Effects of *Saccharomyces cerevisiae* fermentation products on the lactational performance of mid-lactation dairy cows[1]

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ABSTRACT: This study was to evaluate 1 current and 2 newly developed *Saccharomyces cerevisiae* fermentation products (SCFP, Diamond V Original XPC and 2 test products) on the production efficiency of mid-lactation dairy cows. Eighty mid-lactation (164.5 ± 67.5 d in milk: DIM) Holstein cows (56 multiparous and 24 primiparous) were blocked by parity, DIM, and milk production, and randomly assigned to 1 of 4 treatments. Treatments consisted of: 1) Control (CON): corn silage and haylage based ration; 2) XPC: CON ration with Original XPC added at 14 g/d; 3) Product 1 (P1): CON ration with Product 1 added at 5 g/d; and 4) Product 2 (P2): CON ration with Product 2 added at 19 g/d. Treatments were blended with dried distillers grains and then mixed into a total mixed ration at 454 g/d. The first 14 d of the study (d –14 to 0) was for training cows to use the Calan door feeding system and cows were fed the CON ration during this period followed by an 8 wk continuous experimental period. Dry matter intakes were similar ($P > 0.10$) when cows were fed all treatments (25.7, 26.1, 25.1, and 26.2 kg/d for CON, XPC, P1, and P2, respectively). Milk production (33.3, 34.4, 35.5, and 36.8 kg/d) was improved ($P < 0.05$) for cows fed P2 compared to cows fed CON, with cows fed other treatments being intermediate and similar ($P > 0.10$). Feed efficiency (milk yield/dry matter intake) was improved ($P < 0.05$) for cows fed P1 and P2, compared to cows fed CON and XPC (1.30, 1.34, 1.49 and 1.41 kg/kg). Milk fat content was reduced ($P < 0.05$) for cows fed P2 (4.17, 3.93, 4.08, and 3.85%) compared to cows fed CON, with cows fed other treatments being intermediate ($P > 0.10$). Milk protein and lactose percentages were similar ($P > 0.10$) among treatments. Cows fed P2 had reduced ($P < 0.05$) molar proportion of ruminal acetate (63.8, 64.0, 63.1, and 62.3%) and greater ($P < 0.05$) propionate (18.9, 19.3, 19.7, and 20.6%) than cows fed other treatments. Supplementing a dairy ration with SCFP, such as P2, can improve milk production and feed efficiency of mid-lactation cows.

Key words: dairy cow, feed efficiency, milk production, *Saccharomyces cerevisiae* fermentation products

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INTRODUCTION

Feeding a *Saccharomyces cerevisiae* fermentation product (SCFP), to mid lactation dairy cows has been reported to improve feed efficiency (Schingoethe et al., 2004). Manipulating the rumen environment to enhance those microbes that are desirable for improved fiber digestion, lactic acid utilization, ensuring a stabilized anaerobic ruminal environment, and maintaining ruminal pH are paramount for efficient lactational performance. Many studies evaluating SCFP have reported improved

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rumen stability and increased milk production (Poppy et al., 2012), increased rumen pH and VFA concentrations, and decreased lactic acid concentrations (Erasmus et al., 1992; Piva et al., 1993). The soluble unidentified growth factors in SCFP have been shown to stimulate growth of pure ruminal bacteria cultures to enhance cellulose digestion and lactate utilization in vitro (Callaway and Martin, 1997) and the mechanisms of action has been studied extensively (Arakaki et al., 2000; Callaway and Martin, 1997; Dann et al., 2000; Hristov et al., 2010; Mao et al., 2013; Nisbet and Martin, 1991; Yoon and Stern, 1996). In addition, SCFP tended to increase ruminal amylase concentrations (Hristov et al., 2010) and increased ruminal starch digestibility, which may improve milk production in certain feeding situations. The hypothesis was that feeding a dairy ration supplemented with SCFP products containing elevated levels of functional metabolites and bioactive compounds can improve milk production and feed efficiency of mid-lactation cows compared to cows fed a control or commercially available *Saccharomyces cerevisiae* yeast culture (Diamond V Original XPC) diets. The study objective was to evaluate the effect of 1 existing and 2 newly developed SCFP (Diamond V Original XPC and 2 test products) on the milk production efficiency of mid-lactation dairy cows.

