***Saccharomyces cerevisiae* fermentation product in dairy cow diets containing dried distillers grains plus solubles**

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ABSTRACT

Sixteen multiparous Holstein cows (127 ± 52 d in milk) were used in 4 replicated 4×4 Latin squares with 4-wk periods to evaluate interactions of dietary inclusion of a fermentation product of *Saccharomyces cerevisiae* (SC; XPC, Diamond V Mills, Cedar Rapids, IA) and dried distillers grains plus solubles (DDGS) on production of milk and milk components when fed diets containing approximately 30% dietary neutral detergent fiber with calculated forage neutral detergent fiber of 19.3% of diet dry matter (DM). Treatments were a 2×2 factorial arrangement with SC included at 0 or 14 g/d and DDGS at 0 or 20% of diet DM. Diets consisted of 27% corn silage, 18% alfalfa hay, and 55% concentrate mix on a DM basis. Diets not containing DDGS included additional corn, soybean meal, expeller soybean meal, soyhulls, and rumen inert fat to remain isocaloric and isonitrogenous with DDGS diets. Dry matter intake (26.0 kg/d) was similar for all diets. Milk production increased with the addition of SC to diets (43.6 vs. 42.0 kg/d for diets without SC) and decreased for cows fed diets containing DDGS (42.0 kg/d vs. 43.6 kg/d for diets not containing DDGS). Milk fat percentage (3.05 vs. 3.22% for DDGS and non-DDGS diets, respectively) and yield (1.27 vs. 1.41 kg/d) were decreased by the addition of DDGS but were not affected by the addition of SC. Concentrations of long-chain, polyunsaturated, *trans*-, and conjugated fatty acids in milk of cows fed DDGS were increased, but milk fatty acid profiles were not affected by SC. Milk true protein concentrations were similar for all diets; however, the addition of SC increased yield of true protein (1.32 vs. 1.27 kg/d). Concentrations of milk urea nitrogen increased when SC was included in the diet with DDGS. The DDGS decreased yields of energy-corrected milk (39.4 vs. 42.1 kg/d) and tended to decrease feed efficiency (1.53 vs. 1.61 kg of energy-corrected milk/kg of

dry matter intake). Body weights and condition scores were not affected by treatments. Results suggest that diets containing minimal amounts of forage fiber and DDGS at 20% of diet DM will contribute to decreased milk production and milk fat depression. The addition of SC did improve milk and milk protein yields but did not prevent milk fat depression caused by DDGS. Production responses to SC were similar when cows were fed DDGS or non-DDGS diets.

Key words: *Saccharomyces cerevisiae*, distillers grain, lactating cow

INTRODUCTION

Dried corn distillers grains with solubles (DDGS) have become a common source of protein and energy for lactating dairy cows. Much of the energy content of DDGS, however, is in the form of polyunsaturated fat, primarily linoleic acid. It has been demonstrated that feeding polyunsaturated fatty acids in dairy cow diets may cause milk fat depression (Palmquist et al., 1993), largely through ruminal formation of *trans* intermediates from the biohydrogenation of linoleic acid having suppressive effects on milk fat synthesis (Griinari et al., 1998; Baumgard et al., 2000). Accordingly, DDGS have been reported to cause milk fat depression when fed to lactating dairy cows in field conditions. Most controlled research experiments, however, have failed to validate this effect (Anderson et al., 2006; Kleinschmit et al., 2006) until dietary concentrations of DDGS exceed 20% of diet DM (Hippen et al., 2004; Abdelqader et al., 2009) or forage fiber in the diet is replaced with fiber from byproduct feeds (Cyriac et al., 2005). Leonardi et al. (2005), on the other hand, demonstrated linear, though slight, decreases in milk fat content as DDGS increased in diets from 0 to 15% of diet DM. Current research indicates that milk fat depression will be observed in cows fed diets containing DDGS if effective fiber in the diet is marginal (Hippen et al., 2004; Leonardi et al., 2005; Cyriac et al., 2005; Abdelqader et al., 2009). In a classic experiment, Griinari et al. (1998) demonstrated severe milk fat depression when unsaturated fat from

Received December 28, 2009.

Accepted February 2, 2010.

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corn oil was added to diets containing decreased forage, providing indication of the potential effects of fat from distillers grains on milk fat production when forage concentrations are marginal.

Much research has been conducted relating nature and content of dietary fiber to milk fat production. Based upon this body of research, the NRC (2001) recommendation for dietary fiber for lactating dairy cows is within the range of 25 to 33% of diet DM as total NDF and, of that, NDF from forage is to be maintained between 15 to 19% of diet, with greater forage NDF required as total dietary NDF decreases. Reviews, notably Zebeli et al. (2007), have demonstrated a general inverse relationship between dietary effective fiber and milk fat percentage. More specifically, Beauchemin and Yang (2003) recommended a minimum NDF from forage sources of 21 to 23% of diet DM for diets containing barley grain.

