcass weight, yield grade, longissimus area, kidney, pelvic and heart fat, and quality grade, but decreased (linear effect, $p = 0.01$) dressing percentage. It is concluded that kaolinite supplementation up to 2% of diet DM may enhance energetic efficiency of calf-fed Holstein steers in a manner independent of changes in characteristics of ruminal and total tract digestion. (**Key Words:** Kaolinite, Feedlot, Supplementation, Cattle, Growth, Digestion)

INTRODUCTION

Clay minerals (bentonite, kaolinite, zeolite) are ubiquitous in nature. Unique structural properties lend to their usefulness as feed additives. Zeolites are a family of minerals of volcanic origin that are composited of crystalline aluminosilicates. Their dimensional structures are characterized by an ability to lose and gain water reversibly and to exchange cations without major change of their structure (Trckova et al., 2004). Bentonite and kaolinite clay (or kaolin) on the other hand, are members of phillosilicates. Bentonite is a rock constituted of highly colloidal plastic clays composed mainly by montmorillonite (Safaei et al., 2014). The particular characteristic of bentonite is its capability to form gel with water and its high cation exchange capacity (about half the CEC of zeolite clay). Kaolinite is formed by the weathering of aluminous minerals such a feldspar, a plastic clay mineral (Owen et al., 2012), kaolinite has a low shrink–swell capacity and a low cation-exchange capacity (1 to 15 meq/100 g). Recognized as safe for feeding to livestock (EFSA, 2016), kaolinite is widely used as a binder for pelleted feeds, for anti-caking, as an anti-diarrheal and for aflatoxin reduction (Spotti et al., 2005). Due to its chemical, and antimicrobials properties, kaolinite supplementation has been shown to also enhance average

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daily gain (ADG), feed efficiencies, and carcass yields in non-ruminants species (Trckova et al., 2004). However, very little work has been reported that evaluates the effects of kaolinite supplementation on growth-performance of feedlot cattle is limited. The objective of this experiment was to examine the influence of kaolinite clay supplementation (0%, 1%, or 2% diet dry matter [DM] basis) on characteristics of digestion, feedlot growth performance and carcass characteristics of calf-fed Holstein steers fed a steam-flaked corn-based diet.

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.

Trial 1: Characteristics of digestion and ruminal fermentation

Animals, sampling and treatments: Six Holstein steers (539±15 kg) with cannulas in the rumen (3.8 cm internal diameter) and proximal duodenum were used in a replicated 3×3 Latin square experiment to study treatment effects on characteristics of digestion. Dietary treatments consisted of a steam-flaked corn-based growing-finishing diet supplemented (diet DM basis) with 0%, 1%, or 2% of kaolinite clay (Ione Minerals Inc., Ione, CA, USA). Composition of experimental diets is shown in Table 1. Chromic oxide (3.0 g/kg of diet air-dry basis) was used as an indigestible marker to estimate nutrient flow and digestibility. Steers were maintained in individual pens (4 m^2) with automatic waterers. Diets were fed at 0800 and 2000 h daily. In order to avoid feed refusals, dry matter intake (DMI) was restricted to 10.3 kg/d (equivalent to 1.9% of live weight [LW]). Experimental periods consisted of a 10-d diet adjustment period followed by a 4-d collection period. Between each experimental period, steers were allowed a 7-d recovery period during which all steers were fed the control diet. During collection, duodenal and fecal samples were taken twice daily as follows: d 1, 0750 and 1350 h; d 2, 0900 and 1500 h; d 3, 1050 and 1650 h, and d 4, 1200 and 1800 h. Individual samples consisted of approximately 700 mL of duodenal chime and 200 g (wet basis) of fecal material. Samples from each steer within each collection period were composited for analysis. During the final day of each collection period, ruminal samples were obtained from each steer via ruminal cannula 4 h after feeding. Ruminal fluid pH was determined on fresh samples. Samples were strained through 4 layers of cheesecloth. Two milliliters of freshly prepared 25% (wt/vol) meta-phosphoric acid was added to 8 mL of strained ruminal fluid. Samples were then centrifuged (17,000×*g* for 10 min), and supernatant fluid was stored at –20°C for volatile fatty acids (VFA) analysis by gas chromatograph. Upon completion of the experiment, ruminal fluid was obtained via the ruminal cannula from all steers and composited for isolation of ruminal bacteria by differential centrifugation (Bergen et al., 1968).

