FINAL REPORT

Effect of low-fat dried distillers grains inclusion in finishing diets on feedlot cattle total tract digestibility and ruminal fermentation parameters. Project AIC125.

Submitted To:

Minnesota Corn Growers Association
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Executive Summary

High dietary fat levels are known to suppress ruminal fiber and total tract organic matter digestion due to the toxic effects on growth of ruminal microbes; cellulolytic bacteria and protozoa being the most sensitive ones. Decreased cellulolytic activity due to high dietary fat decreases rates of fiber digestion and particle size reduction. These effects interact to increase ruminal solids retention time, which effects a reduction in intake and overall feedlot performance. Therefore, low fat content of low-fat distillers grains could attenuate negative effects of high dietary fat on ruminal fermentation, support improved rumen function, and subsequently enhance overall nutrient digestibility, feed intake and utilization, and feedlot cattle performance. In addition, reduced sulfur concentration in low-fat distillers grains as a result of less CDS added back to the distillers fraction may permit increased inclusion of this new product in feedlot diets.

To date, however, little data are available on the feeding value of low-fat distillers grains. A previous study conducted with feedlot heifers by Kansas State University evaluated feeding steam-flaked corn diets containing 13% DM traditional distillers grains plus solubles or low-fat DDG and no treatment differences in feedlot performance or carcass characteristics. Similar results were observed in a previously funded MCG—AURI study at the University of Minnesota where feeding dry-rolled corn (DRC)-based finishing diets containing 35% DM traditional or low-fat DDG to finishing steers caused no differences in feedlot performance or carcass characteristics. On the other hand, inclusion of 35% DM traditional WDGS to DRC- or high-moisture corn-based finishing diets resulted in greater final BW, average daily gain (ADG) and hot-carcass weight compared with low-fat WDGS inclusion. Lower fat concentration and consequently reduced energy value of low-fat distillers grains compared with traditional DGS may account for the latter results.

Therefore, basic fermentation research is warranted to determine effects of low-fat distillers grains inclusion in finishing diets on ruminal fermentation and feed digestibility and to allow for a better understanding of its potential effects on feedlot cattle performance. This information may assist in creating feeding recommendations to best utilize this new product as a feedstuff in feedlots throughout the Midwest. The objective of this research was to evaluate the effect of low-fat dried distillers grains with solubles (LF-DDGS) on organic matter (OM) total tract digestibility and ruminal fermentation parameters. Inclusion of LF-DDGS resulted in lower NH_3-N concentration and increased ruminal VFA compared with traditional DDGS which may be the consequence of enhanced growth of ruminal microorganisms as a result of reduced dietary fat. Partial replacement of DRC by LF-DDGS, and its potential effects on growth of ruminal microbes and NH_3-N utilization, led to no change in NH_3-N or VFA while that by conventional DDGS led to increased NH_3-N concentration and decreased ruminal VFA concentration. These data demonstrated that LF-DDGS are an appropriate substitute for both corn and conventional DDGS in diets of feedlot cattle. These data support our observations that inclusion of LF-DDGS or conventional DDGS at 35% of diet dry matter sustain growth and efficiency at equal rate as corn-based diets. There is no reason to alter the price of LF-DDGS relative to conventional DDGS when including this new alternative in diets of feedlot cattle.

Effect of low-fat dried distillers grains inclusion in finishing diets on feedlot cattle total tract digestibility and ruminal fermentation parameters.

