Milk Production and Composition from Cows Fed Wet Corn Distillers Grains[1]

D. J. SCHINGOETHE,*,[2] M. J. BROUK,*,[3] and C. P. BIRKELO†,[4]
*Dairy Science Department and
†Animal and Range Science Department,
South Dakota State University, Brookings 57007

ABSTRACT

Twelve lactating Holstein cows were utilized in a repeated switchback design to evaluate milk production and milk fat composition responses to wet corn distillers grains. Total mixed diets consisted of 31.4% corn silage, 18.4% alfalfa hay, and either 50.2% of a concentrate mix that contained mostly corn and soybean meal or 19.4% of a concentrate mix that contained mostly corn and 31.2% wet corn distillers grains. The first 4 wk of each 6-wk period were for adaptation to diets; data were collected during wk 5 and 6 of each period. Although dry matter intake (22.1 vs. 19.7 kg/d) was lower when cows were fed the wet corn distillers grains diet, milk production (30.7 vs. 30.8 kg/d) was similar for cows fed both diets. Milk fat (3.60 vs. 3.85%) was slightly higher, and protein (3.06 vs. 2.84%) was lower, when cows were fed the wet corn distillers grains diet. Milk fat from cows fed wet corn distillers grains contained lower concentrations of saturated fatty acids and higher concentrations of long-chain and unsaturated fatty acids. The feeding of wet corn distillers grains increased the proportion of unsaturated fatty acids in milk fat without changing milk production.
(**Key words**: wet corn distillers grains, lactating cows, milk composition)

Abbreviation key: **CDG** = corn distillers grains.

INTRODUCTION

Most research with corn distillers grains (**CDG**) has been designed to evaluate it as a protein source (17, 22, 26). In reality, CDG is also a good source of energy, primarily because it contains relatively high amounts of fat and digestible fiber (5, 22, 26). Diets for dairy cows that contain 30% of the ration DM as CDG would provide approximately 0.5 kg/d of additional fat composed of primarily $C_{18:1}$ and $C_{18:2}$ fatty acids (10). We are not aware of reports that analyzed the fatty acid composition of milk fat when CDG was fed to lactating cows. However, dietary fats that are high in long-chain unsaturated fatty acids increased the amounts of $C_{18:0}$ and $C_{18:1}$ in milk fat (4), which may improve processing, healthfulness, and marketability of dairy products.

The objective of this experiment was to determine milk production and milk composition from cows fed wet CDG. A companion study (C. P. Birkelo, M. J. Brouk, and D. J. Schingoethe, 1996, unpublished data) with these cows determined the NE_L value of wet CDG.

MATERIALS AND METHODS

Cows and Diets

Twelve multiparous Holstein cows averaging 23 ± 10.5 d postpartum at the start of the experiment were utilized in a repeated switchback design (9) to evaluate the effect of feeding wet CDG on milk production and composition. Six-week experimental periods consisted of 4 wk of adaptation to diets, and data were collected during wk 5 and 6.

Cows were assigned to three groups of 4 cows each according to calving dates. Two cows within each group were randomly assigned to either the control or the wet CDG diet in the initial period. Diets were switched each period so that all cows received each diet twice during the experiment. Cows were housed in free stalls during the diet adaptation periods, and a stanchion barn was utilized during the collection periods.

Cows were fed total mixed diets (Table 1) containing either 0 (control) or 31.2% (DM basis) wet CDG. The wet CDG replaced all of the soybean meal and nearly one-half of the corn in the control diet. Diets were formulated to meet or exceed CP, ADF, Ca, P, Mg, and vitamin recommendations for lactating cows

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[2]Reprint requests.
[3]Present address: Department of Animal Science, University of Missouri, Columbia 65211.
[4]Present address: 901 Teller Lanes, Woodland Park, CO 80866.

TABLE 1. Ingredient content of control and wet corn distillers grains (CDG) diets.

