January 2007

Digestibility, Rumen Metabolism, and Site of Digestion for Finishing Diets Containing Wet Distillers Grains or Corn Oil

Kyle J. Vander Pol
University of Nebraska - Lincol

Matt K. Luebbe
University of Nebraska - Lincoln, mluebbe2@unl.edu

Grant Crawford
University of Nebraska-Lincoln

Galen E. Erickson
University of Nebraska-Lincoln, gerickson4@unl.edu

Terry J. Klopfenstein
University of Nebraska-Lincoln, tklopfenstein1@unl.edu

Digestibility, Rumen Metabolism, and Site of Digestion for Finishing Diets Containing Wet Distillers Grains or Corn Oil

Kyle J. Vander Pol
Matt K. Luebbe
Grant I. Crawford
Galen E. Erickson
Terry J. Klopfenstein[1]

Summary

Five ruminally and duodenally fistulated, Holstein steers were used in a 5X5 Latin square metabolism experiment to evaluate digestibility of wet distillers grains plus solubles (WDGS) compared with corn fiber and corn oil in finishing diets. Treatments were a 40% WDGS diet, a composite of corn fiber and corn protein (COMP), COMP plus corn oil to equal the distillers diet (COMP+OIL), and dry-rolled corn control diets without (CON) or with corn oil (CON+OIL). Cattle fed WDGS had numerically lower rumen pH compared with cattle fed other treatments. Cattle fed the WDGS had greater propionate, lower acetate:propionate ratios, greater total tract fat digestion, and a greater proportion of unsaturated fatty acids reaching the duodenum than cattle fed other treatments. These data indicate the higher energy value of WDGS compared with corn is not due to acidosis control, but to more propionate production, higher fat digestibility, and more unsaturated fatty acids reaching the duodenum.

Introduction

The increasing supply and availability of wet distillers grain plus solubles (WDGS) has made it a popular feed resource for finishing cattle. One of the primary drivers of its use in finishing diets is the higher energy value of WDGS compared with corn (*2006 Nebraska Beef Report,* pp. 51-53). However, it is unclear whether the higher energy value of WDGS is attributed to fat (greater energy) or acidosis control. The fat content of WDGS is roughly three times that of corn. It is also unclear if fat from distillers grains is protected from rumen biohydrogenation compared to corn oil.

The objectives of this research were to determine the effect of feeding WDGS or supplemental fat on performance and rumen metabolism and digestibility, with an aim of determining what is responsible for the higher energy value of WDGS compared with corn in finishing diets.

Procedure

A metabolism trial was conducted to evaluate effects of feeding WDGS, a composite of corn fiber (corn bran) and corn protein (corn gluten meal), or supplemental corn oil on various aspects of feeding behavior, digestion, duodenal fatty acid profile, and metabolism in finishing diets. The trial utilized a 5x5 Latin square experiment design with five Holstein steers previously equipped with cannulas in the rumen and proximal duodenum. Dietary treatments (Table 1) were 40% WDGS (WDGS), a composite consisting of corn bran and corn gluten meal (COMP), a composite consisting of corn bran, corn gluten meal, and corn oil (COMP + OIL), and 2 DRC-based high concentrate controls without (CON) and with corn oil (CON + OIL). The COMP diet was formulated to be equal in NDF and CP to the WDGS diet. The COMP + OIL diet was formulated to be equal in NDF, CP, and EE to the WDGS diet. The CON + OIL diet was formulated to be equal in EE to the WDGS diet. All diets contained Rumensin and Tylan

(Continued on next page)

Table 1. Composition of diets fed to Holstein steers in metabolism experiment evaluating wet distillers grains plus solubles or corn oil with or without added corn bran.