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Summary

Excessive dietary fat can negatively affect growth of fiber-digesting ruminal microorganisms and consequently decrease OM total tract digestibility (OMD), feed intake and overall performance in feedlot cattle. Compared with conventional dried distillers grains (DDG), the lower fat and greater protein content of low-fat DDG (LF-DDG) could attenuate these effects. An experiment was conducted to evaluate effects of LF-DDG inclusion in beef cattle finishing diets on total tract digestibility and ruminal fermentation. Six ruminally cannulated Holstein steers (317 ± 7 kg initial BW) were assigned randomly to a duplicated 3 x 3 Latin square design. Steers were fed *ad libitum* once daily one of three dietary treatments containing (DM basis) 84% dry-rolled corn (DRC), 10% ryegrass haylage, and 6% supplement (CON) or 53% DRC, 10% ryegrass haylage, 2% supplement, and 35% traditional DDG (TRAD) or LF-DDG (LF). Dietary CP and fat concentrations measured 12.1, 15.9, and 19.9% and 3.7, 6.7, and 4.5% for CON, TRAD, and LF, respectively. Steers were intra-ruminally dosed with chromic oxide and fecal grab samples collected to determine OMD. Ruminal fluid was collected to measure VFA and ammonia-N (NH_3-N) concentrations. Ruminal pH was continuously recorded by ruminal probes. Intake of OM was greater for TRAD (8.26 ± 0.04 kg) and LF (8.31 ± 0.04 kg) than CON (8.09 ± 0.04 kg; $P \leq 0.01$). Dietary treatment did not affect OMD ($P = 0.12$) or ruminal pH ($P = 0.64$; 69.7, 69.0, and 72.8 ± 1.2% and 5.78, 5.73 and 5.66 ± 0.09 for CON, TRAD and LF, respectively). Ruminal NH_3-N concentration was less and ruminal VFA was greater for CON (2.74 ± 1.14 mg/dL and 92.8 ± 5.8 m*M*) and LF (2.69 ± 1.14 mg/dL and 92.4 ± 5.8 m*M*) than TRAD (3.75 ± 1.15 mg/dL and 74.6 ± 5.8 m*M*; $P \leq 0.04$). Inclusion of LF-DDG resulted in less NH_3-N concentration and greater ruminal VFA compared with traditional DDG. Partial replacement of DRC by LF-DDG led to no change in NH_3-N or VFA while that by conventional DDG led to increased NH_3-N concentration and decreased ruminal VFA.

Introduction

In the traditional dry-grinding ethanol production process, thin stillage or distillers solubles (water plus soluble solids) and wet distillers grains (WDG; suspended solids) are obtained after centrifugation of whole stillage (Berger and Singh, 2010). Through evaporation, thin stillage results in syrup or condensed distillers solubles (CDS), which are added back to WDG to obtain WDG with solubles (WDGS; Berger and Singh, 2010; Kalscheur and García, 2010). The latter

can be subject to a drying process resulting in dried distillers grains (DDG) with solubles (DDGS; Crawford, 2010). Compared to distillers grains, CDS have greater fat and mineral content and smaller crude protein (CP) and fiber content. Therefore, as more CDS is added back to the WDG, fat and mineral contents, such as sulfur, increase and CP decreases in the final product (Kalscheur and García, 2010). New technologies, such as oil extraction from syrup, have been implemented to improve ethanol yield and fermentation efficiency and to reduce the amount of DDGS produced in conventional dry-grinding process (Berger and Singh, 2010). Through centrifugation of syrup, about one third of the oil is recovered, which results in DDGS containing 30% less fat and 14% more protein compared with conventional DDGS (Lüking and Funsch, 2009). Extraction of oil directly from DDGS has also been implemented in few dry grind ethanol plants in the United States (Berger and Singh, 2010) as well as solvent-based extraction methods (Saunder and Rosentrater, 2009). In sum, reduced amount of CDS added back to the distillers fraction and/or oil extraction from CDS or DDGS result in low-fat distillers grains.

High dietary fat levels are known to suppress ruminal fiber and total tract organic matter digestion due to the toxic effects of lipids on growth of ruminal microbes; cellulolytic bacteria and protozoa being the most sensitive ones (Brooks et al., 1954; Zinn, 1989; Zinn et al., 2000; Onetti et al., 2001; Maia et al., 2007; Maia et al., 2010). Reduced cellulolytic activity due to high dietary fat may decrease rates of fiber digestion (Corrigan et al., 2008) and particle size reduction, and it may increase ruminal solids retention. These effects lead to reduced intake and poorer overall feedlot performance (Zinn, 1989). Therefore, low fat content of low-fat distillers grains could attenuate negative effects of high dietary fat on ruminal fermentation and allow improved rumen function; subsequently, enhancing overall nutrient digestibility, feed intake and utilization, and feedlot cattle performance. In addition, reduced sulfur concentration in low-fat distillers grains as a result of less CDS added back to the distillers fraction may allow for increased inclusion of this new product in feedlot diets.