MATERIALS AND METHODS

This study was conducted at the South Dakota State University-Dairy Research and Training Facility from February 3, 2014 to June 29, 2014 under approval by the South Dakota State University Animal Care and Use Committee. Eighty (40 cows each in period 1 and 2) mid-lactation [164.5 d in milk (DIM) ± 67.5] Holstein cows (56 multiparous and 24 primiparous) were blocked by parity, DIM, and milk production and randomly assigned to 1 of 4 treatments. The experimental total mixed ration (TMR) were 1) Control (CON): a standard corn silage and alfalfa haylage; 2) XPC: CON TMR with Original XPC added at 14 g/d; 3) Product 1 (P1): CON TMR with an experimental SCFP product (Not marketed; Diamond V, Cedar Rapids, IA) added at 5 g/d; and 4) Product 2 (P2): CON TMR with an experimental SCFP product (NutriTek, Diamond V, Cedar Rapids, IA) added at 19 g/d. The CON received only 454 g/d of dried distiller's grains, while the experimental treatments were blended with dried distiller's grains and mixed into a TMR at 454 g/d. The 2 new proprietary products (Diamond V, Cedar Rapids, IA) have been developed with elevated levels of unique functional metabolites and bioactive compounds. Fermentation substrates, process, and proprietary metabolite concentrations differ between these products. Titration work with both products in previous studies using early lactation cows (I. Yoon, unpublished data) demonstrated improved milk production over XPC and the feeding rates used for this follow up study were determined from the titration studies. The ingredient composition of the CON TMR is given in Table 1. The TMR consisted of (DM basis) 33.0% corn silage, 22.0% alfalfa haylage, and 45.0% concentrate mix. The nutrient composition of the forages, grain mix, and the basal TMR are given in Table 2. Rations were formulated to meet or exceed the nutrient requirements of a 700 kg body weight mature Holstein dairy cow producing 38.5 kg milk having a 3.70% milk fat and 3.10% milk protein consuming a DMI of 24.0 kg/d (NRC, 2001).

The first 14 d of the 70 d experimental period (d –14 to 0) was intended for training cows to use the Calan feeding door system. During this time period all cows were fed the CON ration. Cows were switched to their respective experimental treatment rations continuously for the next 8 wk. Recombinant bovine somatotropin (rbST; Posilac, Elanco, Greenfield, IN) was administered every 2 wk during the study period. Due to facility limitations, this study was conducted in 2 time periods of 40 cows each time period. There was a 1 wk break between the end of period 1 and the start of period 2, and there was also a forage adjustment/change between time periods.

Table 1. Ingredient composition of the basal or control ration[1,2]

Ingredients	% of DM
Corn silage	33.02
Alfalfa haylage	22.00
Corn grain, ground fine	17.92
Cottonseed, fuzzy	5.21
Soybean meal (47.5% CP)	7.64
Soy Best PEARL[3]	3.38
Corn distillers grain	5.60
Blood meal, ring dried	0.38
Soybean hulls, ground	1.32
Energy Booster 100[4]	0.57
Calcium carbonate	0.96
Salt, white	0.47
Sodium bicarbonate	0.57
Magnesium oxide	0.19
Urea (281% CP)	0.09
Vitamin trace mineral premix[5]	0.21
Vitamin premix E (44,000 IU/kg)	0.06
Fat, animal veg blend	0.47

[1]The TMR had a forage-to-concentrate ratio of 55:45 (DM basis) with the forage ratio containing 60% corn silage and 40% alfalfa haylage.

[2]The TMR ration was formulated using Agricultural Modeling and Training Systems software (Agricultural Modeling and Training Systems, Groton, NY).

[3]Grain States Soya, West Point, NE.

[4]Milk Specialties Global, Eden Prairie, MN.

[5]Vitamin A, 3,740,000 IU/kg; vitamin D3, 935,000 IU/kg; vitamin E, 12,155 IU/kg; menadione, 18.7 mg/kg; choline, 622.6 mg/kg; iron, 0.49%; zinc, 3.49%; manganese, 3.48%; copper, 7,507 mg/kg; iodine, 499 mg/kg; cobalt, 327 mg/kg; selenium, 165 mg/kg.