Ingredient	Diet	
	Control	CDG
	(% of DM)	
Corn silage	31.4	30.9
Alfalfa hay, chopped	18.4	18.5
Wet CDG	...	31.2
Corn, rolled	30.7	17.0
Soybean meal, 44% CP	16.7	...
Calcium carbonate	1.39	1.35
Dicalcium phosphate	0.87	0.56
Trace-mineralized salt[1]	0.20	0.19
Magnesium oxide	0.13	0.12
Vitamin A, D, and E premix[2]	0.10	0.10
Vitamin E premix[3]	0.06	0.06

[1]Contained 93 to 98% NaCl, 0.35% Zn, 0.28% Mn, 0.175% Fe, 0.035% Cu, 0.007% I, and 0.007% Co.

[2]Contained 4,400,000 IU of vitamin A, 880,000 IU of vitamin D, and 400 IU of vitamin E/kg.

[3]Contained 44,000 IU of vitamin E/kg.

(15). The wet CDG was obtained weekly from a commercial ethanol plant and stored at ambient temperature in steel drums. Spoilage was a minor problem, but, when visible spoilage occurred, the spoiled wet CDG was discarded.

Cows were fed once daily for ad libitum intake in a free-stall barn during the diet adaptation period. When cows were moved to the stanchion barn for data collection, feed offered was limited to 95% of the amounts offered during the adaptation period to decrease orts. Cows were milked twice daily at 0500 and 1600 h throughout the experiment. Daily feed intakes and milk production were recorded for individual cows throughout the experiment. Body weights were recorded at the beginning and end of each collection period.

Milk samples from each cow were collected at each milking during the last 6 d of each period. Daily samples were composited on a weighted milk production basis, and the composited sample was split into two portions for analyses. One portion was refrigerated at 4°C until analyzed for fat, CP, lactose, and SNF by mid infrared spectrophotometry (Multispec; Foss Food Technology Corp., Eden Prairie, MN) using an instrument equipped with the A and B filter combination with corresponding wavelengths of 5.73 and 3.4 to 3.5 μm for the determination of milk fat (2). Milk was also analyzed for SCC using a Fossomatic 90 (Foss Food Technology Corp.) (2). The other portion of the original milk sample was stored at –20°C and later thawed at 4°C; an aliquot was composited for each cow for each collection period. Composite samples were stored at –20°C until total fat content was determined by the Mojonnier method (3) and fatty acid composition was determined by GLC separation of butyl esters (7) using an SP-2330 (0.75 mm i.d. × 60 m) borosilicate glass column (Supelco, Inc., Bellefonte, PA).

Samples of concentrate mixes, alfalfa hay, corn silage, wet CDG, and each total mixed diet were collected daily during wk 5 and 6 of each period and frozen at –20°C until processed for analyses. Samples were dried at 55°C for 48 h and ground through an ultracentrifuge mill with a 1-mm screen (Brinkman Instruments Co., Westbury, NY); aliquots of each ingredient and total mixed diet from each day were composited by period for analyses. Feed composites were corrected to a 100% DM basis by drying an aliquot at 100°C for 48 h. Contents of CP, NPN (CDG only), ether extract, and ash were determined (2). Permanganate lignin and ADF were determined by the procedure of Robertson and Van Soest (23), acid detergent insoluble N was determined by Kjeldahl N (2) of the acid detergent insoluble fraction, and NDF was determined as described by Van Soest et al. (30) using procedure A. Fatty acid composition was determined by GLC of methyl esters (29).

Samples of ruminal fluid were obtained 4 h postfeeding on 2 consecutive d at the end of each period by applying vacuum to an esophageal tube fitted with a suction strainer into a 250-ml bottle. Samples were immediately placed on ice. The initial 100 ml of ruminal contents obtained were discarded prior to collecting samples to minimize saliva contamination. A 100-ml aliquot of each sample was centrifuged at 475 × g for 10 min; the supernatant was decanted, acidified with 0.5 ml of 0.1N HCl, and frozen at –20°C until analyzed for ruminal ammonia (8). An additional 10-ml aliquot was acidified with 2 ml of 25% metaphosphoric acid, centrifuged at 475 × g for 10 min, decanted, and frozen at –20°C until analyzed for VFA by GLC (20). Samples of jugular vein blood were drawn into serum separation tubes at the time of ruminal sampling, prepared, and stored (28) for serum urea analysis (8).