To date, however, little data are available on the feeding value of low-fat distillers grains. Depenbusch et al. (2008) fed steam-flaked corn diets containing 13% DM traditional distillers grains plus solubles or low-fat DDG. Those authors observed no treatment differences in feedlot performance or carcass characteristics of feedlot heifers. Similar results were observed by Kelzer et al. (2011) when feeding dry-rolled corn (DRC)-based finishing diets containing 35% DM traditional or low-fat DDG. On the other hand, inclusion of 35% DM traditional WDGS to DRC- and high-moisture corn-based finishing diets resulted in greater final BW, average daily gain (ADG) and hot-carcass weight compared with low-fat WDGS inclusion (Gigax et al., 2011). Lower fat concentration and consequently reduced energy value of low-fat distillers grains compared with traditional ones may account for the latter results (Gigax et al., 2011). Therefore, research on effects of feeding low-fat DGS on ruminal fermentation parameters and feed digestibility is warranted. Findings will allow for a better understanding of potential effects of low-fat DGS on feedlot cattle performance. This information may assist in creating feeding

recommendations to best utilize this new product as a feedstuff in feedlots throughout the Midwest.

The objective of this research was to evaluate the effect of low-fat dried distillers grains with solubles (LF-DDGS) on organic matter (OM) total tract digestibility and ruminal fermentation parameters.

Note: This study is a follow-up to the MCGA/MCR&PC FY 09 RFP funded study determining the effect of low-fat distillers grains on feedlot cattle live performance, carcass characteristics, and meat quality.

Materials and Methods

The experiment was conducted at the University of Minnesota North Central Research and Outreach Center in Grand Rapids, MN, from June 5th to August 6th, 2011. Six Holstein steers (698 ± 14 lb initial BW) fitted with flexible ruminal cannula were assigned randomly to a replicated 3 x 3 Latin square design to allow for six replications per treatment. The experiment consisted of three 21-d periods. Diet adaptation occurred over d 1 to 16, and sample collection occurred over d 17 to 21 of each period. Steers were group-housed by treatment during the adaptation period (16 d) and individually housed in metabolism stalls during the collection period (5 d). Steers were weighed prior to feeding on d 1 of each period. During adaptation periods, steers were stepped-up to their assigned treatment which consisted of one of three dietary treatments offered at 0900 h: 0% (CON), 35% traditional DDGS (TRAD), and 35% LF-DDGS (LF) inclusion (DM basis; Table 1). Bunks were monitored daily to adjust feed offering. After adaptation, diets were offered *ad libitum*. During collection period, refusals were recorded daily and kept in the bunk unless they represented more than 5% of daily feed delivery. In this case, the refusal was removed, weighed and sampled. Otherwise, refusals were removed, weighed and sampled at the end of the collection period. Intake was estimated as the difference between feed delivered and refused.

To determine OM digestibility, animals were intra-ruminally dosed at 0700 and 1900 h with 7.5 g of chromic oxide contained in gelatin capsules from d 11 to 21. Fecal grab samples were collected at 0700, 1300, and 1900 h over d 17 to 21 and stored at -20° C. After completion of the experiment, fecal samples were freeze-dried, ground and composited by steer and period for determination of OM by ash content analysis and chromium element by atomic absorption spectrophotometry. Total feces production was estimated through chromic oxide concentration in feces. Digestibility of OM was estimated as the difference between OM intake and excretion.

Ruminal pH was recorded by sensors programmed to measure and record ruminal pH every 5 min (Kahne Ltd., Auckland, NZ). Probes were inserted into the rumen of each steer on d 16 and

removed at the end of each period. Data were downloaded from individual probes upon completion of each period.

Concentration of volatile fatty acids (VFA) and ammonia-N (NH_3-N) were measured in ruminal fluid samples collected on d 21 at -1, 2, 4, 8, 12, 16, and 24 h post-feeding. Ruminal fluid samples were collected by a manual suction strainer inserted through the ruminal cannula. Concentration of VFA was determined by gas chromatography and NH_3-N by the Kjeldahl method.

Data were analyzed using the Mixed procedure of SAS 9.3 (SAS Institute, Cary NC). For pH, VFA, and NH_3-N a repeated measure structure was considered. The model included dietary treatment, time, treatment by time interaction, and period as fixed effects and animal within square and square as random effects. When significant, the time effect was evaluated by polynomial contrasts and treatment means were separated using a *t* test. Effects were considered significant when *P* values were less than 0.05 and were considered trends when *P* values were between 0.05 and 0.10.