Table 1. Composition of experimental diets fed to steers (DM basis)

Item	Kaolinite level (%)		
	0	1	2
Ingredient composition (%)			
Steam-flaked corn	67.53	66.53	65.53
Distillers dried grains plus solubles	10.00	10.00	10.00
Sudan grass hay	12.00	12.00	12.00
Molasses cane	4.00	4.00	4.00
Yellow grease	3.00	3.00	3.00
Urea	1.20	1.20	1.20
Limestone	1.80	1.80	1.80
Magnesium oxide	0.15	0.15	0.15
Trace mineral salt[1]	0.30	0.30	0.30
Kaolinite clay	-	1.00	2.00
Monensin (g/T)	35.00	35.00	35.00
Nutrient composition (DM basis)[2]			
Net energy (Mcal/kg)			
Maintenance	2.21	2.19	2.17
Gain	1.54	1.53	1.51
Crude protein (%)	14.0	13.9	13.8
Calcium (%)	0.79	0.79	0.80
Phosphorus (%)	0.34	0.33	0.33
Potassium (%)	0.75	0.75	0.74
Magnesium (%)	0.29	0.29	0.29
Sulfur (%)	0.16	0.16	0.16

DM, dry matter.
[1] 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; NaCl, 92.96.
[2] Based on tabular values for individual feed ingredients (NRC,1996).

Sample analysis and calculations: Feed, duodenal and fecal samples were subject to the following analysis: DM (oven drying at 105°C until no further weight loss; method 930.15; AOAC, 2000); ash (method 942.05; AOAC, 2000), Kjeldahl N (method 984.13; AOAC, 2000); aNDFom [Van Soest et al., 1991, corrected for neutral detergent fiber (NDF)-ash, incorporating heat stable α-amylase (Ankom Technology, Macedon, NY, USA) at 1 mL per 100 mL of NDF solution (Midland Scientific, Omaha, NE, USA)]; chromic oxide (Hill and Anderson, 1958), and starch (Zinn, 1990). Microbial organic matter (OM) and nitrogen leaving the abomasum were calculated using purines as a microbial marker (Zinn and Owens, 1986). The OM fermented in the rumen was considered equal to OM intake minus the difference between the amount of total OM reaching the duodenum and microbial OM reaching the duodenum. Feed N escape to the small intestine was considered equal to total N leaving the abomasum minus ammonia-N, microbial N

(MN) and endogenous N, assuming endogenous N is equivalent to 0.195 $W^{0.75}$ (Orskov et al., 1986). Ruminal microbial efficiency was estimated as duodenal MN, g/kg OM fermented in the rumen and N efficiency represent the duodenal non-ammonia N, g/g N intake. Methane production (mol/mol glucose equivalent fermented) was estimated based on the theoretical fermentation balance for observed molar distribution of VFA (Wolin, 1960).

Statistical design and analysis: Treatment effects on characteristics of digestion in cattle were analyzed as a replicated 3×3 Latin square design using the MIXED procedure (SAS Inst. Inc., Cary, NC, USA). Treatments effects on digestion and fermentation variables were tested by means of polynomial contrasts (SAS Inst.; Version 9.3). Contrasts were considered significant when the p-value was $\leq$0.05, and tendencies were identified when the p-value was >0.05 and $\leq$0.10.