Table 2. Nutrient composition (% of DM unless otherwise noted) of corn silage, alfalfa haylage, and TMR

	Feed ingredient[1]				
Nutrient	Grain mix	Corn silage	Alfalfa haylage first crop (Bunker)	Alfalfa haylage fourth crop (Bag)	TMR
DM, %	87.5	33.7	25.5	62.7	46.1
CP	24.3	7.8	15.8	24.7	19.3
SP, % CP	25.1	58.8	38.0	47.3	40.2
NH3-N, % CP	—	9.5	79.0	6.1	—
Fat	7.34	2.93	3.74	1.89	4.8
NDF	15.6	41.9	45.1	32.8	29.6
ADF	10.7	24.7	35.5	24.7	19.7
Starch	31.8	32.3	—	—	23.7
Ash	7.55	4.25	12.4	8.58	7.52
Ca	1.12	0.21	1.97	1.57	1.01
P	0.44	0.21	0.38	0.33	0.37
Mg	0.46	0.17	0.40	0.40	0.37
K	1.08	0.76	3.20	2.17	1.48
Na	0.75	0.03	0.11	0.13	0.35
Cl	0.64	0.13	0.84	0.40	0.55
S	0.24	0.05	0.24	0.33	0.22
Lactic acid	—-	4.74	0.87	3.06	—-
Butyric acid	—-	0.00	4.49	0.00	—-
IVDMD	—-	72.7	61.1	78.5	83.3
NDFd, 30 h		49.6	27.1	55.6	64.2
NEL, Mcal/kg (Calc.)	—-	—-	—-	—-	1.75

[1]The TMR had a forage-to-concentrate ratio of 55:45 (DM basis) with the ratio of forages being 60% Corn silage and 40% Alfalfa haylage (DM basis).

In time period 1, all of the alfalfa haylage was sourced from a first cutting alfalfa haylage bunker. In time period 2, the alfalfa haylage was sourced on a 50/50 DM basis between the bunker and an Ag Bag of fourth cutting alfalfa haylage. Cows were fed once daily at 0700 h using a Calan Super Data Ranger (American Calan, Inc., Northwood, NH) where all forages, grain mixes and treatments were mixed for a minimum of 5 min prior to experimental TMR delivery. Feed intake was measured daily. Amount of feed offered was adjusted daily to achieve 10% refusals (orts), which were collected daily and weighed prior to feeding fresh experimental TMR.

Cows were milked 3 times daily (0600, 1400, and 2100 h) and the amounts were recorded electronically (DeLaval-ALPRO, Kansas City, MO) at each milking. Individual milk samples were collected at each milking once per week. Milk samples were composited by day on a milk weight basis and frozen at –20°C for future analysis. Another set of individual milk samples were sent to Dairy Herd Improvement Association Heart of America (Manhattan, KS) for analysis of fat, protein, lactose, MUN, and SCC as described by AOAC (Association of Official Analytical Chemists International, 2002). Milk urea nitrogen concentrations were measured using a modified Berthelot reaction (ChemSpec 150 Analyzer, Bentley Instruments, Chaska, MN), while near infrared spectroscopy (Bentley 2000 Infrared Milk Analyzer, Bentley Instruments, Chaska, MN) was used to analyze milk concentrations of fat, protein, and lactose. Somatic cell counts were determined using a flow cytometer laser (Somacount 500, Bentley Instruments). Somatic cell counts were converted to a log $base_{10}$ SCC. Fat-corrected milk (3.5%) was calculated by the equation: (0.432 × kg milk) + (16.216 × kg fat) and ECM was calculate by the equation: (0.327 × kg milk) + (12.95 × kg fat) + (7.65 × kg protein) as described by Orth (1992).