Statistical Analysis

Milk production, milk composition, and feed intake data were analyzed using the GLM procedures of SAS (25). Data were subjected to least squares ANOVA with cow, group, period, diet, and the interaction of period and diet in the model. Group and the interaction never achieved significance ($P > 0.20$) and were subsequently dropped from the model and included with residuals as the error term. Serum urea N, VFA, and ruminal ammonia data were averaged within individual cows within each collection period, and the means were subjected to ANOVA. Significance was declared at $P < 0.05$ unless otherwise noted.

RESULTS AND DISCUSSION

The chemical composition of dietary ingredients and diets is shown in Table 2. Coefficients of variation of wet CDG for DM, CP, NDF, ADF, ether extract, and ash were 3.5, 10.3, 9.1, 20.0, and 12.7%, respectively, for samples collected throughout the experiment. These values were similar to those reported by Belyea et al. (5), demonstrating the variability in nutrient content that is inherent to by-products. Coefficients of variation for other ingredients were less than those for CDG.

The CP content (39.5%) of wet CDG was greater than previously reported values for wet (4, 5, 14, 16) and dry (12, 27) CDG and was greater than typical CP contents of CDG currently available from ethanol plants in the midwestern US. The higher CP content could have resulted because of a more complete extraction of the starch from the grain, resulting in a greater concentration of CP in the wet CDG. Although ammonia was added to the mash as a N source for the yeast, little was found in the wet CDG (0.02%). The NDF residue contained a mean of 4.3% N (26.9% CP). Thus, of the 39.5% CP in wet CDG, nearly 40% (15.6% CP) was associated with NDF. Muscato et al. (16) found that NDF residue of dried brewers grains contained 40% of the total N compared with 15 and 4% for corn and SBM, respectively. The content of NDF-bound N explains why the sum of CP, NDF, ether extract, and ash content of wet CDG was greater than 100%. Most of the NDF-bound N was likely AA N (15). The ADIN content of the wet CDG was equivalent to 5.5% CP (DM basis) (13.9% of the total CP). This percentage might indicate some heat damage if greater than 3% of CP as ADIN, which is used to indicate heat damage for forages, is appropriate with wet CDG (5). Comparable values for ADIN content have been reported by other researchers (6, 11, 24); however, much greater values (32.9 to 39% of CP) have been reported for dark distillers grains (24). The difference between NDF-bound CP and ADIN could represent the amount of CP bound in the hemicellulose fraction of the fiber. Crude protein bound to the hemicellulose is likely available for digestion (1).

The ether extract content of wet CDG was less than that reported by Larson et al. (14) and greater than that reported by Schingoethe et al. (26). Cell-wall content (NDF) was also greater than that reported previously (14) as was ADF content (26). Increases of these components might have been due to

TABLE 2. Chemical composition of concentrate mixes, forages, wet corn distillers grains (CDG), and total mixed diets from control and CDG diets.

Measurement	Concentrate mix		Corn silage	Alfalfa hay	Wet corn distillers grains	Diet[1]	
	Control	CDG				Control	CDG
DM, %	87.1	86.7	47.3	82.9	30.9	68.5	47.0
				(% of DM)			
CP	22.4	9.8	7.9	19.6	39.5	18.0	21.0
NPN	...	...	...	...	0.02	...	...
Ether extract	3.0	2.9	3.1	2.2	8.5	3.1	5.1
ADF	3.9	3.5	24.0	38.1	23.4	16.9	21.3
ADIN	...	...	...	...	0.88	...	...
NDF	13.2	11.5	41.0	50.0	58.1	28.3	42.9
Lignin	0.9	0.8	2.7	7.4	7.4	3.0	3.7
Ash	7.5	12.2	4.4	9.5	2.4	7.1	5.9
Ca[2]	1.59	3.4	0.23	1.41	0.15	1.13	1.04
P[2]	0.74	0.81	0.22	0.22	0.71	0.48	0.49
Mg[2]	0.33	0.48	0.19	0.33	0.18	0.29	0.27
NE_L,[2] Mcal/kg	1.80	1.61	1.60	1.35	2.04	1.65	1.69
NE_L,[3] Mcal/kg	...	...	...	...	2.21	1.70	1.82