	Treatment [a], % of diet DM				
Item	WDGS	COMP	COMP + OIL	CON	CON + OIL
Dry-rolled corn	51.0	46.8	42.7	88.0	84.6
WDGS	40.0	—	—	—	—
Corn bran	—	29.6	29.6	—	—
Corn gluten meal	—	11.6	11.6	—	—
Alfalfa hay	5.0	5.0	5.0	5.0	5.0
Corn oil	—	—	4.1	—	3.4
Molasses	—	3.0	3.0	3.0	3.0
Dry supplement [b]	4.0	4.0	4.0	4.0	4.0
Limestone	1.60	1.30	1.30	1.60	1.60
Fine ground corn	1.38	2.10	2.08	0.46	0.34
Urea	—	—	—	1.15	1.27
Salt	0.30	0.30	0.30	0.30	0.30
Potassium chloride	0.53	0.11	0.13	0.30	0.30
Molasses	0.10	0.10	0.10	0.10	0.10
Beef trace mineral [c]	0.05	0.05	0.05	0.05	0.05
Rumensin-80 [d]	0.02	0.02	0.02	0.02	0.02
Tylan-40 [e]	0.01	0.01	0.01	0.01	0.01
Vitamin A-D-E [f]	0.01	0.01	0.01	0.01	0.01
Nutrient Analysis, %					
CP	17.9	17.9	17.9	12.5	12.5
NDF from by-product	22.6	22.6	22.6	0.0	0.0
Ether Extract	7.2	3.2	7.2	3.9	7.2
Sulfur	0.36	0.20	0.19	0.16	0.15

[a] WDGS = wet distillers grains plus solubles (WDGS) diet, COMP = composite diet, COMP + OIL = composite + corn oil diet, CON = control diet, CON + OIL = control + corn oil diet.
[b] Supplement formulated to be fed at 4% of diet DM.
[c] Premix contained 10% Mg, 6% Zn, 4.5% Fe, 2% Mn, 0.5% Cu, 0.3% I, 0.05% Co.
[d] Premix provided 300 mg/day monensin.
[e] Premix provided 90 mg/day tylosin.
[f] Premix contained 1500 IU vitamin A, 3000 IU vitamin D, 3.7 IU vitamin E per g.

(Elanco Animal Health, Indianapolis, Ind.). Periods were three weeks in length with 16 days for adapting steers to experimental diets and 5 days for data collection. For days 1 through 16, steers were housed in individual, slotted-floor pens with rubber mats in a temperature controlled room and ad libitum access to water. On day 17, steers were moved within the same room to tie stalls and tethered.

Steers were fed once daily at 0700 hour and were allowed ad libitum intake. Continual monitoring of DMI by steers was accomplished through use of feed bunks suspended on load cells (Omega, Stamford, Conn.) and connected to a computer with data acquisition software (Labtech, Wilmington, Mass.) that recorded bunk weight every minute over the entire feeding period. Data were obtained for continuously monitored DMI on days 17 through 21 of the collection period, and included daily DMI, time spent eating, number of meals consumed, and average meal size. Feed ingredients were sampled weekly and composited by period, while feed refusals were sampled on days 17 through 21 and composited by period and stored frozen. At the conclusion of each period, feed ingredients and feed refusal composites were freeze-dried and ground to pass through a 1 mm screen of a Wiley mill (Thomas Scientific, Swedesboro, N.J.).

Chromic oxide (Landers-Segal Color Co., Montvale, N.J.) was dosed intraruminally 2X daily to provide 15 g/steer daily on days 14 through 20, to provide an estimate of duodenal flow and fecal output.

Ruminal fluid samples were collected every two hours on day 17 between 0700 and 1900 hours. Approximately 50 ml were collected, which was immediately frozen for later analysis. Ruminal volatile fatty acids (acetate, propionate, butyrate, isobutyrate, valerate, and isovalerate) were measured using gas chromatography.

Ruminal pH was measured continuously on days 18 to 21 with submersible pH probes (Sensorex, Stanton, CA) fitted through the rumen cannula and suspended in rumen fluid. Rumen pH measurements were collected with software (Labtech, Wilmington, Mass.) with a reading taken every six seconds and averaging data across every 1 minute (1,440 measurements/day). Ruminal metabolism measurements included average ruminal pH, maximum and minimum ruminal pH, ruminal pH change (maximum minus minimum), ruminal pH variance, and ruminal pH area below 5.6. Average ruminal pH was calculated as the average of 1,440 measurements recorded daily. Ruminal pH variance and area below 5.6 were calculated as described by Cooper et al. (*1997 Nebraska Beef Report,* pp. 49-52).