Trial 2: Growth performance and carcass characteristics

Animals and diets: One hundred eight Holstein steers (132.4±5.6 kg) were used in a 308-d experiment to evaluate the influence of kaolinite clay supplementation on growth performance, dietary net energy (NE), and carcass characteristics. Cattle originated from Tulare, California, and were received at the University of California Desert Research Center, El Centro, on April 29, 2014. Upon arrival, steers were treated for parasites (Dectomax Injectable, Zoetis, New York, NY, USA), and injected subcutaneously with tuluthramycin (Draxxin, Pfizer, New York, NY, USA), and 500,000 IU vitamin A (Vital E-A+D, Stuart Products, Bedford, TX, USA). Steers were balanced by weight and assigned within weight groupings to 18 pens (6 steers/pen). Pens were 78 m^2 with 33 m^2 of overhead shade, automatic waterers, and fence-line feed bunks. Dietary treatments were the same as in Trial 1. Composition of experimental diets is shown in Table 1. Diets were prepared at weekly intervals and stored in plywood boxes located in front of each pen. Steers were allowed *ad libitum* access to their experimental diets. Fresh feed was provided twice daily. On day 112 and 224, all steers were injected subcutaneously with 500,000 IU vitamin A (Vital E-A+D, Stuart Products, USA) and implanted with Revalor-S (Intervet, Millsboro, DE, USA).

Estimation of dietary net energy: For calculating steer performance measures of live weight were reduced 4% to account for digestive tract fill. Final shrunk LW was carcass-adjusted by dividing hot carcass weights (HCW) by the decimal fraction of the average dressing percentage (0.618). Daily energy gain (EG; Mcal/d) was calculated by the equation: $EG = ADG^{1.097}\ 0.0557W^{0.75}$, where W is the mean shrunk weight (kg; NRC, 1984). Maintenance energy (EM) was calculated by the equation: $EM = 0.084W^{0.75}$ (Garrett, 1971). Dietary net energy for gain (NE_g) was derived from net energy for maintenance (NE_m) by the equation: $NE_g = 0.877\,NE_m - 0.41$ (Zinn et al., 2008). DMI is related to energy requirements and dietary NE_m according to the equation: $DMI = EG/(0.877NE_m–0.41)$, and can be resolved for estimation of dietary NE by means of the quadratic formula: $x = (–b–\sqrt{b^2 – 4ac})/2c$, where: $x = NE_m$, a = –0.42EM, b = 0.887EM+0.41DMI+EG, and c = –0.887DMI (Zinn et al., 2008).

Carcass data: The HCW were obtained at time of slaughter. After carcasses chilled for 48 h, the following measurements were obtained: Longissimus (LM) area (cm^2) by direct grid reading of the muscle at the 12th rib; subcutaneous fat (cm) over the LM at the 12th 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 (USDA, 1997; using 3.0 as minimum slight, 4.0 as minimum small, 5.0 as minimum modest, 6.0 as minimum moderate, etc.), and estimated retail yield of boneless, closely trimmed retail cuts from the round, loin, rib and chuck (% of HCW; Murphey et al., 1960) = 52.56–1.95×subcutaneous fat–1.06×KPH+0.106×LM area–0.018× HCW.

Statistical design and analysis: Performance (gain, gain efficiency, and dietary energetics) and carcass data were analysed as a randomised complete block design. The experimental unit was the pen. The MIXED procedure of SAS (SAS Institute, 2004) was used to analyse the variables. The fixed effect consisted of treatment, and pen as the random component. Treatment effects were tested by means of orthogonal polynomials (SAS Inst.; Version 9.3). Contrasts were considered significant when the p-value was $\leq$0.05, and tendencies were identified when the p-value was >0.05 and $\leq$0.10.

RESULTS AND DISCUSSION

Trial 1: Characteristics of digestion and ruminal fermentation

Treatment effects on characteristics of ruminal and total tract digestion of experimental diets are shown in Table 2. There were no treatment effects ($p\geq0.10$) on ruminal microbial efficiency (g MN/kg OM fermented) or ruminal and total tract digestion N. Very limited information has been reported regarding the effects of kaolinite supplementation on site and extent of digestions of steers fed high-grain finishing diets. Previous studies evaluating supplemental zeolite clay at levels comparable to that of the present study (McCollum and Galyean, 1983; Cole et al., 2007) likewise did not show an effect of supplementation on N digestion in finishing diets fed to cattle.