On a weekly basis, DM content of forages, grain mix, and TMR were determined by drying feed samples in a 105°C oven (Despatch LEBI-75, Despatch Industries, Minneapolis, MN) for 24 h and feed sheets adjusted accordingly. Feed samples (forages, grain mix, experimental treatment mixes and TMR) were collected weekly and composited by month and sent to Analab (Fulton, IL) for laboratory nutrients analyses (Table 2). Samples were analyzed using AOAC (Association of Official Analytical Chemists International, 1998) methods as: DM (935.29), ADF (973.18), CP (990.03), NDF (2002.04), ADIN (973.18 and 976.06), neutral detergent insoluble protein (2002.04 without sulfite and 976.06), lignin (973.18), ash (942.05), Na (985.01), Cl (915.01), Ca (985.01), P (985.01), Mg (985.01), S (923.01), Fe (985.01), Cu (985.01), Zn (985.01), K (985.01), Mn (985.01), and pH (981.12). The following methods were utilized to measure the remaining nutrients: starch (Glucose Reagent Set, AMRESCO, Solon, OH and ALPKEM Corporation, 1990), soluble protein (Krishnamoorthy et al., 1982), oil/fat (Damon, 1966), NH_3–N (United States Environmental Protection Agency, 1993, method 351.2 and International Organization for Standardization, 2013, method 11732), NDF digestibility (NDFd; Van Soest et al., 1991), incubated for 30 h using the Kansas State Buffer (Marten and Barnes, 1980), in vitro dry matter digestibility (24 h ruminal and 24 h enzymatic digestion using the Kansas State Buffer (Marten and Barnes, 1980), lactic acid (El Rassi, 1996), acetic acid (Cancalon, 1993), NFC (NRC, 2001), NE_L (NRC, 2001), relative forage quality (Rohweder et al., 1978), and sugar (Analab, Fulton, IL defined method, in process of entering a Single Laboratory Validation from the Association of American Feed Control Officials).

Body weight and BCS were collected each week, 3 h after feeding. Three graduate students scored body condition independently based on the score system of 1 to 5. Score 1 was considered to be emaciated and 5 to be obese (Wildman et al., 1982). Body weights were measured using an electronic scale designed for animals (model AWB-5K-SYS, Triner Scale and Manufacturing Company, Inc., Olive Branch, MS).

During wk 4 and 8 of each experimental time period, 1 rumen fluid sample was collected via esophageal

tube aspiration from each cow 2 to 4 h after feeding. The esophageal tube was coated with lubricant (Wal-Mart Stores, Inc. Bentonville, AR) to reduce the risk of irritation of the esophagus and attached to a hand-operated pump. The first 100 mL of rumen fluid was discarded to minimize saliva contamination. After collection, rumen fluid was mixed thoroughly and pH was measured using an electronic pH meter (Corning 350, Corning Inc., Corning, NY). If the rumen fluid collected was at a pH > 7.0, rumen fluid was discarded and additional rumen fluid was collected to ensure minimal saliva contamination. Two 10-mL rumen fluid samples were collected, where one 10-mL sample was added to a vial containing 200 μL of 50% (vol/vol) H_2SO_4, mixed, and frozen at –20°C, and later analyzed for NH_3–N concentrations following the procedures of Chaney and Marbach (1962). The other 10-mL sample of rumen fluid was mixed with 2 mL of 25% (wt/vol) meta-phosphoric acid, mixed, and frozen at –20°C for later analysis of VFA concentrations using an automated gas-liquid chromatograph (model 6890, Hewlett-Packard) having a flame-ionization detector. Before analyzing for VFA, samples were processed according to the procedures of Erwin et al. (1961). Rumen fluid samples were thawed and centrifuged at 30,000 × *g* for 20 min at 20°C (Eppendorf 5403, Eppendorf North America, Hauppauge, NY) before laboratory analyses were conducted.

During wk 4 and 8 of each experimental time period at the same time as rumen sampling, cows were secured for collection of two 10-mL mammary vein blood samples and two 10-mL tail vein blood samples, 2 to 3 h after feeding, via Vacutainer tubes containing K_2–EDTA (Becton Dickinson Vacutainer Systems, Rutherford, NJ). One 6-mL tail vein blood sample was collected using a Vacutainer tube containing sodium fluoride (Beckton Dickinson Vacutainer Systems, Rutherford, NJ). Blood samples were centrifuged at 2,000 × *g* for 20 min at 5°C (CR412 centrifuge; Jouan Inc., Winchester, VA) to obtain plasma, which was stored frozen at –20°C for later analysis. Blood plasma was analyzed for glucose [Liquid Glucose (Oxidase) Reagent Set; Pointe Scientific, Inc., Canton, MI], NEFA [HR Series NEFA-HR(2) Microtiter Procedure, Wako Diagnostics, Richmond, VA] and Plasma Urea Nitrogen (PUN;Urea nitrogen direct test, Stanbio laboratory, Boerne, TX).