To the contrary, addition of *Saccharomyces cerevisiae* fermentation product (SC) has been demonstrated to improve efficiency of production of ECM (Schingoethe et al., 2004), partly by improvements in fiber digestibility and subsequent increases in the fat content of the milk. Further, Longuski et al. (2008) demonstrated improved fat concentrations and yield in milk from cows supplemented with SC when high moisture corn was substituted for dry corn in diets containing 6% DDGS. Improvements in milk fat concentrations from improved fiber digestibility when feeding SC have been extensively reviewed by Desnoyers et al. (2009). Therefore, the hypothesis of this research was that feeding SC in diets containing DDGS would improve lactation performance and minimize the effects of the DDGS on milk fat depression in diets with minimal forage fiber.

MATERIALS AND METHODS

All procedures in this study were carried out under approval of the South Dakota State University Animal Care and Use Committee. Sixteen Holstein cows that averaged 127 DIM (SD = 52 d) were used in replicated 4 × 4 Latin squares to evaluate the interaction of SC (Original XPC Yeast Culture, Diamond V Mills, Cedar Rapids, IA) and DDGS (Glacial Lakes Energy LLC, Watertown, SD) added to diets. Cows were assigned to squares based upon DIM and pretreatment milk production. Treatments were applied in a 2 × 2 factorial design containing 0 or 14 g/d of SC and 0 or 20% of diet DM as DDGS and were fed for 4-wk periods. Total mixed diets (Table 1) on a DM basis consisted of corn silage (27%), alfalfa hay (18%), and a concentrate mix (55%) containing SC or DDGS, respective of treatment. As formulated, forage NDF was to be 20.4% of diet DM. Diets not containing DDGS included additional

corn and soybean meal plus expeller soybean meal (SoyPlus, West Central Soy, Ralston, IA), soyhulls, and rumen inert fat (Energy Booster 100, Milk Specialties Company, Carpentersville, IL) to remain isocaloric and isonitrogenous with DDGS diets. Diets were formulated to meet or exceed NRC requirements (NRC, 2001).

Cows were housed in a curtained free-stall barn and fed individually using Calan Broadbent feeder doors (American Calan Inc., Northwood, NH). Cows were assigned to doors 2 wk before the start of the experiment. The experiment was conducted from May 25 to September 15, 2006. Cows were individually fed the respective diets once daily (0800 h) for ad libitum consumption with continuous access to feed except during milking. Amounts fed and refused were recorded daily. Body weights and BCS (3 independent recorders; scale of 1 to 5, with 1 being emaciated and 5 being obese; Wildman et al., 1982) were recorded at the beginning of the experiment and at the end of each period.

Samples of alfalfa hay, corn silage, concentrate mixes, and diets were collected on alternate days during the last week of each period (4 samples/wk), made into composites by period and diet, and stored at -20°C until analyses. Composites of samples were analyzed for DM (105°C for 24 h), CP (AOAC, 1997) using a LECO-428 combustion analyzer (Leco Corp., St. Joseph, MI), and ether extract (EE) with petroleum ether (AOAC, 1997). Neutral detergent fiber and ADF were measured using the Ankom A200 (Ankom Technology Corp., Fairport, NY) filter bag technique. Determinations of ADF were made according to AOAC (1997; 973.18 C), whereas NDF was determined according to Van Soest et al. (1991) with the addition of 4 mL of α-amylase and 20 g of sodium sulfite. Starch was measured as dextrose after treating samples with glucoamylase using a YSI 2700 Select Biochemistry Analyzer (YSI Life Sciences, Yellow Springs, OH; Holm et al., 1986). Minerals were quantified according to AOAC (1997) methods (985.01) using an inductively coupled plasma spectrometer (Thermo Jarrell Ash, Franklin, MA). Additional samples of diets collected on the same days were evaluated for particle size using the Penn State Particle Separator (Kononoff et al., 2003).

Samples of ruminal fluid were collected 3 h after the morning feeding on the last 2 d of each period using an esophageal tube and hand-operated pump. To minimize saliva contamination, the initial portion collected, approximately 50 mL, was discarded. The pH was determined with a standardized pH meter (Corning Inc., Corning, NY) immediately after collection. Ten milliliters of rumen fluid was mixed with 2 mL of 25% (wt/vol) metaphosphoric acid according to Erwin et al. (1961) and placed in ice until transported to the laboratory, where it was frozen at -20°C. For quantifi-

Table 1. Ingredient composition of diets that contained *Saccharomyces cerevisiae* fermentation product (SC) or no SC (NSC) with dried distillers grains with solubles (DDGS) or without DDGS (NDDGS)