Results and Discussion

Intake of DM and OM was greater ($P < 0.01$) for TRAD (19.2 and 18.2 ± 0.1 lb) and LF (19.2 and 18.3 ± 0.1 lb) than CON (18.6 and 17.8 ± 0.1 lb; Table 2). Digestibility of OM was numerically greater for LF (72.8 ± 1.2%) and CON (69.7 ± 1.2%) than TRAD (69.0 ± 1.2%) but this difference was not statistically significant ($P = 0.12$; Table 2).

Ruminal pH was similar among treatments ($P = 0.64$) and averaged 5.78, 5.73 and 5.66 ± 0.09 for CON, TRAD and LF, respectively; this result was independent from time (treatment*time, $P = 0.17$). Ruminal pH decreased during the first 4 h post-feeding and then increased until next feeding event ($P < 0.001$; Figure 1).

Ruminal NH_3-N concentration was less for CON (2.74 ± 1.14 mg/dL) and LF (2.69 ± 1.14 mg/dL) than TRAD (3.75 ± 1.15 mg/dL; $P = 0.03$) regardless of time (treatment*time, $P = 0.79$). Ruminal NH_3-N decreased during the first 12 h post-feeding and then increased until next feeding event ($P < 0.001$; Figure 2). Ruminal total VFA concentration was greater for CON (92.8 ± 5.8 m*M*) and LF (92.4 ± 5.8 m*M*) than TRAD (74.6 ± 5.8 m*M*; $P < 0.01$; Table 3), and increased for 8 h post-feeding and then decreased until cattle were re-fed ($P < 0.01$; Figure 3), regardless of time (treatment*time, $P = 0.53$; Table 3). Taken together, less ruminal NH_3-N and greater total VFA concentration for CON and LF compared with TRAD suggest increased use of NH_3-N and growth of ruminal microbes for lower-fat containing rations. Similarly, decreasing ruminal NH_3-N, increasing VFA concentration and decreasing ruminal pH as time elapsed after feeding also indicate increased use of NH_3-N and growth of microbes over time.

Except one h before feeding (treatment*time, $P < 0.01$, Table 3 and Figure 4), when molar proportion of acetate tended ($P < 0.08$) to be less, and that of propionate tended ($P < 0.07$) to be greater for CON compared with TRAD, molar proportions of these VFA were similar among treatments. Molar proportions of acetate and propionate for LF were not different from those for CON and TRAD at any time (Figure 4). Acetate molar proportion followed a quadratic trend for TRAD, decreasing after feeding and increasing after 12 h post feeding (Figure 4). In contrast, molar proportion of acetate for CON increased for 4 h post-feeding then decreased and finally increased before next feeding event (Figure 4). Even though the quadratic trend was the same for TRAD and LF ($P = 0.92$), change in acetate molar proportion across time was numerically less pronounced for LF than TRAD (Figure 4). Propionate molar proportion changed almost in the opposite direction as acetate proportion for the three treatments (Figure 4). Differences in acetate and propionate molar proportion indicated changes in proportions of cellulolytic and amylolytic ruminal microbes. In spite of the fact that results from this experiment are not absolutely conclusive in this regard, they suggest that greater propionate and smaller acetate molar proportion for CON compared with TRAD and LF (Figure 4) may be related to higher starch and lower NDF concentrations, respectively, (Table 1) and their effects on starch- and cellulose-digesting microbes. In addition, a decrease in acetate molar proportion for 12 h after feeding the TRAD diet may be associated with negative effects of high dietary fat level on cellulolytic bacterial population; response of acetate molar proportion in LF represents an intermediate situation between TRAD and CON (Figure 4). Finally, lower intake and possibly slower rate of passage for CON compared with TRAD and LF (Table 2) might have been beneficial for slower-growing microorganisms such as cellulose-digesting compared with amylose-digesting ones.

Branched-chain VFA (BCVFA) are supplied by amino acid-fermenting bacteria, saccharolytic and lactate-utilizing bacteria such as *Megasphaera elsdenii* which deaminate branched-chain amino acids (Russell, 2002). Greater supply of starch and enhanced growth of BCVFA-producing bacteria when feeding CON may explain greater BCVFA concentration for CON compared with TRAD and LF (Table 3).