Statistical Analysis

All data were subjected to least squares ANOVA using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC; version 9.4) as a replicated randomized complete block design. The statistical model used was: $Y_{ijkl} = \mu + T_i + B_j + Rep_l(B_j) + TM_k + (T_i \times TM_k) + e_{ijkl}$, where Y_{ijkl} = dependent variable, μ = overall mean, T_i = treatment effect, B_j = Block or time period effect, $Rep_l(B_j)$ = replication nested within block, TM_k = week, and $(T_i \times TM_k)$ = treatment by week interactions, and e_{ijkl} = random error. Block and replication (block) were considered to be random, while all other variation sources were considered fixed. Experimental wk was considered a repeated measurement in time having an autoregressive covariance structure. Data are presented as Least Squares Means and significant difference was declared at $P < 0.05$ and trends at $P < 0.10$.

RESULTS AND DISCUSSION

Feed Analysis

The analyzed nutrient composition of the grain mix, corn silage, alfalfa haylage bunker and bag, and the TMR are given in Table 2. The nutrient composition of the grain mix met or exceeded formulation specifications. The corn silage nutrient composition would be typical of corn silage grown in the upper Midwest (NRC, 2001). The nutrient composition of the alfalfa haylage differed between the first cutting and the fourth cutting (discussed later). The TMR nutrient composition exceeded CP formulation specifications due to differences in alfalfa haylage CP concentrations. The ration was formulated using AMTS software (Agricultural Modeling and Training Systems, Groton, NY) to contain 17.2% CP, 1.72 Mcal/kg NE_L, 32.1% NDF, 20.6% ADF, and 41.5% NFC on a DM basis. Other nutrient parameters met or exceeded NRC (2001) nutrient guidelines for lactating dairy cows in mid-lactation (Table 2).

Milk Production, Composition, and Quality

Milk production (Table 3) was improved ($P < 0.05$) for cows fed P2 compared to cows fed CON, with cows fed remaining treatments (XPC and P1) being intermediate and similar. Cows fed CON, XPC, and P1 were similar ($P > 0.10$) in milk production. Feeding P2 to lactating dairy cows increased milk production approximately 10.5% when compared to cows fed the CON treatment. These results support previous studies (Ramsing et al., 2009; Hippen et al., 2010; and Zaworski et al., 2014) demonstrating improved milk production for cows fed SCFP. In the meta-analysis reported by Poppy et al. (2012), milk yield increased 1.18 kg/d when cows were fed SCFP. Similarly, SCFP supplementation increased 3.5% FCM by 1.61 kg/d.

Lower milk production was observed for cows during time period (block) 1 (32.4 kg/d) compared to the milk production by cows in time period (block) 2 (37.6 kg/d). The reason(s) for the lower milk production during time period (block) 1 can be attributed to

Table 3. Milk production and composition by mid-lactation dairy cows fed *Saccharomyces cerevisiae* fermentation products

	Treatment[1]				
Parameter	CON	XPC	P1	P2	SE
Milk, kg/d	33.3[a]	34.4[ab]	35.5[ab]	36.8[b]	2.38
4% FCM[2], kg/d	34.1	34.0	35.7	35.6	2.35
3.5% FCM[2], kg/d	36.8	36.8	38.6	38.4	2.53
ECM[3], kg/d	36.5	36.4	38.3	38.2	2.42
Milk Components					
Fat, %	4.17[a]	3.94[ab]	4.08[ab]	3.85[b]	0.11
Protein, %	3.22	3.12	3.20	3.12	0.06
Lactose, %	4.88	4.90	4.94	4.91	0.08
SNF, %	9.05	8.96	9.09	8.98	0.08
Total Solids, %	13.22	12.90	13.18	12.84	0.15
Component yields					
Fat, kg/d	1.38	1.35	1.44	1.39	0.09
Protein, kg/d	1.07	1.07	1.13	1.14	0.06
Lactose, kg/d	1.64[a]	1.69[ab]	1.76[ab]	1.82[b]	0.14
SNF, kg/d	3.02	3.08	3.23	3.3	0.22
Total Solids, kg/d	4.41	4.44	4.66	4.69	0.32
Milk quality					
MUN, mg/dl	16.0	16.4	16.2	16.3	1.16
SCC, $\log_{10}$	5.0	4.8	4.9	5.1	0.18

