Production Response of Lactating Cows Fed Dried Versus Wet Brewers' Grain in Diets with Similar Dry Matter Content^{1,2}

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ABSTRACT

Twenty-four Holstein-Friesian dairy cows (20 intact and 4 fitted with rumen cannula) during early lactation (56 ± 25.3 d in milk) were assigned to two treatments to determine intake and production responses to feeding dried and wet brewers' grain. There were two cows fitted with a rumen cannula in each treatment. Cows were fed a total mixed ration twice daily containing either dried or wet brewers' grain at 15% of the dietary dry matter (DM). The diet contained 47% forage and 53% concentrate. The experimental design was a replicated 2×2 Latin square with two periods of 5 wk each. First 2 wk in each period were considered as adaptation to diets and data from the last 3 wk were used for treatment comparisons. Dried and wet brewers' diets contained 68.0 and 66.5% DM, respectively. Feeding brewers' grain dry or wet to dairy cows had no influence on feed intake (25.6 vs. 25.1 kg/d), fat corrected milk yield (40.1 vs. 40.7 kg/d), milk composition and feed consumption. The pH, ammonia, total volatile fatty acids and molar ratios of volatile fatty acids in the rumen fluid were not different between treatments. Fatty acid composition of milk fat from cows fed diets containing dry or wet brewers' grain was identical, except C_{18:2} and C_{18:3} fatty acids were lower in milk fat from cows fed wet brewers' grain compared with dried brewers' grain. The results from the present study suggest that the performance of cows fed either dried or wet brewers' grain at 15% of dietary DM was similar when diets had the same DM. The average price for dried and wet brewers' grain in the United States from July 2001 to June 2002 was \$145.3

and \$96.9/metric tonne DM, respectively. Using wet instead of dried brewers' grain will save \$49/metric tonne minus the difference in storage costs. Wet brewers' grain can be fed to dairy cows in areas that are close to the brewery and provides nutritive value similar to the dried brewers' grain.

(**Key words:** cow, brewers' grain, milk, dairy)

Abbreviation key: CLA = conjugated linoleic acid, DBG = dried brewers' grain, WBG = wet brewers' grain.

INTRODUCTION

Brewery byproducts are residues of grains that are used to produce beer. The residue can be marketed directly as wet brewers' grain (**WBG**) or as dried brewers' grain (**DBG**). Brewers' grain derived mainly from barley fermented to produce beer has about 23% CP and is high in digestible fiber. Due to their fibrous nature and low energy content, brewers' grains are suitable for ruminants, particularly in dairy cows, to balance intake of large amounts of high starch diets.

The moisture content in WBG ranges between 65 to 75%. Dried brewers' grain is easy to store because of its low moisture content. However, drying incurs additional costs. Several researchers have studied the feeding value of brewers' grain for dairy cows. Conrad and Rogers (1977) reported more milk per unit of DM for rations containing WBG than DBG. Davis et al. (1983) found that feeding cows 0, 20, 30, and 40% of WBG on DM basis resulted in decreased DMI at the 30 and 40% levels; however, the performance on the 0 and 20% diets was similar. Hoffman et al. (1988) fed diets containing 21.5% DBG and 23.5% WBG and observed no change in feed intake, milk yield, and milk composition of cows in early lactation. The rations were isonitrogenous in this study, but DM contents were 69.9 and 47.3% in DBG and WBG diets, respectively. Jersey cows fed wet brewers' grain at 0, 15, or 30% of the diet in hot, humid weather had similar intakes and milk yield (West et al., 1994).

Information on nutritive value of DBG vs. WBG for high producing dairy cows fed diets of similar DM

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²Trade names and the names of commercial companies are used in this report to provide specific information. Mention of a trade name or manufacturer does not constitute a guarantee or warranty of the product by the Utah State University or an endorsement over products not mentioned.

content is limited. Based on the milk yield response and drying costs, it might be beneficial to feed WBG in areas close to a brewery. The objective of this research was to determine intake, production, and ruminal fermentation characteristics of dairy cows fed diets containing DBG and WBG with similar DM content.