In a previous feedlot finishing study (MCGA/MCR&PC FY 09 RFP), Kelzer et al. (2011) observed no differences in cattle performance when 35% of DRC was replaced by 35% traditional or low-fat DDG. However, as described previously, less ruminal total VFA and greater NH_3-N concentration were observed when replacing DRC by traditional distillers but no change when replacing it by low-fat distillers. These results suggest detrimental effects of increasing dietary fat on growth of ruminal microbes. Dietary NDF and fat concentrations were greater for diets used in the present than in the previous study (3.6, 6.0, and 3.5% fat, and 15.6, 22.4, and 20.7% NDF for CON, TRAD and LF, respectively in previous experiment and Table 1 for the present one). In addition, considering DMI and dietary NDF and fat concentration in both experiments for each treatment, the increase in g fat/g NDF consumed ratio when replacing DRC by traditional DDGS was greater for the present than for Kelzer's et al. (2011; Table 4). Finally,

less DMI as a percentage of BW in the present (2.0% BW) compared with the previous experiment (2.3% BW) might have resulted in slower rate of passage and consequently greater ruminal retention time for the microorganisms to be exposed to detrimental effects of high dietary fat.

In conclusion, inclusion of LF-DDGS resulted in lower NH_3-N concentration and increased ruminal VFA compared with traditional DDGS which may be the consequence of enhanced growth of ruminal microorganisms as a result of reduced dietary fat. Partial replacement of DRC by LF-DDGS, and its potential effects on growth of ruminal microbes and NH_3-N utilization, led to no change in NH_3-N or VFA while that by conventional DDGS led to increased NH_3-N concentration and decreased ruminal VFA concentration.

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Table 1. Diet composition (DM basis).

	Treatment[1]		
	CON	TRAD	LF
Dry-rolled corn, %	84.0	53.0	53.0
Traditional DDGS, %	-	35.0	-
Low-fat DDGS, %	-	-	35.0
Grass haylage, %	10.0	10.0	10.0
45.7%-CP supplement, %	6.0	-	-
1.4%-CP supplement, %	-	2.0	2.0
NEg, Mcal/cwt	57.1	60.6	60.6
CP, %	12.1	15.9	19.9
Fat, %	3.7	6.7	4.5
Starch, %	54.2	37.3	38.9
NDF, %	19.0	24.1	21.5

[1] CON: no distillers grains inclusion; TRAD: 35% traditional dried distillers grains with solubles (DDGS); LF: 35% low-fat DDGS.

Table 2. Effect of inclusion of traditional or low-fat dried distillers grains with solubles (DDGS) in finishing diets on intake and total tract digestibility.

	Treatment[1]				
	CON	TRAD	LF	SEM[2]	*P*-value
DMI, lb/d	18.6 [b]	19.2 [a]	19.2 [a]	0.1	<0.01
OMI, lb/d	17.8 [b]	18.2 [a]	18.3 [a]	0.1	<0.01
OM digestibility, %	69.7	69.0	72.8	1.2	0.12

[1] CON: no distillers grains inclusion; TRAD: 35% traditional DDGS; LF: 35% low-fat DDGS.
[2] Standard error of the mean.
ab Means with different superscripts differ ($P < 0.05$).