[a,b]Means within a row with different superscripts, differ ($P < 0.05$).

[1]CON = Control diet; XPC = Original XPC (SCFP), Diamond V, Cedar Rapids, IA; P1 = Product 1 (SCFP), Diamond V, Cedar Rapids, IA; P2 = Product 2 (SCFP), Diamond V, Cedar Rapids, IA.

[2]4% Fat-corrected-milk = (0.4 × milk kg) + (15.0 × kg fat); 3.5% FCM was determined using the following equation: (0.432 × kg milk) + (16.216 × kg fat) as described by Orth (1992).

[3]ECM was determined using the following equation: (0.327 × kg milk) + (12.95 × kg fat) + (7.65 × kg protein) as described by Orth (1992).

the alfalfa haylage bunker quality. The alfalfa haylage used in time period (block) 1 was very high in moisture, butyric acid and ammonia concentrations, which are indicative of a poor fermentation (Table 2). During time period (block) 2, better quality alfalfa haylage stored in a bag was available and 50/50 mixture of bunker and bag alfalfa haylage were used. The adjustment in sources of alfalfa haylage increased CP concentrations, but reduced ration ammonia-nitrogen concentrations in time period (block) 2 TMR compared to time period (block) 1 that could have an impact on cow responses. An additional explanation is that lactating dairy cows average 198 ± 62 DIM in time period (block) 1 compared to 153 ± 51 DIM for experimental cows in time period (block) 2, therefore a reduction in DIM would have an impact on milk yield (Table 3).

Milk fat percentages were reduced ($P < 0.05$) for cows fed P2 compared to cows fed CON, with cows fed other treatments being intermediate (Table 3). Although milk fat percentages were quite high for mid- to late-lactation dairy cows, the high milk fat percentages may be partially attributed to the high butyric acid concentrations observed in the alfalfa haylage bunker. The milk fat percentage differences results in similar ($P > 0.10$) production of 4% and 3.5% FCM for cows fed all treatments. Percentages of milk protein and lactose were similar ($P \geq 0.10$) among cows fed all treatments. Previous studies have reported similar milk components for lactating dairy cows fed SCFP compared to cows fed control rations (Ramsing et al., 2009; Schingoethe et al., 2004; and Zaworski et al., 2014).

Dry Matter Intake, Feed Efficiency, Body Weight, and Body Condition Scores

Dry matter intakes, body weights, and body condition scores were similar ($P > 0.10$) among cows fed all treatments (Table 4). Body weight gains were observed to be greater ($P < 0.05$) for cows fed P1 compared to cows fed P2, with the remaining treatments being intermediate and similar, while the lost in BCS were similar among cows fed all the treatments. Feed efficiency, denoted by Milk/DMI, was greater ($P < 0.05$) for cows fed P1 compared to cows fed CON and XPC. Cows fed P2 was tending ($P < 0.08$) to being greater than cows fed CON and XPC but similar ($P > 0.10$) to cows fed P1. Feed efficiency, denoted by ECM/DMI, was greater ($P < 0.05$) for cows fed P1 compared to cows fed the other treatments. Previous studies (Allen and Ying, 2012; Schingoethe et al., 2004) have reported incorporating SCFP in the rations of mid-lactation cows resulted in similar DMI, which is consistent with these data. In contrast, DMI increased in response to the addition of SCFP in studies (Erasmus et al., 1992; Dann et al., 2000) with early lactation cows. The effect of SCFP on DMI depends on the stage of lactation of cows (Poppy et al., 2012).