Fecal samples (approximately 50 g) were collected at 0700, 1300, and 1900 on days 17 through 20. Fecal samples were composited by day and stored frozen. Duodenal samples (approximately 250 ml) were collected at 1000, 1600, and 2200 hours on day 20, and 0700, 1300, and 1900 hours on day 21. At the conclusion of each period, fecal and duodenal composites were freeze-dried and ground to pass through a 1mm screen of a Wiley mill. After grinding, samples were composited by period.

Feed ingredient, feed refusal, duodenal, and fecal sample analysis included DM, ash, CP, NDF, total starch, and ether extract. Duodenal and fecal samples were ashed, digested with a phosphoric acid-manganese sulfate solution, and analyzed for chromium using atomic absorption spectrophotometer. Duodenal samples were analyzed for fatty acids according to the born trifluoride-methanol procedure utilizing gas chromatography.

All data were analyzed as a 5 x 5 Latin square design using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) with steer (random effect) x period (fixed effect) as the experimental unit. Repeated samples were made on experimental units for volatile fatty acids. These data were also analyzed as a repeated measurement, with hour repeated. Autoregressive (AR-1) covariance structures were utilized with final covariance structure based on the lowest AIC for covariance structures with successful convergence. There were no significant period effects (*P*> 0.10) observed for any variable measured; therefore, results are reported by dietary treatment.

Results

Average ruminal pH was greatest (*P*<0.10) for the COMP + OIL treatment and numerically lowest for the WDGS treatment, however, maximum pH, minimum pH, and pH change were not different among treatments (Table 2). Time below pH 5.6 was the least (*P*<0.10) for the COMP + OIL treatment. This is partially due to the lower digestibility of the COMP + OIL diet due to NDF (corn bran) and oil. These results are consistent with previous data with corn bran (Sayer et al., *2005 Nebraska Beef Report,* pp. 39-41). Interestingly, time below pH 5.6 was numerically greatest for the WDGS. No differences were observed between treatments for time below pH 5.3 or 5.0, respectively. Molar proportions of acetate were lower (*P*<0.10) and propionate were higher (*P*<0.10) for the WDGS treatment. Molar proportion of butyrate was not affected by treatment. Lower acetate and greater propionate molar proportions for the WDGS treatment resulted in lower (*P*<0.10) acetate:propionate ratio for the WDGS compared with the other treatments. The greater acetate:propionate ratios for the diets containing corn bran indicate fiber digestion was being promoted, similar to previous results (Sayer et al., *2005 Nebraska Beef Report,* pp. 39-41).

Dry matter intake and OM intake were lowest (*P*<0.10) for cattle fed the CON + OIL diet (Table 3). Neutral detergent fiber intake was greatest (*P*<0.10) for cattle fed the COMP and COMP + OIL diets and least (*P*<0.10) for cattle fed the CON and CON + OIL diets. Starch intake was greatest (*P*<0.10) for cattle fed the CON diet. Dietary fat intake was greatest (*P*<0.10) for cattle fed the WDGS and CON + OIL diets and least (*P*<0.10) for cattle fed the COMP and CON

Table 2. Ruminal pH variables and volatile fatty acids profiles of steers fed wet distillers grains plus solubles (WDGS), a composite, or supplemental corn oil.

Item	WDGS	COMP	COMP + OIL	CON	CON + OIL	SEM	F-test[b]
	Treatment [a]						
Ruminal pH Variables							
Average pH	5.24[f]	5.40[f]	5.66[e]	5.37[f]	5.38[f]	0.10	0.08
Maximum pH	5.77	6.06	6.30	5.91	5.92	0.15	0.16
Minimum pH	4.95	4.90	5.09	4.88	5.00	0.08	0.42
pH change	0.82	1.16	1.21	1.02	0.91	0.11	0.13
Time < 5.6, min	1251[e]	1047[e]	652[f]	1136[e]	1050[e]	123	0.03
Time < 5.3, min	916	515	166	630	634	184	0.12
Time < 5.0, min	242	186	17	81	157	105	0.59
Volatile Fatty Acid Profile and Acetate:Propionate Ratio[c]							
Acetate	41.9[f]	48.8[e]	49.3[e]	48.2[e]	49.1[e]	3.0	0.04
Propionate	40.0[e]	36.6[f]	34.8[f]	36.7[f]	34.7[f]	3.0	0.06
Butyrate	12.7	8.5	9.7	10.7	12.8	1.5	0.20
A:P [d]	1.05[f]	1.33[e]	1.42[e]	1.31[e]	1.41[e]	0.3	0.04