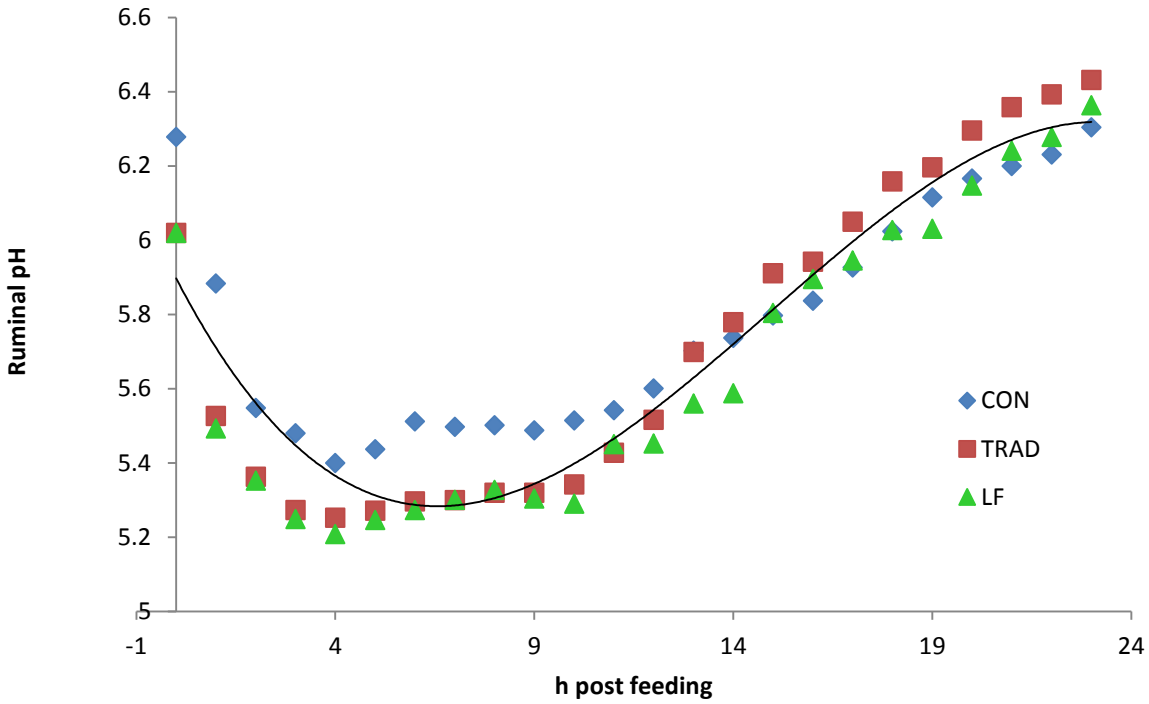

Figure 1. Ruminal pH as affected by hours post feeding in animals fed a diet with no distillers grains inclusion (CON) or with 35% (DM basis) of traditional (TRAD) or low-fat dried distillers grains with solubles (LF). Significant cubic contrast for pH against time ($P < 0.001$).