Schingoethe et al. (2004) reported similar BW and BCS when cows were fed a SCFP, which is in agree-

Table 4. Dry matter intake (DMI), feed efficiency, body weight (BW), BW gain, body condition score (BCS), and BCS gains by mid-lactation dairy cows fed *Saccharomyces cerevisiae* fermentation products.

	Treatment[1]				
Parameter	CON	XPC	P1	P2	SE
DMI, kg/d	25.7	26.1	25.1	26.2	0.87
Milk/DMI	1.30[b]	1.34[b]	1.49[a]	1.41[ab]	0.08
ECM/DMI	1.43[b]	1.42[b]	1.61[a]	1.47[b]	0.08
BW, kg	700.1	718.2	702.5	706.0	1.18
BW gain, kg/d	1.12[ab]	1.21[ab]	1.33[a]	1.06[b]	0.71
BCS	3.09	3.09	3.08	3.07	0.07
BCS gain, kg/d	-0.11	-0.05	-0.09	-0.09	0.11

[a,b]Means within a row with different superscripts, differ ($P < 0.05$).

[1]CON = Control diet; XPC = Original XPC (SCFP), Diamond V, Cedar Rapids, IA; P1 = Product 1 (SCFP), Diamond V, Cedar Rapids, IA; P2 = Product 2 (SCFP), Diamond V, Cedar Rapids, IA.

ment with these data. Similarly, adding SCFP alone or in combination with DDGS did not affect BW and BCS in multiparous Holstein cows (Hippen et al., 2010). Feed efficiency, when calculated from the production of FCM and energy-corrected milk (ECM) per kilogram of feed consumed, was higher ($P < 0.05$) when a SCFP was fed to mid-lactation Holstein cows in summer (Schingoethe et al., 2004), which is in agreement with these data (Table 4), which were collected during the warmer time [time point (block) 2 average high daily temperature of 19.4 and 25°C during May and June 2014, respectively; US Climate data, 2015]. The meta-analysis reported by Poppy et al. (2012) demonstrated that when cows were fed SCFP during early lactation (< 70 DIM), DMI was increased by 0.62 kg/d (95% CI: 0.21 to 1.02, $P = 0.003$), while it was decreased in the late lactation studies by 0.78 kg/d (95% CI: –1.36 to –0.21; $P = 0.001$). The additional DMI in early lactation appears to generally support additional production (Poppy et al., 2012) and reduced tissue mobilization (Dann et al., 2000). In later lactation cows, the reduction in DMI and concurrent increase in milk production (Poppy et al., 2012) can result in an improvement in production efficiency and income over feed costs.

Rumen Fluid and Blood Analyses

The molar concentrations of ruminal acetate were lower ($P < 0.05$) for cows fed P2, while the ruminal molar concentrations of propionate were higher ($P < 0.05$; Table 5) compared to cows fed the CON, with the remaining treatments being intermediate. Similarly, plasma urea nitrogen (Table 6) and rumen ammonia nitrogen (Table 5) concentrations were greater ($P < 0.05$) for cows fed P1 and P2 compared to cows fed CON and XPC treatments. Ruminal concentrations of propionate were reported to be greater when SCFP was fed (Harrison et al., 1988; Kwan et al., 2016; and Yoon et al., 1997). In addition, Callaway and Martin (1997) and Brainard et al. (2016) reported that SCFP stimulated the growth of ruminal bacteria that utilize lactic acid, thereby increasing ruminal propionate production. The increases in ruminal propionate concentrations would aid in increasing milk yields, which was observed (Table 3) by increasing glucose supply. These explanations are further supported by Yoon and Stern (1996) and Miller-Webster et al. (2002), who reported that SCFP improves ruminal DM and protein digestibility, leading to higher concentrations of propionate or ammonia, or both (Harrison et al., 1988; Miller-Webster et al., 2002; and Erasmus et al., 2005). In a study by Mao et al. (2013) different low quality forage sources were evaluated in an in vitro study to determine the impact of SCFP. The molar concentrations of acetate decreased, while molar concentrations of propionate linearly increased ($P < 0.01$) with increasing inclusion rates of SCFP for rice straw, corn silage and corn silage with grain substrates. The increase in molar concentrations of propionate for cows fed P2 diets explains the increased lactose yield (Table 3), which supports the increase in milk production for those cows compared to cows fed the remaining treatments.