Item, % of DM	NSC		SC	
	NDDGS	DDGS	NDDGS	DDGS
Alfalfa hay	18.0	18.0	18.0	18.0
Corn silage	27.0	27.0	27.0	27.0
Steamed flaked corn	29.0	25.8	28.9	25.7
Soybean meal, 44% CP	13.0	6.72	13.0	6.70
DDGS	0	20.0	0	20.0
Expeller soybean meal ¹	4.74	0	4.74	0
Soybean hulls	4.58	0	4.58	0
Rumen inert fat ²	1.23	0	1.23	0
Calcium carbonate	0.85	1.06	0.85	1.06
Sodium bicarbonate	0.54	0.54	0.54	0.54
Salt, white	0.41	0.41	0.41	0.41
LOL Dairy Micro Premix ³	0.28	0.28	0.28	0.28
Magnesium oxide	0.16	0.16	0.16	0.16
Dicalcium phosphate	0.16	0	0.16	0
SC ⁴	0	0	0.06	0.06
Vitamin E20 ⁵	0.03	0.03	0.03	0.03
Zinpro 4-Plex ⁶	0.03	0.03	0.03	0.03

¹SoyPlus (West Central Soy, Ralston, IA).²Energy Booster 100 (Milk Specialties Company, Carpentersville, IL).³Dairy Micro Premix (Land O' Lakes Inc., St. Paul, MN); Ca, 4.64%; Mg, 10.3%; Fe, 4,783 mg/kg; Cu, 4,857 mg/kg; Co, 122 mg/kg; Mn, 17,793 mg/kg; Zn, 26,556 mg/kg; I, 408 mg/kg; Se, 144 mg/kg; vitamin A, 545,000 IU/kg; vitamin D, 109,000 IU/kg; vitamin E, 2,181 IU/kg.⁴*Saccharomyces cerevisiae* fermentation product (XPC, Diamond V Mills, Cedar Rapids, IA).⁵Contained 20,000 IU of vitamin E/kg.⁶Zinpro Corporation (Eden Prairie, MN).

cation of VFA, samples were thawed and centrifuged at $30,000 \times g$ at 4°C for 20 min. Volatile fatty acids were determined by the procedure of Erwin et al. (1961). The samples were assayed with a gas chromatograph (model 6890 Series II, Hewlett-Packard, Palo Alto, CA) equipped with a capillary column (Nukol, Sigma-Aldrich, St. Louis, MO) and flame ionization detector to determine the concentration of VFA. The split ratio in the injector port (250°C) was 100:1 and a flow of 1.3 mL of He/min. Column and detector temperatures were maintained at 130 and 225°C , respectively.

Cows were milked daily at 0600, 1400, and 2100 h. Milk was sampled from all 3 milkings during 2 consecutive days at the end of each period. Daily composites of the milk samples were analyzed for fat, protein, and MUN (AOAC, 1997) by mid-infrared spectrophotometry (Multispec, Foss Food Technology Corp., Eden Prairie, MN). Somatic cell count (AOAC, 1997) was determined using a Fossomatic 90 (Foss Food Technology Corp.). A second aliquot of milk of the composite from the last day of each period was stored at -20°C for fatty acids analysis. Milk fatty acids were prepared as butyl esters according to the procedure of Sukhija and Palmquist (1988) with some modification. Briefly, 10 mL of milk was centrifuged at $2,800 \times g$ for 30 min at room temperature. The fat cake was removed, trans-

ferred to microtubes, and centrifuged at $19,300 \times g$ for 30 min at room temperature (Luna et al., 2005). The fat (10–20 mg) was then placed into extraction tubes (13×100 mm) with Teflon-lined screw caps, followed by 750 μL of butanol and 25 μL of internal standard (12-tridecanoic acid, Nu-Chek Prep Inc., Elysian, MN); it was then vortexed for 20 s. Samples were vortexed at low speed during the slow addition of 75 μL of acetyl chloride, gassed with N_2 , capped tightly, and heated on a dry heating block at 100°C for 90 min. After samples were cooled to room temperature, 5 mL of 6% K_2CO_3 were added and the samples were vortexed for 30 s. One milliliter of hexane was added and samples were vortexed for another 30 s. Samples were then centrifuged for 25 min at $2,800 \times g$ and the bottom layer was aspirated and discarded. The remaining hexane layer containing butyl esters was washed 4 times with distilled deionized water and centrifuged after each wash for 25 min at $2,800 \times g$. The upper layer, hexane and fatty acids, was removed and placed in injection vials for GC analysis.

The fatty acids, as butyl esters, were analyzed by gas chromatography equipped with a flame ionization detector and an autoinjector (Hewlett-Packard model 6890). Fatty acids were separated using a CP-Sil 88 fused silica capillary column (100 m $\times$ 0.25 mm i.d. $\times$

0.20 μm film thickness; Varian Inc., Lake Forest, CA). The split ratio at the injector port was set at 100:1 with a column He flow of 2 mL/min. The column temperature was held at 50°C for 1 min after injection, then increased at 5°C/min to 145°C, held at 145°C for 30 min, increased to 190°C at 10°C/min, and held at 190°C for 30 min. Finally, the temperature was increased at 5°C/min to 210°C and held at 210°C for 40 min. The injection and detector temperatures were 230°C. Individual fatty acids were identified by order of elution and comparison to commercially known prepared reference standards (GLC-606 and GLC-566, Nu-Chek Prep Inc.).