[1]The control diet was calculated at a 18.4:31.4:50.2 ratio of alfalfa hay, corn silage, and concentrate, respectively; the CDG diet was calculated at a 18.5:30.9:19.4:31.2 ratio of alfalfa hay, corn silage, concentrate, and CDG, respectively.

[2]Estimated from NRC (16).

[3]Determined with cows used in this experiment (C. P. Birkelo, M. J. Brouk, and D. J. Schingoethe, 1996, unpublished data).

TABLE 3. Fatty acid composition of concentrate mixes, forages, wet corn distillers grains (CDG), and total mixed diets from control and CDG diets.

Fatty acid[1]	Concentrate mix		Corn silage	Alfalfa hay	Wet corn distillers grains	Diet[2]	
	Control	CDG				Control	CDG
	(% of DM)						
14:0	0.33	0.12	0.01	0.12	0.02	0.18	0.03
16:0	0.45	0.43	0.38	0.37	1.54	0.41	0.75
18:0	0.09	0.08	0.06	0.06	0.28	0.08	0.14
18:1	0.76	0.74	0.68	0.05	2.40	0.63	1.12
18:2	1.25	0.80	1.29	0.24	5.74	1.33	2.46
18:3	0.07	0.03	0.06	0.31	0.15	0.14	0.16
20:0	0.02	0.02	0.02	0.02	0.04	0.02	0.04
22:0	0.02	0.02	0.02	0.03	0.02	0.02	0.03
22:1	0.08	0.03	0.04	0.08	0.05	0.06	0.03
24:0	0.01	0.01	0.01	0.02	0.03	0.01	0.02
Total	3.07	2.27	2.57	1.29	10.27	2.88	4.75

[1]Expressed as number of carbons:number of double bonds.

[2]The control diet was calculated at a 18.4:31.4:50.2 ratio of alfalfa hay, corn silage, and concentrate, respectively; the CDG diet was calculated at a 18.5:30.9:19.4:31.2 ratio of alfalfa hay, corn silage, concentrate, and CDG, respectively.

the more complete removal of starch or, in the case of NDF, fiber-bound N.

Diets were originally formulated to be similar in CP content. However, the CP content of the wet CDG diet was greater than that of the control diet because of the higher than expected CP content of the wet CDG. Both diets contained excess CP for lactating dairy cows (16), partially because of our efforts to maximize the amount of wet CDG fed. Fat, NDF, and ADF contents of the wet CDG diet were greater than those in the control diet because of the high concentrations of these components in the wet CDG compared with the corn and soybean meal it replaced. The wet CDG diet contained slightly more energy than the control diet because of the greater energy content of wet CDG [(17); C. P. Birkelo, M. J. Brouk, and D. J. Schingoethe, 1996, unpublished data] compared with corn and soybean meal in the control diet.

Inclusion of wet CDG in the diet provided an additional 2.0 percentage units of fatty acids to the ration. Most of this increase was $C_{18:1}$ and $C_{18:2}$ fatty acids (Table 3). Total fatty acid concentrations were lower than the ether extract concentrations in both diets. The use of total fatty acids is the most accurate and recommended procedure (29) for determining fat content of feeds.

Dry matter intake (Table 4) was lower ($P < 0.01$) when cows were fed the wet CDG diet, but intakes were more than adequate to meet nutrient requirements (16). This lower DMI might have been partially related to the DM content (47%) of the wet CDG diet. Intake of DM is sometimes reduced when dietary DM is less than 60% (13). Problems with palatability of diets were not apparent. The higher NDF content of the CDF diet might have increased ruminal fill or decreased rate of passage, which would have decreased DMI (16). The energy content of the CDG diet (Table 2) was slightly greater than that of the control diet, and the energy was apparently well utilized.