[a]WDGS = wet distillers grains plus solubles (WDGS) diet, COMP = composite diet, COMP + OIL = composite + corn oil diet, CON = control diet, CON + OIL = control + corn oil diet.
[b]Data were analyzed using a protected F-test where numbers represent *P* – value for variation due to treatment.
[c]Molar proportion, mol/100 mol.
[d]A:P = acetate:propionate ratio.
[e,f]Means within a row with unlike superscripts differ (*P*<0.10).

Table 3. Influence of wet distillers grains plus solubles (WDGS), a composite, or supplemental corn oil on characteristics of ruminal and total-tract digestion.

Item	WDGS	COMP	COMP + OIL	CON	CON + OIL	SEM	F-test [b]
	Treatment [a]						
Intake, lb/d							
DM	17.2[e]	18.3[e]	19.4[e]	17.4[e]	13.4[f]	1.5	0.06
OM	16.3[e]	17.6[e]	18.7[e]	16.5[e]	12.6[f]	1.3	0.05
NDF	5.1[f]	6.6[e]	7.0[e]	3.1[g]	2.2[g]	0.4	< 0.01
Starch	7.3[f]	7.5[f]	7.5[f]	11.5[e]	8.4[f]	0.4	< 0.01
Fat	1.50[e]	0.84[g]	1.67[e]	0.90[fg]	1.17[f]	0.13	< 0.01
Ruminal digestibility, %							
Apparent OM	43.6	42.3	39.0	47.0	41.3	5.7	0.89
True OM[c]	64.1	60.1	58.4	63.4	58.2	4.8	0.84
NDF	71.0	52.0	55.6	56.2	60.1	6.0	0.25
Apparent starch	79.5[e]	84.7[e]	76.6[e]	76.6[e]	62.1[f]	5.5	0.03
True starch[d]	83.8[e]	87.9[e]	85.9[e]	81.5[e]	70.0[f]	4.3	0.03
Postruminal digestibility, % entering							
OM	48.0	38.1	33.5	51.1	52.2	6.9	0.24
NDF	34.5[ef]	48.5[e]	19.1[f]	47.4[e]	44.1[ef]	9.1	0.08
Starch	70.8[e]	52.6[fg]	39.7[g]	56.7[ef]	72.2[e]	7.4	0.04
Total-tract digestibility, %							
DM	81.0[e]	74.5[f]	71.1[f]	81.6[e]	80.3[e]	1.7	< 0.01
OM	82.5[e]	75.8[f]	72.2[f]	82.2[e]	82.4[e]	1.8	< 0.01
NDF	78.9[e]	65.9[f]	64.5[f]	78.2[e]	78.8[e]	3.2	< 0.01
Starch	94.6[e]	91.7[ef]	90.6[f]	92.2[ef]	89.0[f]	1.7	0.10
Fat	81.0[e]	64.1[g]	67.6[fg]	72.5[f]	72.8[f]	3.7	< 0.01

[a]WDGS = wet distillers grains plus solubles (WDGS) diet, COMP = composite diet, COMP + OIL = composite + corn oil diet, CON = control diet, CON + OIL = control + corn oil diet.
[b]Data were analyzed using a protected F-test where numbers represent *P* – value for variation due to treatment.
[c]Corrected for microbial OM reaching the duodenum.
[d]Corrected for microbial starch.
[e,f,g]Means within a row with unlike superscripts differ (*P*<0.10).

diets. The primary factor responsible for the lower starch and fat intake for cattle fed the CON + OIL diet is the low overall DMI compared with cattle fed the other diets. However, corn oil did not affect DMI of steers fed the COMP + OIL diet.