MATERIALS AND METHODS

Animals and Treatments

Twenty-four Holstein-Friesian dairy cows (20 intact and 4 fitted with rumen cannula) during early lactation were blocked into 12 groups according to average milk yield during the week prior to the start of the experiment. Cows were randomly assigned to two treatments. There were two cows fitted with a rumen cannula in each treatment. The experimental design was a replicated 2×2 Latin square with two periods of 5 wk each. First 2 wk in each period were considered as an adaptation to the diets and data from the last 3 wk were used for treatment comparisons.

Ingredient composition of the diets is in Table 1. Diets had similar ingredient composition, except that brewers' grain was either dried or wet at 15% of the dietary DM. The experiment was conducted at the George B. Caine Dairy Teaching and Research Center at Utah State University, Logan. Animal care and procedures were approved and conducted under established standards of the Utah State University Institutional Animal Care and Use Committee.

Cows were housed in a tie-stall barn and fed individually. Diets contained 47% forage and 53% grain mix and were fed as a TMR twice daily. Sixty percent of the total daily feed was offered after the morning milking and the remaining 40% after the evening milking. Cows were fed 5 to 10% more than their anticipated intake on an as-fed basis. Diets were formulated to meet the nutrient requirements of cows producing 50 kg of 3.5% FCM/d according to NRC (1989) recommendations. Brewers' grain (dried and wet) was supplied by the A-L Gilbert Company, Oakdale, CA. The DBG and WBG were prepared from the same batch of brewers' grain. The DBG was manufactured by drying WBG at an average temperature of 80°C in a rolling drum dryer filled with steam tubes (Louisville Dryer Co., Louisville, KY). Dried brewers' grain (8 to 10%) from the same batch was added into the drum to help dryer work easier. No other processing was done to the material. Material was then pressed through a mill to yield pellets of an average 0.476 cm diameter and 0.952 cm length. The DBG and WBG were stored in a commodity shed and Ag-bag silo placed on concrete, respectively.

Cows were weighed at the beginning of the experiment on 2 consecutive days after the morning milking.

Table 1. Ingredient and chemical composition of diets.

Composition	Diet ¹	
	DG	WG
Ingredient	% of DM	
Alfalfa hay ²	40.0	40.0
Corn silage ²	7.0	7.0
Dried brewers' grain ³	15.0	0.0
Wet brewers' grain ³	0.0	15.0
Steam rolled corn	21.2	21.2
Soybean meal ⁴ (Soyplus)	6.5	6.5
Cottonseed whole linted	3.0	3.0
Ener G II ⁵	2.0	2.0
Dehydrated beet pulp	3.0	3.0
Sugar beet molasses	1.0	1.0
Sodium bicarbonate	0.2	0.2
Mineral and vitamin ADE mix ⁶	1.1	1.1
Chemical		
DM	68.0 ± 1.6	66.5 ± 1.6
NE _L , Mcal/kg, DM ⁷	1.692	1.692
CP	16.5 ± 0.07	16.5 ± 0.08
NDF	40.4 ± 0.18	42.0 ± 0.12
ADF	24.4 ± 0.12	24.5 ± 0.11

¹Cows were fed diet containing dried brewers' grain (DG) or wet brewers' grain (WG) at 15% of dietary DM.

²Alfalfa hay and corn silage contained 88.7, 17.3, 46.2, 36.0 and 37.6, 6.3, 51.7, 29.6% DM, CP, NDF, and ADF, respectively.

³Dried and wet brewers' grain contained 92.3, 23.6, 71.0, 59.8, 26.6 and 33.6, 23.6, 69.0, 70.0, 27.7% DM, CP, rumen undegraded protein (% of total CP) NDF, and ADF, respectively. Dried and wet brewers' grain had (DM basis) 0.28, 0.77, 0.26, 0.48, 0.02, and 0.34, 0.79, 0.27, 0.46, 0.015% Ca, P, Mg, K, and Na, respectively. The trace mineral content of DBG and WBG were 114, 84, 15, 48, 1.5 and 126, 81, 18, 43, 1.8 mg/kg DM Fe, Zn, Cu, Mn and Mo, respectively.