There were no treatment effects ($p\geq0.10$) on ruminal and total tract digestion of OM, starch and NDF. Because their sorbent properties that increase the ruminal fluid viscosity (Spotti et al., 2005), it has been postulated that inclusion of clay could decrease fluid dilution rate, possibly enhancing

Table 2. Influence of supplementation level of kaolinite clay on characteristics of apparent ruminal and total tract digestion in Holstein steers

Item	Kaolinite level (% diet DM)			SEM	p-value	
	0	1	2		Linear	Quadratic
Steer replicates	6	6	6			
Intake (g/d)						
DM	10,278	10,278	10,278			
OM	9,606	9,606	9,605			
NDF	1,595	1,661	1,728			
N	213	212	211			
Starch	5,371	5,298	5,225			
Flow to duodenum, g/d						
OM	5,250	5,036	5,392	151	0.53	0.16
NDF	1,059	958	1,053	60	0.94	0.22
Starch	955	993	1123	88	0.21	0.69
Non-ammonia N	239	235	236	9.5	0.85	0.82
Microbial N	140	145	141	5.6	0.85	0.59
Feed N	77	68	72	8.0	0.72	0.52
Ruminal digestion (%)						
OM	59.91	62.64	58.57	1.50	0.54	0.10
NDF	33.26	41.99	30.31	3.48	0.25	0.22
Starch	82.22	81.27	78.55	1.65	0.15	0.67
Feed N	64.15	68.00	65.61	3.79	0.79	0.52
MN efficiency [1]	24.47	24.19	25.29	1.23	0.65	0.66
N efficiency [2]	1.12	1.11	1.12	0.05	0.96	0.82
Fecal excretion (g/d)						
DM	2,392	2,648	2,684	52	<0.01	0.12
OM	1,969	2,099	2,096	56	0.15	0.36
NDF	913	972	965	40	0.39	0.53
Starch	86.9	83.6	88.7	16.4	0.94	0.84
N	60.1	64.3	64.2	2.6	0.29	0.52
Total tract digestion (%)						
DM	76.7	74.3	73.9	0.5	<0.01	0.13
OM	79.5	78.2	78.2	0.6	0.15	0.37
NDF	42.7	41.0	44.2	2.4	0.68	0.44
Starch	98.4	98.4	98.3	0.3	0.88	0.84
N	71.8	69.7	69.5	1.2	0.21	0.53

DM, dry matter; SEM, standard error of the mean; OM, organic matter; NDF, neutral detergent fiber; MN, microbial N.

[1] Microbial nitrogen, g/kg organic matter fermented.

[2] Non-ammonia nitrogen flow to the small intestine as a fraction of nitrogen intake.

the extent of ruminal digestion. However, the effect of zeolites and bentonite on ruminal passage rate has been inconsistent (McCollum and Galyean, 1983). Decreased total tract DM digestion with no effect on OM digestion has been reported previously with the inclusion of bentonite in sorghum-based (Martin et al., 1696) and corn silage-based (Ivan et al., 1992) diets. Likewise, Dinius et al. (1970) observed that total tract DM digestion decreased linearly with increasing kaolinite supplementation. Decreased total tract DM digestion with clays supplementation is expected, due to indigestibility of clay, itself.

Kaolinite supplementation did not affect (p>0.10) ruminal pH (averaging 5.82), VFA molar proportions or estimated methane production. Based on diet formulation, expected ruminal pH was 5.73 (NRC, 1996), in reasonably good agreement with observed. Tate et al. (2015) likewise did not observe effects of kaolinite supplementation (7.5 and 15 g/kg DM) on ruminal pH (determined *in vitro*). The lack of effects of kaolinite supplementation on ruminal pH and VFA profiles is consistent with non-appreciable effects on measures of ruminal digestion of OM, starch, NDF, and N (Table 3).