TABLE 4. Dry matter intake, milk production, milk composition, and BW of cows fed control and wet corn distillers grains (CDG) diets.

	Diet		
	Control	CDG	SE
DMI, kg/d	22.1	19.7**	0.43
Milk, kg/d	30.7	30.8	0.66
4% FCM, kg/d	28.8	29.9	0.65
ECM,[1] kg/d	31.0	31.5	0.68
Fat			
%	3.60	3.85	0.09
kg/d	1.10	1.17	0.03
Protein			
%	3.06	2.84**	0.02
kg/d	0.93	0.87*	0.02
Lactose			
%	4.83	4.85	0.03
kg/d	1.48	1.50	0.04
SCC, $\times 10^3$/ml	280	230	73
BW, kg	589	575	8.7

[1]Energy-corrected milk (19).

*Different from control ($P < 0.05$).

**Different from control ($P < 0.01$).

TABLE 5. Ruminal VFA and ammonia concentrations and serum urea concentrations for cows fed control or wet corn distillers grains (CDG) diets.[1]

Measurement	Diet		SE
	Control	CDG	
VFA, mol/100 mol			
Acetate (A)	61.6	63.4†	0.4
Propionate (P)	23.3	22.2**	0.5
Isobutyrate	1.0	0.8**	0.04
Butyrate	11.0	10.8	0.2
Isovalerate	1.7	1.4†	0.06
Valerate	1.4	1.4	0.04
Total, μmol/ml	113.6	97.7**	3.4
A:P	2.8	2.9	0.07
Ruminal ammonia, mg/dl	14.2	11.7†	0.7
Serum urea, mg/dl	21.3	26.1†	0.7

†Different from control ($P < 0.1$).

**Different from control ($P < 0.01$).

[1]Data are presented as least squares means.

Milk production (Table 4) was similar for cows fed the control and CDG diets. Percentages and production of milk fat were higher ($P < 0.1$) when cows were fed the wet CDG diet. Slightly higher fat production resulting from the wet CDG diet could be attributed to increased fiber fermentation, resulting in increased ruminal acetate production. Acetate has been shown to favor milk fat production, and propionate favors body fat production (18). Ruminal ratios of acetate to propionate were only modestly affected in this study (Table 5).

The decreased milk protein content ($P < 0.01$) and protein production ($P < 0.05$) of cows fed CDG (Table 4) might have been due to the higher fat content of the diet (7, 28). Some researchers (21) observed decreased availability of CP from the wet CDG; however, the apparent digestibility of CP was greater (C. P. Birkelo, M. J. Brouk, and D. J. Schingoethe, 1996, unpublished data), and ruminal ammonia was lower (Table 5), for cows fed the CDG in this study than for those fed the control diet. Lysine might have been limiting because 80% of the diet was derived from corn products, which are first-limiting in lysine (17).

The fatty acid composition of milk fat was affected by diet (Table 6). Concentrations of long-chain ($C_{18:0}$ to $C_{18:2}$) and unsaturated fatty acids increased ($P < 0.01$), and concentrations of medium-chain ($C_{14:0}$ to $C_{17:1}$), short-chain ($C_{4:0}$ to $C_{12:0}$), and total saturated fatty acids decreased ($P < 0.01$) for cows fed wet CDG. Concentrations of $C_{18:1}$ and $C_{18:2}$ were increased substantially when cows were fed wet CDG, reflecting the highly unsaturated fat in CDG (Table 3) and other corn products (10). The changes observed were similar to observations of others (3, 6, 9) when other highly unsaturated sources of fatty acids were fed to lactating cows. Such alterations in fatty acid content would be sufficient to alter positively the processing properties of dairy products made from such milk (4).