⁴A registered trademark for soybean meal product (West Central Soy, Ralston, IA).

⁵A registered trademark for rumen-inert calcium-salts of long-chain fatty acids (Bioproducts, Inc., Fairlawn, OH); contained 82.3% fat and 8.8% Ca.

⁶Contained 21% Ca, 11% P, 64% NaCl, 0.8% K, 0.8% Mg, 0.44% S, 0.40% Mn, 0.55% Zn, 0.35% Fe, 0.003% Se, 0.14% Cu, 0.008% I, 0.002% Co, 796,013 IU of vitamin A/kg DM, 200,000 IU of vitamin D/kg DM and 1985 IU of vitamin E/kg DM.

⁷Calculated using NRC (1989) NE_L values for feeds.

Average milk yield for the week prior to the start of the experiment, DIM and BW were 47.2 ± 6.6 kg/d, 56 ± 25 and 699 ± 48 kg, respectively. The study was conducted from February 1 to April 7. The average minimum and maximum temperatures on the experimental farm during this time were -2.8°C (range -12.2 to 4.4°C) and 10.6°C (range -0.6 to 23.9°C), respectively. The average relative humidity on the farm was 76.9% during the study.

Sampling, Analysis, Calculations, and Diet Composition

To simplify data collection, the experimental week ran from Wednesday through Tuesday. Daily amounts of feed offered and orts were recorded. Orts were removed daily. Samples of each TMR and orts from indi-

vidual cows were collected daily. The TMR samples for each diet were stored in the freezer (-20°C). The orts samples were mixed for cows within each treatment and stored in the freezer. Weekly composite samples of TMR and orts were analyzed for DM. Samples of forage and other dietary ingredients were collected once weekly and analyzed for DM. The DM content of feed ingredients was determined by oven drying at 60°C for 48 h. Dietary formulations were adjusted weekly, if necessary, to account for small changes in ingredient DM content. Samples of dried feed and orts were ground through a Wiley Mill using a 1-mm screen (Arthur H. Thomas, Philadelphia, PA).

Weekly samples of alfalfa hay, corn silage, and bi-weekly composite samples of grains were analyzed for CP, NDF, and ADF. The CP was determined with a Protein Nitrogen Analyzer model NA-2100 (ThermoQuest Italia S.P.A., Strada Rivoltana, Milan, Italy). The samples were analyzed for NDF and ADF using the Filter Bag Technology of ANKOM (ANKOM²⁰⁰ Fiber Analyzer, ANKOM Technology Corporation, Fairport, NY). Composite samples of brewers' grain were analyzed for RUP (Roe and Sniffen, 1990) and mineral content using a Thermo Jarrell Ash IRIS Advantage Inductively Coupled Plasma Radial Spectrometer (Thermo Optek Corporation, Franklin, MA). The samples were further dried at 105°C for 8 h to determine the absolute DM. Chemical analysis data were expressed on this final DM. Once a week, a representative sample of WBG was collected from the Ag-bag silo and stored in a freezer for further analysis of pH. To determine pH, a 50-g WBG sample was blended with water for 30 to 45 s to yield a final mixture with 5 g/kg DM. This blended mixture was filtered through one layer of cheesecloth, and pH determined in the filtrate using a pH meter (model #310, Orion Research Inc., MA). The average pH in WBG during the entire experiment was 4.40 ± 0.23 SD. The pH of wet brewers' grain was within normal range and suggests that undesirable fermentation did not occur during the study. The DM, CP, NDF, and ADF content of DBG and WBG were (mean $\pm$ SD) 92.3 ± 1.0 , 23.6 ± 0.8 , 59.8 ± 5.8 , $26.6 \pm 0.8\%$ and 33.6 ± 1.6 , 23.6 ± 0.9 , 70.0 ± 2.7 , $27.7 \pm 1.5\%$, respectively. The RUP in DBG and WBG was 71.0 and 69% of total CP, respectively.