Data were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). Fixed effects were SC, DDGS, and period. Random effects were cow within square. Interactions of all effects were examined and removed from the model as deemed nonsignificant. One cow (no SC and DDGS treatment) was removed from analysis during period 1 because of mastitis, and 1 (SC and no DDGS treatment) was removed from analysis of period 4 because of a foot problem. Model effects were considered significant at $P \leq 0.05$, with trends noted at $0.05 < P < 0.10$.

RESULTS AND DISCUSSION

The nutrient composition of the diets (Table 2) was similar to that formulated. Because of a change in source of alfalfa hay, the CP of the diets was slightly higher than anticipated, averaging 17.7% analyzed versus 17.2% formulated, and NDF from forage was less than formulated, averaging 19.3% analyzed versus 20.4% formulated. Ether extract concentrations of diets were similar but less than expected because diets were formulated to contain 4.2% fat but analyzed content of EE averaged 3.7%. This may be partially attributable to decreased lipid content of corn silage compared with formulated values. Further, concentrations of EE in concentrates not containing DDGS were determined to be less than formulated (Table 3). This was not likely attributable to formulation errors because analysis of the TMR proved consistent EE values across treatment diets. Rather, differences in formulated versus analyzed values for the concentrates and lesser concentrations for diets in general may be partly attributable to use of petroleum ether for fat determination compared with formulation using values obtained by extraction with diethyl ether.

Table 2. Nutritional characteristics of diets that contained *Saccharomyces cerevisiae* fermentation product (SC) or no SC (NSC) with dried distillers grains with solubles (DDGS) or without DDGS (NDDGS)

Item	NSC		SC	
	NDDGS	DDGS	NDDGS	DDGS
DM, % of diet	52.6	51.8	51.1	52.5
Nutrient, % of DM				
CP	17.5	17.8	17.4	18.2
ADF	18.5	17.3	18.4	18.0
NDF	29.7	31.7	29.0	30.3
NDF from forage ¹	19.3	19.3	19.3	19.3
NFC ²	43.8	41.1	44.4	41.9
Starch	29.6	27.6	30.2	28.1
Ether extract ³	3.65	3.72	3.75	3.80
Ca	0.80	0.80	0.82	0.77
P	0.37	0.38	0.36	0.38
Mg	0.34	0.35	0.34	0.36
K	1.30	1.13	1.28	1.17
S	0.20	0.26	0.20	0.27
Na	0.35	0.36	0.33	0.36
Cl	0.35	0.38	0.37	0.43
NE _L , ⁴ Mcal/kg	1.60	1.61	1.62	1.62
Particle size, ⁵ % as is basis				
>19.0 mm	11.0	11.1	11.1	10.7
>8.0 mm	39.1	39.4	40.7	39.3
>1.18 mm	38.2	34.7	37.1	34.7
Bottom pan	11.6	14.8	11.0	15.4

¹Calculated from forage analysis.

²NFC = $100 - (\% \text{ NDF} + \% \text{ CP} + \% \text{ ether extract} + \% \text{ ash})$.

³Petroleum ether.

⁴Calculated using NRC (2001).

⁵Determined by Penn State Particle Separator (Kononoff et al., 2003).

Table 3. Nutrient composition of diet components and concentrates containing *Saccharomyces cerevisiae* fermentation product (SC) and no SC (NSC) with dried distillers grains with solubles (DDGS) or without DDGS (NDDGS)

	Distillers grain	Forage		Concentrate			
		Alfalfa hay	Corn silage	NSC		SC	
				NDDGS	DDGS	NDDGS	DDGS
DM, % as is	91.2	89.9	26.2	87.6	88.3	87.7	87.6
Nutrient, % of DM							
CP	31.1	22.8	8.84	19.0	19.2	18.7	18.6
ADF	13.0	26.1	31.0	7.64	6.50	7.43	6.17
NDF	29.6	35.3	47.8	12.2	16.4	11.6	13.9
NFC ¹	33.7	31.0	35.9	59.6	54.3	60.6	58.6
Starch	ND ²	5.10	25.0	27.0	28.0	26.5	29.6
Ether extract ³	9.35	2.02	2.65	3.96	4.75	3.56	4.63
Ca	0.04	1.45	0.30	0.82	0.80	0.75	0.85
P	0.69	0.31	0.26	0.39	0.42	0.37	0.42
Mg	0.32	0.34	0.22	0.33	0.39	0.31	0.37
K	0.95	2.23	1.02	0.98	0.75	0.90	0.75
S	0.53	0.28	0.12	0.21	0.33	0.20	0.31
Na	0.21	0.08	0.03	0.46	0.56	0.41	0.54
Cl	ND	0.21	0.30	0.43	0.45	0.38	0.45

¹NFC = 100 - (% NDF + % CP + % ether extract + % ash).

²ND = not determined.

³Determined with petroleum ether.