Trial 2: Growth performance and carcass characteristics

The effects of kaolinite clay supplementation on 308-d feedlot growth-performance of calf-fed Holstein steers are shown in Table 4. There were no treatment effects (p>0.10)

Table 3. Influence of supplementation level of kaolinite clay on ruminal pH, volatile fatty acid profile and estimate methane production

Item[1]	Kaolinite level (% diet DM)			SEM	p-value	
	0	1	2		Linear	Quadratic
Ruminal pH	5.87	5.74	5.86	0.09	0.94	0.30
Ruminal VFA (mol/100 mol)						
Acetate	53.2	50.8	50.8	1.8	0.52	0.19
Propionate	36.6	36.6	35.8	2.8	0.83	0.91
Butyrate	10.2	12.6	9.4	1.8	0.75	0.24
Acetate/propionate	1.61	1.53	1.63	0.17	0.95	0.68
Estimated methane[2]	0.40	0.40	0.42	0.03	0.73	0.70

DM, dry matter; SEM, standard error of the mean; VFA, volatile fatty acids.

[1] Measured at 4-h posprandium (morning meal).

[2] Estimated methane based on VFA molar proportions as mol/mol glucose equivalent fermented (Wolin, 1960).

Table 4. Influence of supplementation level of kaolinite clay on growth performance of feedlot steers

Item	Kaolinite level (% diet DM)			SEM	p-value	
	0	1	2		Linear	Quadraticc
Days on test	308	308	308			
Pen replicates	6	6	6			
Live weight (kg)[1]						
Initial	132.4	132.3	132.5	0.86	0.97	0.92
Final[2]	576.8	584.1	580.09	4.83	0.56	0.39
ADG (kg)						
1 to 112 d	1.39	1.40	1.42	0.01	0.11	0.73
112 to224 d	1.53	1.53	1.53	0.02	0.99	1.0
224 to 308 d	1.40	1.47	1.40	0.04	0.93	0.13
1 to 308 d	1.44	1.47	1.46	0.02	0.58	0.40
DMI (kg/d)						
1 to 112 d	5.42	5.35	5.43	0.05	0.95	0.25
112 to 224 d	8.31	8.18	8.32	0.11	0.98	0.32
224 to 308 d	10.45	10.67	10.44	0.11	0.55	0.06
1 to 308 d	7.82	7.83	7.85	0.05	0.70	0.99
ADG/DMI (kg/kg)						
1 to 112 d	0.257	0.262	0.263	0.002	0.59	0.377
112 to 224 d	0.184	0.187	0.184	0.002	0.97	0.222
224 to 308 d	0.135	0.138	0.134	0.003	0.87	0.349
1 to 308 d	0.185	0.187	0.186	0.001	0.62	0.205
Dietary NE (Mcal/kg)						
Maintenance						
1 to 112 d	2.06	2.09	2.10	0.01	0.08	0.38
112 to224 d	2.18	2.21	2.19	0.02	0.62	0.23
224 to 308 d	2.12	2.13	2.11	0.03	0.97	0.64
1 to 308 d	2.15	2.18	2.16	0.02	0.58	0.21
Gain						
1 to 112 d	1.40	1.43	1.43	0.01	0.08	0.38
112 to224 d	1.50	1.53	1.51	0.02	0.62	0.23
224 to 308 d	1.45	1.46	1.44	0.03	0.97	0.64
1 to 308 d	1.47	1.50	1.48	0.01	0.58	0.21
Observed:expected dietary NE						
Maintenance						
1 to 112 d	0.93	0.96	0.97	0.006	<0.01	0.41
112 to224 d	0.99	1.01	1.01	0.008	0.03	0.24
224 to 308 d	0.96	0.98	0.98	0.014	0.32	0.66
1 to 308 d	0.97	1.00	1.00	0.007	0.07	0.22
Gain						
1 to 112 d	0.91	0.95	0.96	0.008	<0.01	0.41
112 to224 d	0.98	1.02	1.02	0.011	0.03	0.24
224 to 308 d	0.95	0.97	0.97	0.018	0.33	0.66
1 to 308 d	0.97	1.00	1.00	0.009	0.07	0.22

DM, dry matter; SEM, standard error of the mean; ADG, average daily gain; DMI, dry matter intake; NE, net energy.