Chemical composition of the TMR was calculated from the chemical composition of the individual ingredients of the diet. Water was added to the mixing wagon in the TMR containing DBG about 45 to 60 min prior to feeding to bring the dietary DM close to the diet containing WBG. The actual average DM during the experiment in DG and WG treatment diets was 68.0 and 66.5%, respectively (Table 1). Daily feed intake for individual cows was calculated by subtracting

the weekly mean of orts from the weekly mean of feed offered during that week. The NE_L content of the diets was calculated by using NE_L values (NRC, 1989) for the individual dietary ingredients. The NE_L values used for alfalfa hay, corn silage, brewers' grain (DBG and WBG), steam-rolled corn grain, soybean meal, cottonseed, EnerG II, beet pulp and molasses were 1.40, 1.40, 1.50, 2.04, 1.94, 2.23, 4.96, 1.79, and 1.72 Mcal/kg feed DM, respectively. Calculated NE_L content of both treatment diets was 1.692 Mcal/kg feed DM (Table 1). Weekly mean NE_L intakes were calculated by multiplying the NE_L values of the diets with the mean DMI of individual cows for that week. Orts were assumed to have the same proportion of ingredients as did the diets.

Milk production was recorded daily. Milk samples were collected once a week from four consecutive a.m. and p.m. milkings during wk 3, 4, and 5 in each period. Milk samples were analyzed for fat, protein, lactose, SNF, and urea N by the Rocky Mountain Dairy Herd Improvement Association Laboratory (Logan, UT) with midinfrared wavebands (2 to 15 μm) procedures with a Bentley 2000 (Bentley Instruments, Chaska, MN). Final milk composition for each day was expressed on weighted milk yield of a.m. and p.m. samples. Average fat and protein yields were calculated by multiplying milk yield by fat and protein content of milk for that week on an individual cow basis. Milk energy output was calculated on an individual cow basis using milk fat, protein, and lactose content of milk (Tyrrell and Reid, 1965). Weighted composite milk samples from four consecutive a.m. and p.m. milkings from wk 4 and 5 in each period were analyzed for fatty acid composition including conjugated linoleic acid (CLA) using the procedure of Dhiman et al. (2002).

Rumen fluid samples were collected during the last 2 d in each period from rumen cannulated cows at 0, 1, 2, 3, 6, 9, 12, 18, and 24 h after the morning feeding. Rumen fluid samples were strained through two layers of cheesecloth. The pH was determined in strained rumen fluid samples immediately after collection using a pH meter (model #310, Orion Research Inc., MA). Samples of strained rumen fluid (15 ml) were preserved in a plastic vial containing 0.3 ml of 50% sulfuric acid for ammonia analysis and stored at -20°C for further analysis. Rumen fluid samples (10 ml) were acidified with 98% formic acid (1:1, vol/vol) and stored at -20°C before preparation and analysis of VFA. The rumen fluid samples for ammonia analysis were thawed and centrifuged at $30,000 \times g$ at 4°C ; supernatants were analyzed for ammonia using alkaline phenolhypochloride colorimetric procedure (Chaney and Marbach, 1962). Acidified ruminal fluid samples for

VFA analysis were centrifuged at $10,000 \times g$ at 4°C for 20 min and analyzed for VFA using a procedure of Brotz and Schaefer (1987) and a gas chromatograph model 6890 Series II (Hewlett-Packard Co., Wilmington, DE).

Feed eating rate of cows was measured individually on 2 consecutive days during each period by weighing feed consumed at 1, 4, 8, 10, and 24 h after the first feed was offered.

Chemical composition of the diets is in Table 1. The chemical composition of the diets was similar to the NRC (1989) recommendations for cows producing 50 kg of 3.5% FCM/d. The energy, CP, NDF, and ADF contents of diets were similar because the ingredients used were the same in both treatment diets, except brewers' grain.

Statistical Analysis

Statistical analysis was performed using repeated measures analysis of variance (SAS, 2000). Initially, a base model that included the independent variables of period and treatment and a period $\times$ treatment interaction term was evaluated for each production and milk fatty acid variable. The week and treatment $\times$ week interaction terms were evaluated within the base model using a forward manual selection technique and a critical alpha for inclusion of $P < 0.05$.