Ruminal apparent OM, true OM, and NDF digestibility were not different among treatments (Table 3). Ruminal apparent starch and true starch digestibility were less (*P*<0.10) for cattle fed the CON + OIL diet than for cattle fed the other diets; however, postruminal starch digestion was greatest for the CON + OIL diet. Total tract DM, OM, and NDF digestibility were less (*P*<0.10) for cattle fed the COMP and COMP + OIL diets compared with cattle fed the WDGS, CON, and CON + OIL diets. Total-tract starch digestibility was greater (*P*<0.10) for cattle fed the WDGS diet, relative to cattle fed the COMP + OIL and CON + OIL diets. Therefore, it appears that supplemental corn oil may impede total tract starch digestion relative to fat supplied by WDGS. Therefore, the WDGS appears to have no effect or a positive effect on total-tract starch digestion, with the fat content of WDGS not negatively affecting starch digestion whereas corn oil supplementation does negatively affect starch digestion. Total tract fat digestibility was greatest (*P*<0.10) for cattle fed the WDGS diet and lowest (*P*<0.10) for cattle fed the COMP diet. Interestingly, fat digestibility was greater for WDGS than CON+OIL or COMP+OIL suggesting that some "protection" of fat occurred.

Cattle receiving the WDGS and CON diets had greater (*P*<0.10) proportions of 16:0 reaching the duodenum than cattle receiving the COMP, COMP + OIL, and CON + OIL diets (Table 4). In terms of the long chain fatty acids, cattle receiving diets supplemented with corn oil had greater (*P*<0.10) proportions of 18:0 reaching the duodenum, while cattle receiving the WDGS diet had the least (*P*<0.10) amount of 18:0 reaching the duodenum. In contrast,

(Continued on next page)

cattle receiving WDGS had greater proportions of 18:1 *trans*, 18:1, and 18:2 reaching the duodenum relative to cattle fed the other diets, while cattle receiving diets supplemented with corn oil had the least amount of 18:1 *trans*, 18:1, and 18:2 reaching the duodenum, respectively. These data indicate that the fatty acids in WDGS are not hydrogenated to the same extent in the rumen as fatty acids in supplemental corn oil. This research and other research (*Journal of Animal Science* 78:1738) suggests that unsaturated fatty acids have greater intestinal digestibility than saturated fatty acids.

[1]Kyle Vander Pol, former research technician; Matt Luebbe, research technician; Grant Crawford, graduate student; Galen Erickson, associate professor; and Terry Klopfenstein, professor; Animal Science, Lincoln.

Table 4. Fatty acid profiles of duodenal fat content expressed as a % of fat entering the duodenum of steers fed wet distillers grains plus solubles (WDGS), a composite, or supplemental corn oil.

	Treatment						
Item	WDGS	COMP	COMP +OIL	CON	CON +OIL	SEM	F-test
Medium Chain Fatty Acids							
14:0	0.92[bc]	1.14[b]	0.76[c]	2.07[a]	0.89[bc]	0.22	< 0.01
15:0	0.46[c]	0.69[b]	0.46[c]	1.15[a]	0.46[bc]	0.08	< 0.01
16:0	13.80[a]	12.55[bc]	12.28[b]	13.41[ac]	12.52[bc]	0.37	0.04
16:1 *trans*	0.12[b]	0.28[a]	0.15[b]	0.15[b]	0.15[b]	0.03	0.04
17:0	0.34[b]	0.62[a]	0.37[b]	0.56[a]	0.33[b]	0.05	< 0.01
Long Chain Fatty Acids							
18:0	48.5[c]	55.0[b]	62.1[a]	56.1[b]	60.5[a]	1.4	< 0.01
18:1 *trans*	12.6[a]	9.0[b]	7.4[c]	5.9[c]	7.1[c]	0.7	< 0.01
18:1	9.4[a]	6.6[bc]	5.8[b]	7.0[c]	6.5[bc]	0.4	< 0.01
18:2	8.5[a]	5.9[b]	4.9[bc]	4.9[bc]	4.4[c]	0.5	< 0.01
18:3	0.29[a]	0.28[a]	0.19[b]	0.23[ab]	0.20[b]	0.05	0.04
Other	5.3[b]	7.0[a]	5.2[b]	8.0[a]	6.0[b]	0.5	< 0.01

[a,b,c]Means within a row with unlike superscripts differ (*P*<0.10).