Particle size distribution of the diets (Table 2) indicated similar amounts of material on the top 2 screens of the Penn State Particle Separator. Diets containing DDGS, however, had approximately 3% less on the third screen and 3.8% more material in the bottom pan. Because forage content of diets were identical, differences in the amount of fine material accumulated in the bottom pan must be attributable to greater soyhulls, soybean meal, and steam-flaked corn in diets not containing DDGS. Presumably, the DDGS had finer particle size than the alternative feedstuffs. Though all fractions were within recommendations for TMR for lactating dairy cows (Zebeli et al., 2007), the shift of material from the third screen to the bottom pan represents either more rapidly fermentable feedstuffs or greater rate of passage, depending upon particle density, and has been associated with decreased milk fat concentrations and yields (Grant et al., 1990; Beauchemin et al., 1997; Kononoff et al., 2003; Soita et al., 2005).

Dry matter intakes (Table 4) were similar with or without SC or DDGS in the diet. Body weights and BCS averaged 712.8 ± 16.2 kg and 3.22 ± 0.10 , respectively, were not affected by diet, and increased for all cows as the experiment progressed. Concentrations of VFA in rumen fluid (Table 5) were not influenced by SC in the diets, consistent with the report of Longuski et al. (2008). The inclusion of DDGS, however, decreased the relative concentration and proportion of acetate. The decreased relative proportion of acetate was largely attributable to the inclusion of SC in combination with DDGS ($P < 0.01$ for SC $\times$ DDGS). Conversely, the

concentration of acetate was numerically greatest when SC was included in the diets not containing DDGS. Isobutyrate and isovalerate were increased in diets containing DDGS in the presence of SC. Total concentrations of VFA tended to be decreased in ruminal fluid of cows fed DDGS (82.9 vs. 74.2 mM; $P \leq 0.06$); however, pH of ruminal fluid was not affected by diets. Others have not reported similar changes in acetate concentrations in rumen fluid of cows when fed DDGS; however, decreases in total VFA concentrations in rumen fluid for cows fed DDGS have been reported both numerically (Anderson et al., 2006) and significantly (Kleinschmit et al., 2006).

Milk production (Table 4) increased ($P = 0.05$) with the addition of SC (42.0 vs. 43.6 kg/d) but decreased ($P < 0.05$) when diets contained DDGS (43.6 vs. 41.9). Longuski et al. (2008) also reported increased milk production from cows supplemented with SC in diets containing 21% forage NDF. Though not determined in this study, a recent meta-analysis, which combined research results from both active dry yeast and yeast culture products in dairy cow diets, revealed a consistent increase in milk and FCM yield that was associated with increased OM digestibility (Desnoyers et al., 2009). In contrast to our observed response to DDGS, previous research (Leonardi et al., 2005; Anderson et al., 2006; Kleinschmit et al., 2006) demonstrated a positive response in milk yield with DDGS in diets. Diets in the referenced studies were not isolipidic, however. The negative production response in this experiment may be attributable to balancing fat in DDGS with a ruminally

Table 4. Least squares means for intake, milk yield, and milk composition by dairy cows fed diets containing *Saccharomyces cerevisiae* fermentation product (SC) or no SC (NSC) with dried distillers grains with solubles (DDGS) or without DDGS (NDDGS)

Item	NSC		SC		SEM	Effect ¹ (<i>P</i> -value)		
	NDDGS	DDGS	NDDGS	DDGS		SC	DDGS	SC × DDGS
DMI, kg/d	26.5	25.8	26.0	25.9	0.80	0.74	0.40	0.53
Milk, kg/d	42.5	41.6	44.8	42.3	1.68	0.05	0.04	0.33
Milk fat, %	3.23	3.07	3.21	3.00	0.14	0.64	0.05	0.82
Milk fat, kg/d	1.38	1.26	1.44	1.28	0.08	0.57	0.01	0.70
Milk true protein, %	3.05	3.04	3.02	3.08	0.05	0.76	0.74	0.24
Milk true protein, kg/d	1.29	1.26	1.35	1.30	0.05	0.05	0.14	0.59
Milk urea N, mg/dL	11.2	10.9	10.7	12.4	0.46	0.14	0.03	0.003
FCM, ² kg/d	40.8	38.4	42.7	39.0	1.84	0.30	0.01	0.58
ECM, kg/d	41.1	39.1	43.0	39.7	1.77	0.25	0.02	0.25
ECM/DMI	1.56	1.53	1.66	1.53	0.07	0.24	0.08	0.26
BW, kg	714	710	712	715	16.6	0.78	0.94	0.54
BCS	3.26	3.20	3.23	3.22	0.09	0.88	0.33	0.52

¹SC = effect of *Saccharomyces cerevisiae* fermentation product (NSC vs. SC); DDGS = effect of distillers grains plus solubles (NDDGS vs. DDGS); SC × DDGS = interaction of SC and DDGS.

²3.5% FCM (Perkins, 1937).

inert fat source in the control diets and also possibly by the low amounts of effective fiber from forage, the presence of unsaturated fat, and subsequent effects on rumen fermentation with lesser total VFA produced in rumens of cows fed DDGS in this study (Table 5). This is supported by observed effects on milk fat production and has been documented in other experiments in which distillers grains were fed (Cyriac et al., 2005; Abdelqader et al., 2009).