A similar model was used to evaluate rumen fermentation outcomes; however, the variable week was replaced by hour. Data for rumen fermentation measurements were analyzed separately for each hour when the treatment $\times$ hour interaction was significant ($P < 0.05$). Tukey's test was used to adjust for multiple comparisons. Total feed consumption (eating rate) was compared between treatment groups at each hour using analysis of variance. The base model included the independent variables of period and treatment. The effect of day, day $\times$ treatment interaction and period $\times$ treatment interaction terms were evaluated as described above.

Model fit and the presence of outliers in the data were visually assessed by plotting residual and predicted values. Data transformations were used when necessary to better fit the model. Estimates of treatment group least squares means were reported. Differences between treatment groups were evaluated by *t*-test on the differences of least squares means. Significance was declared at $P < 0.05$ unless otherwise noted. Significance at $P = 0.01$ or less was mentioned as $P < 0.01$ to simplify the tables and text. Trends were described at $P < 0.1$.

RESULTS AND DISCUSSION

Cows fed diets containing DBG and WBG had similar feed intakes, energy intakes, milk yields, energy output in milk, feed utilization efficiency (FCM/DMI) and milk composition (Table 2). Conrad and Rogers (1977) reported that cows produced more milk per unit of DM for rations containing WBG than DBG at 20% of dietary DM when TMR had a different moisture content. The DM content of the diet has been shown to influence feed intake and maximizing DMI is a primary concern in feeding dairy cows to achieve optimum production. Attempt was made in the present study to maintain similar DM in TMR of DG and WG treatments (66.5 to 68.0%). Lahr et al. (1983) added water directly to the mixer with other feed ingredients immediately prior to feeding and observed that feeding TMR with less than 63% DM reduced DMI of lactating dairy cows. The DMI decreased linearly as DM content of diet decreased from 78 to 40% by addition of water and neither milk yield or BW were affected (Lahr et al., 1983). Robinson et al. (1990) fed TMR with 35, 45, 60, and 65% DM attained by soaking the grain mix in water for 24 h and observed no effect on DMI, milk yield, and milk composition. Soaking of grain is not practical for larger dairies. It is common to add water to alfalfa hay-based dairy diets prior to mixing in the Western United States to avoid dustiness and sorting of feed ingredients.

Using cows in the first 140 d of lactation, Murdock et al. (1981) found no differences in DMI, milk yield, and milk composition of cows fed WBG at 15 and 30% of the dietary DM when WBG replaced soybean meal and barley in diets based on alfalfa hay and corn silage. Hoffman et al. (1988) observed no change in feed intake, milk yield, and milk composition of cows fed diets containing 21.5% DBG and 23.5% WBG and total diet DM 69.9 and 47.3%, respectively. However, milk yield and DMI were reduced when WBG replaced soybean meal at more than 20% of dietary DM in cows fed diets based on corn silage (Davis et al., 1983). The treatment diets were not isonitrogenous (Davis et al., 1983) and that may partly explain the reduction in milk yield and DMI. Feeding 0, 15, or 30% of dietary DM as WBG in diets containing 54.6, 43.3, and 35.5% DM, respectively to Jersey cows during hot humid weather did not influence feed intake or milk yield, however, milk protein content was decreased by 0.17 percentage units in 30% WBG compared with control diet containing ground corn (West et al., 1994). Results from the present study suggest that DMI, milk yield, and milk composition of dairy cows fed diets containing 15% of dietary DM as DBG or WBG did not differ when diets had the same amount of DM.

Table 2. Influence of feeding dry vs. wet brewers' grain to dairy cows on DMI, energy intake, milk yield, and milk composition.