Total ruminal VFA concentrations were less ($P < 0.1$) when cows were fed the wet CDG diet (Table 5), which might have indicated reduced fermentation or a slower rate of fermentation. Most of the rapidly fermentable material was removed during the production of wet CDG. Thus, the wet CDG diet likely contained less readily fermentable carbohydrates, and the remaining fermentable fiber would likely be fermented more slowly than would nonstructural carbohydrates. Nonstructural carbohydrate content [100 – (CP + $NDF_{N\text{-free}}$ + ether extract + ash)] of the control and wet CDG diets was estimated to be approximately 43 and 29% of DM, respectively.

Molar percentages of acetate were greater ($P < 0.01$), and molar percentages of propionate were

TABLE 6. Fatty acid composition of milk fat for cows fed control or wet corn distillers grains (CDG) diets.[1]

Fatty acid[2]	Diet		SE
	Control	CDG	
	(g/100 g of fatty acids)		
4:0	3.5	4.0**	0.06
6:0	2.4	2.3	0.04
8:0	1.5	1.4**	0.03
10:0	3.5	2.8**	0.08
12:0	4.0	3.0**	0.10
14:0	11.7	9.2**	0.23
14:1	1.6	1.4**	0.03
15:0	1.2	0.8**	0.04
15:1	0.3	0.3	0.01
16:0	28.8	23.2**	0.42
16:1	2.8	2.8	0.07
17:0	0.7	0.6**	0.01
17:1	0.4	0.3	0.02
18:0	11.5	14.7**	0.35
18:1	19.8	25.6**	0.63
18:2	2.6	3.7**	0.09
Total	96.2	96.0	0.21
Other	3.8	4.0	0.21
SCFA[3]	14.8	13.4**	0.26
MCFA[3]	47.5	38.6**	0.59
LCFA[3]	33.9	44.0**	0.81
Saturated	68.7	61.9**	0.63
Unsaturated	27.5	34.1**	0.71

**Different from control ($P < 0.01$).

[1]Least squares means.

[2]Expressed as number of carbons:number of double bonds.

[3]SCFA = Short-chain fatty acids ($C_{4:0}$ to $C_{12:0}$), MCFA = medium-chain fatty acids ($C_{14:0}$ to $C_{17:1}$), and LCFA = long-chain fatty acids ($C_{18:0}$ to $C_{18:2}$).

lower ($P < 0.1$), but acetate to propionate ratios were not altered ($P > 0.1$) by feeding the wet CDG diet. These results could at least partially explain the differences observed in milk fat content (Table 4). Butyrate and valerate concentrations were unaffected by diet. Isobutyrate concentration was slightly lower ($P < 0.1$), as was isovalerate ($P < 0.01$), when cows were fed wet CDG. Nichols et al. (17) also observed higher acetate and lower branched-chain fatty acid concentrations from cows fed CDG diets. The lower branched-chain fatty acids possibly reflected the relatively low content of branched-chain AA in diets high in corn products.

A decrease ($P < 0.01$) in ruminal ammonia concentration (Table 5) occurred in cows fed wet CDG, which suggested that the CP of the wet CDG diet was less ruminally degradable than CP in the control diet or that the CP was incorporated into microbial protein faster than the CP of the control diet. A slower rate of fermentation of structural carbohydrates and less nonstructural carbohydrates in the CDG diet could also cause a more efficient conversion of ammonia to microbial protein. The higher ($P < 0.01$) serum urea content when cows were fed the wet CDG diet was consistent with lower nonstructural carbohydrate content but contrasted with the lower ruminal ammonia concentrations. Higher serum urea concentrations possibly indicated that protein, either of feed or microbial origin, was absorbed and then deaminated, resulting in increased serum urea concentrations for cows fed the wet CDG diet.

CONCLUSIONS

Wet CDG fed in place of all of the soybean meal and nearly one-half of the corn improved the efficiency of converting feed to milk as was illustrated by similar milk production, even though DMI was lower. Milk protein percentages decreased with the addition of wet CDG to the diet, possibly reflecting the higher fat content of the wet CDG diet. Milk fat from cows fed wet CDG contained more long-chain and unsaturated fatty acids, changes that would positively influence processing properties and the marketability of milk products.

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