According to our hypothesis, milk fat concentrations (3.22 vs. 3.04%) and yields (1.41 vs. 1.27 kg/d) decreased ($P < 0.05$) with the inclusion of DDGS (Table 4). This is contrary to other experiments (Anderson et al., 2006; Kleinschmit et al., 2006), although these

studies contained greater than 50% of diet DM as forage and, as previously mentioned, the investigators did not adjust control diets for additional fat content of distillers grains-based diets. Results are similar, however, to those observed when forage fiber is decreased for diets containing distillers grains (Cyriac et al., 2005) or when diets contained similar amounts of forage fiber to that used in this experiment (Leonardi et al., 2005; Abdelqader et al., 2009). Leonardi et al. (2005) reported that milk fat percentage decreased linearly when DDGS were fed at increasing concentrations up to 15% of DM with diets containing 45% forage, the same amount as fed in the current study. Abdelqader et al. (2009) reported decreased milk fat when DDGS was fed at 30%

Table 5. Least squares means for ruminal VFA and pH of rumen fluid from dairy cows fed diets containing *Saccharomyces cerevisiae* fermentation product (SC) or no SC (NSC) with dried distillers grains with solubles (DDGS) or without DDGS (NDDGS)

Item	NSC		SC		SEM	Effect ¹ (<i>P</i> -value)		
	NDDGS	DDGS	NDDGS	DDGS		SC	DDGS	SC × DDGS
pH	6.88	6.90	6.83	6.76	6.90	0.34	0.74	0.62
Relative proportion, g/100 g of VFA								
Acetate	61.1	61.0	62.4	60.1	0.51	0.65	0.006	0.01
Propionate	17.5	18.2	18.1	18.8	0.58	0.11	0.08	0.99
Isobutyrate	3.66	3.45	3.16	3.55	0.14	0.11	0.46	0.02
Butyrate	10.9	10.8	10.4	10.8	0.16	0.18	0.22	0.11
Isovalerate	3.32	3.07	2.81	3.17	0.13	0.08	0.62	0.01
Valerate	3.50	3.33	3.02	3.50	0.12	0.15	0.16	0.006
Concentration, mM								
Acetate	48.8	44.6	52.8	45.0	3.18	0.42	0.03	0.52
Propionate	14.8	13.6	15.9	14.4	1.48	0.40	0.24	0.85
Isobutyrate	2.87	2.46	2.62	2.64	0.12	0.76	0.08	0.05
Butyrate	8.84	7.92	8.88	8.17	0.60	0.78	0.12	0.84
Isovalerate	2.62	2.19	2.32	2.35	0.12	0.55	0.07	0.04
Valerate	2.76	2.41	2.24	1.99	0.12	0.93	0.20	0.04
Total	80.6	73.2	85.1	75.2	5.5	0.48	0.06	0.78

¹SC = effect of *Saccharomyces cerevisiae* fermentation product (NSC vs. SC); DDGS = effect of distillers grains plus solubles (NDDGS vs. DDGS); SC × DDGS = interaction of SC and DDGS.

of diet and 22.7% forage NDF, greater than the 19.3% forage NDF fed in this study. This experiment was designed with minimal amounts of forage fiber to create opportunity for milk fat depression and, furthermore, diets contained lesser amounts of forage fiber than originally formulated. Beauchemin and Yang (2003) recommended a minimum NDF from forage sources of 21 to 23% of diet DM for diets containing barley grain. Diets in this experiment contained total NDF according to NRC (2001) recommendations of about 30%, but forage NDF was less than 20%. Furthermore, increased proportions of material in the bottom pan of the particle separator for diets containing DDGS support conditions leading to milk fat depression (Beauchemin et al., 1997; Kononoff et al., 2003; Soita et al., 2005). Contrary to our hypothesis, however, SC showed little effect on the milk fat depression caused by DDGS. This is contrary to results by Longuski et al. (2008), where SC prevented depression in milk fat during transition to a diet with highly fermentable starch. In the current study, however, milk fat depression was not likely attributable to increased fermentability of diets as evidenced by rumen fermentation data and was more likely attributable to the presence of an unsaturated fat source in the presence of diets with marginal effective fiber. This combination of factors has not been tested when cows were fed SC in previous experiments.