Item	Treatment ¹		SEM	P
	DG	WG		
DMI, kg/d	25.6	25.1	0.3	0.24
NE _L intake, Mcal/d	43.2	42.5	0.3	0.24
Milk yield, kg/d	42.3	42.8	0.6	0.60
3.5% FCM ² , kg/d	40.1	40.7	0.7	0.50
Milk energy output ³ , Mcal/d	27.5	28.0	0.4	0.42
FCM/DMI	1.57	1.62	0.03	0.16
Fat, %	3.19	3.17	0.04	0.78
Protein, %	3.04	3.02	0.02	0.41
Fat yield, kg/d	1.33	1.35	0.03	0.73
Protein yield, kg/d	1.28	1.28	0.02	0.74
Lactose, %	4.76	4.76	0.02	0.88
SNF, %	8.59	8.57	0.03	0.66
Milk urea N, mg/dl	15.88	15.38	0.25	0.15

¹Cows were fed diet containing dried brewers' grain (DG) or wet brewers' grain (WG) at 15% of dietary DM.

²3.5% FCM = 0.432 (kg of milk) + 16.23 × (kg of fat).

³Calculated using fat, protein, lactose content of milk in an equation by Tyrrell and Reid (1965).

Urea N in milk reflects dietary CP content and protein quality because excess ruminal ammonia enters the blood and is converted to urea in the liver. As a water-soluble compound, urea enters the mammary gland and eventually into the milk. Urea N concentration in milk was the same in both DG and WG treatments.

Table 3. Influence of feeding dry vs. wet brewers' grain to dairy cows on milk fatty acid composition, % of total fatty acids reported.

Fatty acid ²	Treatment ¹		SEM	P
	DG	WG		
C _{8:0}	1.56	1.61	0.04	0.34
C _{10:0}	1.11	1.14	0.02	0.47
C _{12:0}	2.60	2.66	0.06	0.46
C _{14:0}	2.99	3.06	0.06	0.42
C _{14:1}	10.1	10.2	0.1	0.34
C _{15:0}	1.80	1.83	0.12	0.42
C _{16:0}	33.0	33.4	0.2	0.26
C _{16:1}	1.17	1.21	0.03	0.23
C _{17:1}	0.19	0.19	0.01	0.73
C _{18:0}	11.7	11.5	0.2	0.33
<i>Trans</i> -C _{18:1}	4.97	4.93	0.07	0.65
<i>Cis</i> -C _{18:1}	22.4	22.1	0.2	0.40
C _{18:2}	4.94	4.63	0.06	0.01
C _{18:3}	0.72	0.68	0.01	0.01
CLA ³	0.74	0.71	0.02	0.21
SFA ⁴	54.8	55.2	0.3	0.22
UFA ⁵	45.2	44.8	0.3	0.22

¹Cows were fed diet containing dried brewers' grain (DG) or wet brewers' grain (WG) at 15% of dietary DM.

²Number of carbon:number of double bonds.

³Conjugated linoleic acid, *cis*-9, *trans*-11 C_{18:2}.

⁴Saturated fatty acids, sum of C_{8:0}, C_{10:0}, C_{12:0}, C_{14:0}, C_{15:0}, C_{16:0}, and C_{18:0}.

⁵Unsaturated fatty acids, sum of C_{14:1}, C_{16:1}, C_{17:1}, *trans*-C_{18:1}, *cis*-C_{18:1}, C_{18:2}, C_{18:3}, and CLA.

Fatty acid composition of milk fat from cows fed diets containing DBG or WBG was identical except C_{18:2} and C_{18:3} fatty acids were lower in milk fat from cows fed WBG compared with DBG (Table 3). The reasons for reduction in C_{18:2} and C_{18:3} are not clear. Recently CLA has been shown to have anticancer properties (Ha et al., 1987, 1990; and Ip et al., 1994). The CLA was higher in milk fat from cows fed brewers' grain than the average CLA content of milk from cows fed typical dairy diets containing 50% forage and 50% grain (0.70 vs. 0.45% of CLA in milk fat; Dhiman et al., 2002). This higher CLA content was reflected in both diets containing brewers' grain but did not differ between them. Increased CLA in milk from cows fed brewers' grain might be due to increased supply of digestible fiber from brewers' grain. Feeding diets containing higher levels of fiber through forages generally increases the CLA content of milk in dairy cows (Dhiman et al., 1999). Proportions of saturated and unsaturated fatty acids in milk were similar between treatments.