[1] Initial weight is the shrunk off truck arrival weight. Interim and final weights were reduced 4% to account for digestive tract fill.

[2] Final shrunk weight was adjusted for carcass weight by dividing the carcass weight by the decimal fraction of the average dressing percentage (0.618).

Table 5. Influence of supplementation level of kaolinite clay on carcass characteristics of Holstein steers

Item	Kaolinite level (% diet DM)			SEM	Contrast p-value	
	0	1	2		Linear	Quadratic
Pen replicates	6	6	6			
Hot carcass weight (kg)	356.25	360.8	358.8	3.0	0.56	0.39
Dressing percentage	62.1	61.8	61.4	0.2	0.01	0.90
Longissimus area (cm²)	77.6	80.4	79.9	2.8	0.56	0.64
Fat thickness (cm)	0.76	0.89	0.82	0.04	0.35	0.07
KPH (%)	2.43	2.39	2.45	0.05	0.77	0.45
Yield grade (%)[1]	51.8	52.1	52.0	0.3	0.64	0.72
Quality grade[2]	4.93	5.08	4.73	0.22	0.52	0.37

DM, dry matter; SEM, standard error of the mean; KPH, kidney, pelvic and heart fat; LM, lgissimus.
[1] Kidney, pelvic, and heart fat as a percentage of carcass weight.
[2] Assessment of external 12th-rib fat thickness, KPH, LM area, lean and skeletal maturity, lean color, and marbling were used to determine a quality and yield grade for each carcass (USDA, 1997).

on ADG, and gain efficiency (ADG/DMI). Effects of clay inclusion on DMI and ADG in growing-finishing ruminants has not been consistent. Colling et al. (1979) observed decreased ADG and DMI in finishing steers fed high-moisture and steam-flaked corn-based diets supplemented with 2.5% bentonite. In other studies (Cammack et al., 2010), supplementation with 2% to 5% clay (as bentonite or zeolite) did not affect ADG, or gain efficiency. Mendel (1971) did not detect differences in DMI between controls and supplemented steers fed 2% to 4% montmorillonite clay. However, ADG was 8.9% and 13.2% greater with 2% and 4% supplemental montmorillonite, respectively. Berthiaume et al. (2007) observed greater ADG in steers supplemented with 2% bentonite in a silage-based diet.

Kaolinite supplementation tended (linear effect, $p = 0.08$) to increase dietary NE during the initial 112-d period. However, the overall (308-d) effect of supplementation on dietary NE was not appreciable ($p>0.20$). Kaolinite replaced steam-flaked corn in the basal diet (Table 1). Considering the indigestibility of kaolinite (contains no OM), the ratio of observed-to-expected dietary NE increased with kaolinite supplementation. This effect was more pronounced (linear effect, $p\leq 0.03$) during the initial 224 d of the study. Overall (308 d), kaolinite supplementation tended to increase (linear effect, $p = 0.07$) dietary NE by 3% over expected. Based on the apparent absence of effects of supplemental kaolinite on ruminal and total tract digestion, and ruminal fermentation parameters, the positive effect of clay on the dietary energetic may operate in a manner independent of changes in characteristics of ruminal and total tract digestion. However, increases on feed efficiency have been observed in lambs and steers fed diets supplemented with bentonite (Britton et al., 1978).

The effects of supplemental kaolinite on carcass characteristics are shown in Table 5. As expected, there were no treatment effects on HCW, yield grade, LM area, KPH, and quality grade. Kaolinite supplementation linearly decreased ($p<0.01$) dressing percentage. The negative effect of supplemental kaolinite on dressing percentage could be more apparent than real. It has been argued that clay essentially is not absorbed and is excreted with the feces. Because of its density, it is reasonable that the clay particles would accumulate along the digestive tract, particularly in the forestomach regions.

It is concluded that kaolinite supplementation up to 2% of diet DM may enhance energetic efficiency of calf-fed Holstein steers in a manner independent of changes in characteristics of ruminal and total tract digestion.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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