Enhancing ruminal fiber digesting bacteria (Brainard et al., 2016) and shifting the ruminal fermentation to promote propionate production (Table 5 and Kwan et al., 2016) would explain the milk yield increase when feeding a ration containing SCFP. The ration energy density may be the most important factor affecting feed efficiency by lactating dairy cows, and the nutrient digestibility of the ration is the greatest factor determining its energy density. *Saccharomyces cerevisiae* fermentation product, which contains numerous beneficial components, has been shown (Gomez-Alarcon et al., 1990; Schingoethe et al., 2004) to enhance nutrient digestibility and feed efficiency by lactating dairy cows

Table 5. Ruminal ammonia and volatile fatty acids (VFA) by mid-lactation dairy cows fed *Saccharomyces cerevisiae* fermentation products collected via esophageal tubing

	Treatment[1]				
Parameter	CON	XPC	P1	P2	SE
Ammonia-N, mg/dl	18.0^{ab}	16.8^{b}	19.5^{a}	19.6^{a}	1.19
Rumen pH	6.43	6.40	6.35	6.32	0.05
VFA, mM					
Total	88.7^{b}	89.0^{b}	96.0^{a}	94.0^{ab}	2.33
VFA, molar %					
Acetate	63.8^{ab}	64.0^{a}	63.1^{bc}	62.3^{c}	0.39
Propionate	18.9^{b}	19.3^{b}	19.7^{ab}	20.6^{a}	0.32
Isobutyrate	1.34^{a}	1.29^{b}	1.37^{a}	1.32^{ab}	0.02
Butyrate	13.0	12.7	13.0	12.9	0.16
Isovalerate	1.28^{ab}	1.22^{b}	1.31^{a}	1.27^{ab}	0.03
Valerate	1.60	1.54	1.62	1.61	0.03
Acetate/Propionate	3.42^{a}	3.34^{a}	3.26^{ab}	3.11^{b}	0.07

$^{a–c}$Means within a row with different superscripts, differ ($P < 0.05$).

[1]CON = Control diet; XPC = Original XPC (SCFP), Diamond V, Cedar Rapids, IA; P1 = Product 1 (SCFP), Diamond V, Cedar Rapids, IA; P2 = Product 2 (SCFP), Diamond V, Cedar Rapids, IA.

Table 6. Blood glucose, urea nitrogen and non-esterified free fatty acids (NEFA) for mid-lactation dairy cows fed *Saccharomyces cerevisiae* fermentation products

	Treatment[1]				
Parameter	CON	XPC	P1	P2	SE
Glucose, mg/dl	73.7	74.8	71.4	72.9	1.78
Plasma Urea N, mg/dl	20.4^{b}	20.3^{b}	22.0^{a}	22.6^{a}	0.92
NEFA, meq/L	0.114	0.122	0.139	0.142	0.013

^{a,b}Means within a row with different superscripts, differ ($P < 0.05$).

[1]CON = Control diet; XPC = Original XPC (SCFP), Diamond V, Cedar Rapids, IA; P1 = Product 1 (SCFP), Diamond V, Cedar Rapids, IA; P2 = Product 2 (SCFP), Diamond V, Cedar Rapids, IA.

thereby liberating more digestible nutrients and energy per unit DMI for milk production.

Plasma glucose and NEFA were similar ($P > 0.10$) for cows fed all treatments (Table 6).

Conclusions

Feeding a SCFP product with additional functional metabolites and bioactive compounds, increased milk production approximately 10.5% compared to cows fed the CON treatment. However, production of 4% and 3.5% FCM were similar due to changes in milk fat percentages. Dry matter intakes were similar for cows fed all treatments, so the increase in milk production resulted in enhanced feed efficiency for cows fed P1 and tending to increase for cows fed P2. Our data and the literature have shown that feeding a SCFP can decrease ruminal acetate and increase ruminal propionate concentrations, which would explain the increase in milk yield and lactose production when feeding a ration containing SCFP. In conclusion, incorporation of SCFP (P2; NutriTek) to a dairy ration can improve milk production and feed efficiency of mid-lactation cows.

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