Table 4. Influence of feeding dry versus wet brewers' grain on eating rate (cumulative % of offered feed consumed, DM basis) of dairy cows.

Hours after first feed offered	Treatment ¹		SEM	P
	DG	WG		
1	22.6	23.6	1.3	0.56
4	34.2	38.7	1.9	0.10
8	56.2	58.0	1.1	0.26
10	60.0	62.5	1.0	0.08
24	85.6	84.7	0.9	0.47

¹Cows were fed diet containing dried brewers' grain (DG) or wet brewers' grain (WG) at 15% of dietary DM.

Figure 1. Influence of feeding diets containing dried brewers' grain (■) and wet brewers' grain (▲) at levels of 15% of the diet DM to dairy cows on rumen fermentation measurements.

Feed consumption rate is an indicator of palatability of the diet and effects of dietary ingredients on time spent eating, chewing, and ruminating the feed. Results from the present study suggest that feeding DBG or WBG at 15% of the dietary DM had no influence on rate of feed consumption in dairy cows (Table 4). The TMR in both treatment diets had similar DM and feed ingredients and this may be the reason that cows fed diets containing DBG or WBG consumed feed at similar rates.

Treatment interaction with hour was significant for ruminal pH and VFA concentrations. Therefore, patterns of ruminal pH, total VFA, and molar ratios of different VFA during 24 h are shown in Figure 1. The ruminal pH and TVFA concentrations on 12 h were slightly higher in WG than DG; however, the differences between treatments were not significant. Overall statistical analysis of data by hour suggest that feeding diets containing DBG or WBG had no influence on ruminal pH, total VFA, and molar ratios of acetate, propionate, isobutyrate, butyrate, isovalerate, and valerate. To our knowledge there is no study in the literature comparing influence of diets containing DBG or WBG on rumen fermentation characteristics of cows. Davis et al. (1983) observed increase in ruminal pH and decrease in ruminal VFA concentrations when 20, 30, and 40% WBG was added to the diet for dairy cows by replacing soybean meal. The change in rumen fermentation characteristics in the study by Davis et al. (1983) was attributed to higher fiber content of diets containing WBG. In the present study NDF content of DG and WG treatment diets were 40.4 and 42.0% of dietary DM. Slight increase in NDF of WG diet was because of the higher NDF in WBG compared with DBG (70.0 vs. 59.8% of DM). The small increase in NDF content of WG diet had no influence on ruminal fermentation measurements in our study. Daily average ruminal ammonia concentrations were 4.96 and 5.44 mM in DG and WG treatments, respectively. Lack of change in ruminal ammonia concentrations suggests that the rate of degradation of protein in the rumen was same in diets containing DBG or WBG. Acetate:propionate ratios in the rumen fluid was 3.1:1 and 3.0:1 in DG and WG treatments, respectively. Acetate:propionate ratios observed in the present study were within normal range for cows fed a typical dairy diet containing 50% forage and 50% grain (Dhiman et al., 2002).

The average price compiled from Feedstuffs (Minnetonka, MN) for DBG and WBG in the United States (Markets in Atlanta, Boise, Chicago, Kansas City, Minneapolis, Portland, and Saginaw) from July 2001 to June 2002 was \$145.3 and \$96.9/metric tonne DM, respectively. As discussed earlier, the relative nutri-

tive value of DBG and WBG is the same for lactating dairy cows. Therefore, using WBG instead of DBG will save \$49/metric tonne minus the difference in storage costs. The storage of WBG for a lengthy time is always a concern, particularly in warm weather. However, in areas that are close to a brewery it seems profitable to include WBG in dairy cow rations at levels of 15% of the DM with the nutritive value similar to DBG.

CONCLUSIONS

Cow performance data from the present study indicate that the relative nutritive value of DBG or WBG is the same for lactating dairy cows when fed at 15% of dietary DM in a TMR containing similar DM.

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