The fatty acid composition of milk fat from cows fed the experimental diets is reported in Table 6. To summarize, SC did not affect the fatty acid composition. Though they reported alleviation of milk fat depression with the addition of SC to highly fermentable diets, Longuski et al. (2008) also failed to demonstrate changes in fatty acid profiles of milk. Similarly, Desnoyers et al. (2009) also failed to note any relationship of yeast products to milk fatty acid profiles, though positive responses of milk fat are common to dietary additions of yeast products (Longuski et al., 2008; Desnoyers et al., 2009). Addition of DDGS, however, decreased the relative proportions (g/100 g of fatty acids) of short- and medium-chain and saturated fatty acids (products of de novo synthesis) and increased concentrations of long-chain, monounsaturated, and polyunsaturated fatty acids. Changes in milk fatty acid composition observed in this study are consistent with known effects of unsaturated fat supplements on de novo synthesized fatty acids in the mammary gland (Palmquist et al., 1993). As others have observed with the inclusion of dietary fat sources containing linoleic acid in dairy cow diets (Griinari et al., 1998; Leonardi et al., 2005; Soita et al., 2005; Abdelqader et al., 2009), concentrations of *trans* isomers of C18:1 as well as conjugates of C18:2 were increased in milk fat of cows fed DDGS. Of particular note were increased concentrations of *trans*-10 C18:1

and *trans*-10,*cis*-12 conjugated linoleic acid, which have been demonstrated to be related to inhibition (*trans*-10 C18:1) and an effective inhibitor (*trans*-10,*cis*-12 conjugated linoleic acid) of mammary gland de novo fatty acid synthesis (Griinari et al., 1998; Baumgard et al., 2000).

Milk protein (Table 4) was not affected by DDGS, indicating that, within the context of milk supported by the diets, AA present for milk protein production did not appear limiting. Though milk protein concentrations were not affected by SC, production of milk protein was increased ($P = 0.05$) by inclusion of SC (1.28 vs. 1.33 kg/d). This increase was proportional to the increase in milk yield observed with SC supporting the adequacy of dietary protein for quantities of milk produced, though a specific milk protein response to yeast culture has not been reported (Desnoyers et al., 2009). Milk urea nitrogen was increased ($P < 0.03$) with DDGS (10.9 vs. 11.6 mg/dL), and the addition of SC amplified this difference (10.9 vs. 12.4 mg/dL for DDGS diets not containing and containing SC, respectively). Though all diets were formulated to contain equal amounts of CP, analysis of the composite samples of the DDGS diet with SC was determined to have a CP content of 18.1% compared with an average of 17.6% for the other diets (Table 2). Analysis of the individual concentrate mixtures did not reflect this difference that would predict the greater protein content in the DDGS-SC diet, and the increased CP analyzed for this diet may be attributable to sampling variance. Given the above, causative effects for increased MUN in the DDGS-SC diet cannot be determined definitively.

Corresponding with decreased milk fat production by DDGS, production of 3.5% FCM and ECM were also decreased ($P < 0.05$) by DDGS (41.8 vs. 38.6 kg/d and 42.0 vs. 39.4 kg/d for FCM and ECM, respectively). Feed efficiency tended also to be decreased ($P = 0.08$) in diets containing DDGS (1.61 vs. 1.53 kg of ECM/kg of DMI). Supplementation of SC increased component-corrected milk production or feed efficiency in earlier research (Schingoethe et al., 2004; Longuski et al., 2008; Desnoyers et al., 2009); however, only numerical responses were observed in the present study.

CONCLUSIONS

In diets containing marginal quantities of forage fiber, DDGS at 20% of diet DM may contribute to milk yield and milk fat depression. The addition of SC improved milk production but, under the defined conditions, was not able to alleviate the milk fat depression. Inclusion of DDGS in lactation diets demands observance of quantities of effective fiber to maintain milk fat production. Inclusion of SC provided a positive milk and milk

Table 6. Least squares means for fatty acids in milk from dairy cows fed diets containing *Saccharomyces cerevisiae* fermentation product (SC) or no SC (NSC) with dried distillers grains with solubles (DDGS) or without DDGS (NDDGS)