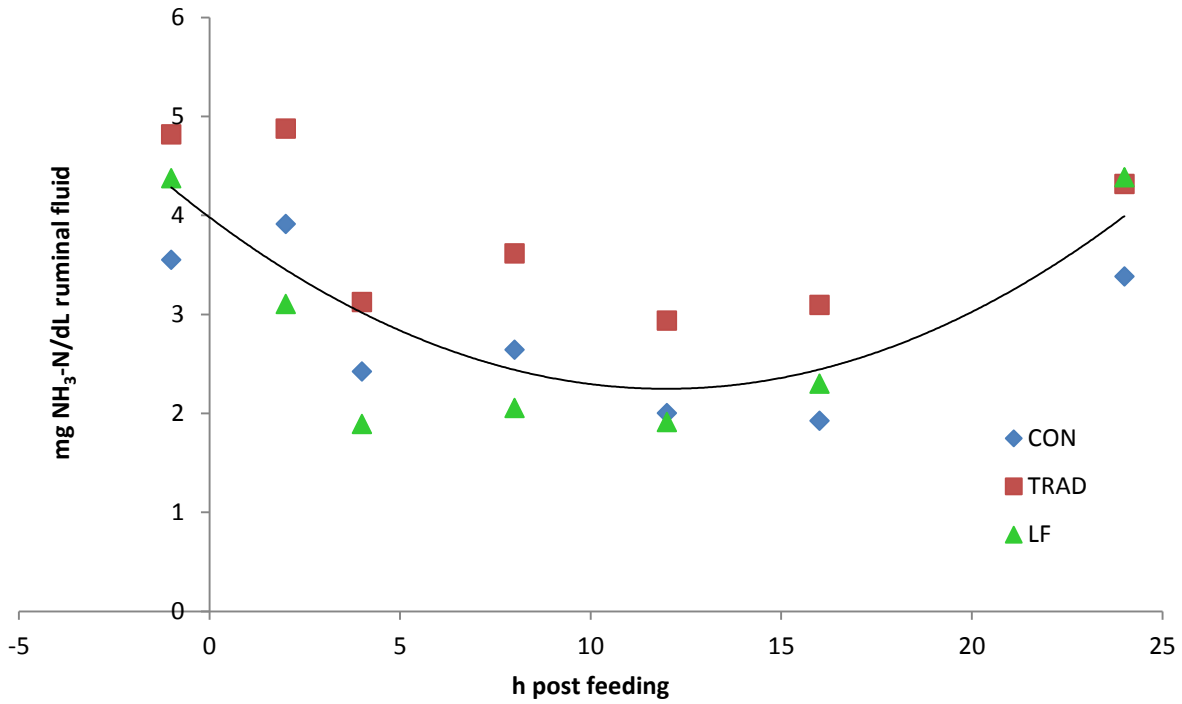

Figure 2. Ammonia-N (NH_3-N) as affected by hours post feeding in animals fed a diet with no distillers grains inclusion (CON) or with 35% (DM basis) of traditional (TRAD) or low-fat dried distillers grains with solules (LF). Significant quadratic contrast for NH_3-N against time ($P < 0.001$).

Table 3. Effect of inclusion of traditional or low-fat dried distillers grains with solubles (DDGS) in finishing diets on total VFA concentration and VFA molar proportion in ruminal fluid.

	Treatment[1]				*P*-value		
	CON	TRAD	LF	SEM[2]	Treat	Time	Treat*Time
Total VFA, m*M*	92.8 [a]	74.6 [b]	92.4 [a]	5.8	<0.01	<0.01	0.53
Individual VFA, mol/100 mol							
Acetate	41.8	44.0	44.2	2.3	0.71	<0.01	<0.01
Propionate	48.7	46.2	46.6	1.1	0.74	<0.01	<0.01
Butyrate	6.0	5.9	4.8	1.5	0.81	<0.01	0.39
Branched-chain VFA, m*M*	1.5 [a]	1.0 [b]	1.2 [b]	0.1	<0.01	0.12	0.73
Acetate:Propionate ratio	0.85	0.95	0.94	1.1	0.69	<0.01	<0.01

[1] No distillers grains inclusion (CON) or 35% (DM basis) of traditional (TRAD) or low-fat dried distillers grains (LF).

[2] Standard error of the mean.

ab Means with different superscripts differ ($P < 0.05$).

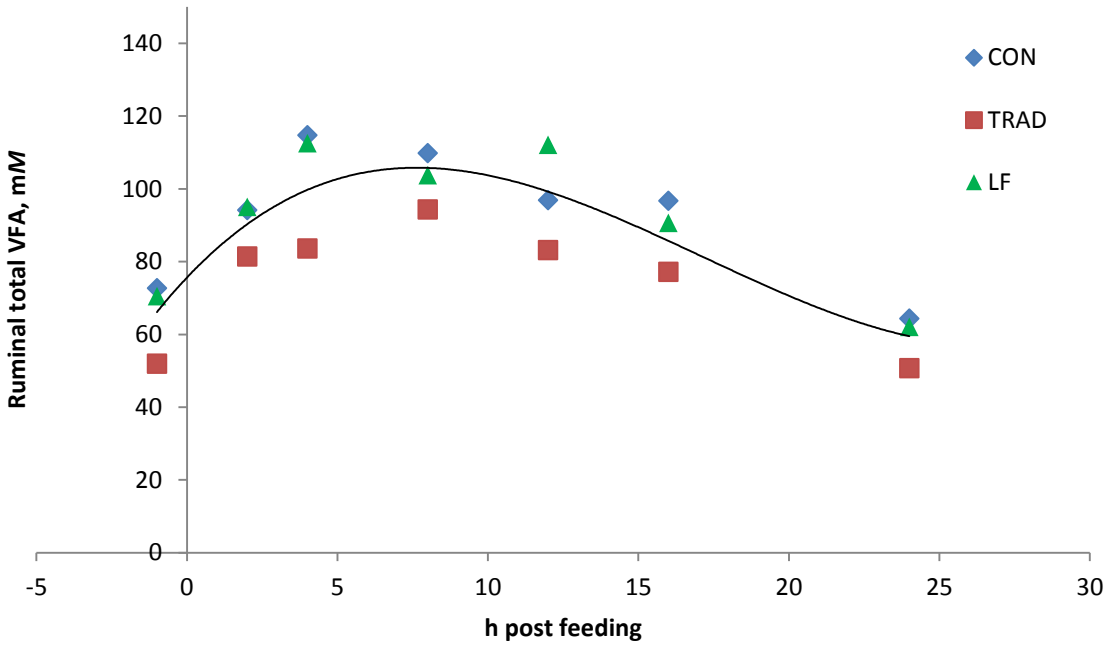

Figure 3. Ruminal total VFA concentration as affected by hours post feeding in animals fed a diet with no distillers grains inclusion (CON) or with 35% (DM basis) of traditional (TRAD) or low-fat dried distillers grains with solules (LF). Significant cubic contrast for VFA against time ($P < 0.001$).

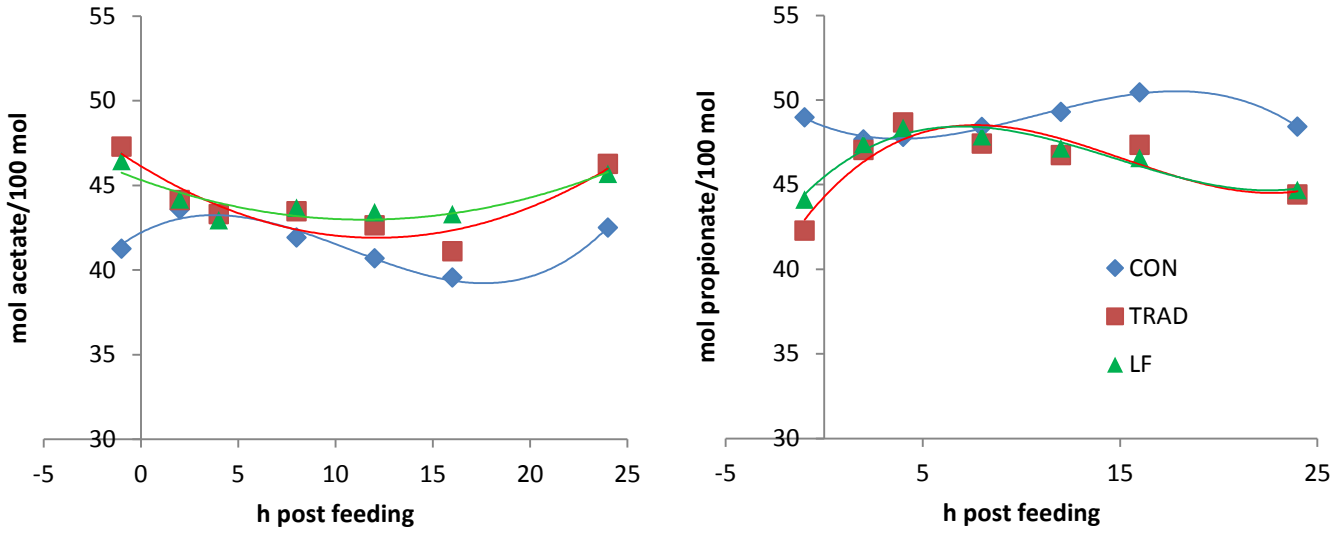

Figure 4. Molar proportion of acetate and propionate in ruminal fluid as affected by hours post feeding in animals fed a diet with no distillers grains inclusion (CON) or with 35% (DM basis) of traditional (TRAD) or low-fat dried distillers grains with solules (LF). Significant quadratic contrast for TRAD and LF and cubic for CON for acetate against time ($P < 0.001$; treat*time $P < 0.01$). Significant cubic contrast for propionate against time ($P \leq 0.03$; treat*time $P < 0.01$).

Table 4. Fat and neutral detergent fiber (NDF) intake and their ratio in cattle fed a dry-rolled corn-based finishing diet with no distillers grains inclusion (CON) or 35% (DM basis) of traditional (TRAD) or low-fat dried distillers grains (LF).

	Kelzer et al. (2011)			Present experiment		
	CON	TRAD	LF	CON	TRAD	LF
Fat intake, g	366	606	345	312	584	392
NDF intake, g	1608	2278	2021	1604	2101	1874
Fat/NDF, g/g	0.23	0.27	0.17	0.19	0.28	0.21