Item, ¹ g/100 g of fatty acids	NSC		SC		SEM	Effect ² (<i>P</i> -value)		
	NDDGS	DDGS	NDDGS	DDGS		SC	DDGS	SC × DDGS
C4:0	3.11	3.32	2.87	2.91	0.10	0.26	0.13	0.35
C5:0	0.40	0.46	0.44	0.49	0.05	0.42	0.29	0.85
C6:0	1.90	1.80	1.88	1.75	0.08	0.39	0.01	0.67
C7:0	0.07	0.08	0.10	0.08	0.01	0.21	0.70	0.16
C8:0	1.30	1.20	1.31	1.18	0.06	0.85	<0.001	0.55
C9:0	0.06	0.05	0.06	0.05	0.01	0.71	0.31	0.45
C10:0	3.53	3.17	3.56	3.11	0.17	0.89	<0.001	0.67
C11:1	0.11	0.10	0.12	0.10	0.008	0.74	0.21	0.51
C12:0	4.26	3.82	4.35	3.80	0.18	0.80	<0.001	0.68
C12:1	0.12	0.12	0.14	0.12	0.007	0.28	0.18	0.66
C13:0	0.16	0.16	0.18	0.15	0.02	0.50	0.28	0.35
C14:0	11.5	10.6	11.6	10.4	0.24	0.88	<0.001	0.64
C14:1 <i>cis</i> -9	1.84	1.83	1.97	1.93	0.12	0.13	0.77	0.80
C15:0	0.46	0.45	0.50	0.45	0.03	0.36	0.18	0.34
C16:0	29.3	26.8	29.5	26.5	0.69	0.83	<0.001	0.47
C16:1 <i>cis</i> -9	1.71	1.65	1.80	1.82	0.13	0.15	0.79	0.61
C16:1 <i>iso</i>	0.50	0.45	0.51	0.45	0.01	0.50	<0.001	0.59
C17:0	0.69	0.57	0.72	0.56	0.02	0.49	<0.001	0.11
C18:0	8.91	9.61	8.68	9.32	0.44	0.40	0.03	0.92
C18:1 <i>trans</i> isomers								
<i>trans</i> -6	0.26	0.64	0.25	0.35	0.02	0.88	<0.001	0.30
<i>trans</i> -9	0.24	0.30	0.22	0.32	0.01	0.95	<0.001	0.10
<i>trans</i> -10	0.93	1.34	0.84	1.47	0.20	0.90	<0.001	0.42
<i>trans</i> -11	1.31	1.51	1.11	1.55	0.12	0.42	0.002	0.25
Total <i>trans</i> C18:1	2.75	3.50	2.43	3.69	0.24	0.76	<0.001	0.19
C18:1 <i>cis</i> isomers								
<i>cis</i> -9	20.9	23.2	21.2	23.4	0.76	0.61	<0.001	0.96
<i>cis</i> -11	0.75	0.76	0.72	0.76	0.05	0.69	0.49	0.75
Total <i>cis</i> C18:1	21.7	24.0	21.9	21.2	0.79	0.64	<0.001	0.97
C18:1 total	24.4	27.51	24.3	27.9	0.90	0.79	<0.001	0.64
C18:2 <i>cis</i> -9, <i>cis</i> -12	3.33	4.02	3.10	4.29	0.14	0.84	<0.001	0.009
Conjugated C18:2								
<i>trans</i> -10, <i>cis</i> -12	0.09	0.12	0.09	0.12	0.01	0.94	0.001	0.91
<i>cis</i> -9, <i>trans</i> -11	0.68	0.82	0.62	0.87	0.06	0.79	<0.001	0.23
Unidentified CLA isomers								
1	0.06	0.11	0.06	0.12	0.02	0.99	0.003	0.55
2	0.005	0.010	0.013	0.009	0.005	0.44	0.94	0.38
3	0.033	0.034	0.033	0.028	0.007	0.65	0.76	0.68
CLA total	0.88	1.10	0.81	1.14	0.08	0.86	<0.001	0.38
C18:3 n-6	0.007	0.0004	0.007	0.003	0.004	0.78	0.14	0.64
C18:3 n-3	0.48	0.37	0.45	0.39	0.01	0.69	<0.001	0.07
C19:0	0.23	0.26	0.24	0.29	0.02	0.07	<0.001	0.13
C20:0	0.14	0.14	0.14	0.14	0.005	0.30	0.50	0.98
C20:1	0.11	0.14	0.06	0.17	0.02	0.59	<0.001	0.01
C20:2	0.028	0.024	0.018	0.024	0.005	0.30	0.82	0.26
C20:3 n-6	0.142	0.137	0.148	0.148	0.010	0.11	0.58	0.68
C20:4 n-6	0.23	0.22	0.22	0.23	0.1	0.75	0.84	0.33
C22:1	0.026	0.019	0.001	0.019	0.011	0.27	0.67	0.27
C20:5 n-3	0.006	0.002	0.017	2.3E ⁻¹⁸	0.003	0.21	0.004	0.08
C22:5 n-6	0.018	0.012	0.037	0.019	0.010	0.23	0.25	0.55
SCFA	6.37	6.13	6.35	5.92	0.24	0.37	0.01	0.43
MCFA	21.5	19.8	21.9	19.7	0.53	0.80	<0.001	0.59
LCFA	71.6	73.5	71.2	73.8	0.70	0.91	<0.001	0.51
SFA	65.6	61.8	65.9	60.8	1.1	0.50	<0.001	0.30
MUFA	28.7	31.7	28.8	32.4	1.0	0.50	<0.001	0.56
PUFA	5.15	5.90	4.82	6.25	0.23	0.95	<0.001	0.05

¹CLA = conjugated linoleic acid; SCFA = short-chain fatty acids, C4 through C9; MCFA = medium-chain fatty acids, C10 through C14; LCFA = long-chain fatty acids, C15 through C22; SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids.

²SC = effect of *Saccharomyces cerevisiae* fermentation product (NSC vs. SC); DDGS = effect of distillers grains plus solubles (NDDGS vs. DDGS); SC × DDGS = interaction of SC and DDGS.

protein production response irrespective of the addition of DDGS in dairy cow diets.

ACKNOWLEDGMENTS

We thank all of the employees of the South Dakota State University Dairy Research Facility (Brookings) for administration of this research and care of the cows. This research was partially supported by funding from Diamond V Mills Inc. (Cedar Rapids, IA).

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