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Effect of Yeast Culture on Efficiency of Nutrient Utilization for Milk Production and Impact on Fiber Digestibility and Fecal Particle Size

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ABSTRACT

Approximately 260 Holstein cows on a commercial dairy were utilized in a switchback study. Treatments consisted of control or 56 g/d of yeast culture. The objectives of this experiment were to quantify the benefit of yeast culture on 1) efficiency of milk production, and 2) nutrient flows within the dairy system that utilizes a solids separator. Milk yield was recorded every 12 d. Pen feed intakes and refusals were recorded daily. Manure fiber particle size was determined from fecal grab samples via wet sieving. In addition, a mixture of feces plus water was sieved through a screen to replicate a manure solids separator. Cows receiving yeast culture showed numerically greater DMI (0.13 kg/d), an increase ($P < 0.001$) in BW gain, greater milk fat content ($P < 0.02$), greater ($P < 0.08$) milk fat yield, less milk protein content ($P < 0.03$), and similar milk protein yield ($P > 0.05$). Milk yields were similar between treatments; however, there was a trend for an increase ($P < 0.19$) in 3.5% fat corrected milk for cows fed yeast culture. Control cows had numerically lower NDF digestibility. Distribution of fecal particles suggests more manure solids may pass the manure solids separator to the manure lagoon and therefore reduce the amount of manure solids collected with the separator. Yeast culture was shown to impact nutrient use by the animal and affect manure particle partition.

Key words: yeast culture, milk production, nutrient utilization, fecal particle size

INTRODUCTION

Dairy farms use the manure produced on the farm as fertilizer for crops. Application of manure is based on N and P concentrations of the manure and the crops' requirements for these nutrients. If requirements are met with manure application and there is excess manure, it must be either applied above the requirement or removed from the farm. If the manure is over-applied, nutrient run-off into surface waters or leaching into ground waters may occur, causing an adverse environmental impact such as eutrophication. Removing manure from the farm can be economically unfavorable due to the high concentration of water. A solid form of manure is a more economically favorable way to transport nutrients off the farm.

Solid separation of dairy manure is an effective practice of removing solids and nutrients from the effluent (Chastain et al., 2001). The remaining liquid will subsequently have a decreased amount of nutrients such as N and P. The solids portion can be removed from the farm boundaries as a way to decrease nutrient application to the farm fields. An increase in diet digestibility can result in a decrease in nutrient and solid content of manure. Previous field study research has shown feeding yeast culture reduces undigested feed particles in manure (Belknap and Yoon, 2001).

Feeding yeast culture can increase feed efficiency and net return of lactating dairy cattle. Schingoethe et al. (2004) observed a 7% increase in feed efficiency (kg of energy-corrected milk/kg of DMI) when yeast culture was fed to midlactation cows during heat stress. Diet DM, hemicellulose, and CP digestibility increased when a yeast culture was supplemented (Wiedmeier et al., 1987). Shaver and Garrett (1997) calculated a net return of \$0.13/d per cow when feeding yeast culture to commercial dairy herds. The objectives of this experi-

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ment were to quantify the benefit of yeast culture in a dairy ration on 1) efficiency of milk production, and 2) nutrient flows within the dairy system that utilizes a solids separator.

MATERIALS AND METHODS

Animals

Approximately 260 Holstein cows were utilized in a 96-d lactation switchback designed study. The study was conducted on a commercial dairy farm in western Washington and consisted of 40- and 49-d periods. The Washington State University Animal Care and Use Committee approved the experimental protocol. Cows were blocked and assigned to treatments based on the following criteria: >30 DIM, milk production, parity, pregnancy, and BW. Treatments consisted of control (no supplemental yeast culture) or 56 g/d of yeast culture (Diamond V XP Yeast Culture, Diamond V Mills, Cedar Rapids, IA). Average pen DIM for control and treatment groups were 179 and 191, respectively, at the beginning of trial. Cows were milked 3 times a day. Cows removed from pens for health reasons were excluded from the study. Therefore, only 222 cows completed the study (111 cows per pen).

Diets

All diets were fed as a TMR, mixed using a Loewen mixer (Matsqui, British Columbia, Canada), and loaded per manufacturer's recommendations. Diets were balanced at or above National Research Council's recommendations for high-producing Holstein cows in midlactation by a consulting nutritionist (NRC, 2001). The basal diet TMR consisted of soybean meal, steam rolled corn, cull raw potatoes, canola meal, whole cottonseed, corn silage, alfalfa hay, and vitamin-mineral mix (Table 1). Yeast culture was incorporated into a premix (56 g XP yeast culture in 140 g premix) containing ground corn, mill run, and soybean meal that was mixed into the TMR at a rate of 56 g yeast/d per cow. The control diet was TMR plus 140 g/d of the carrier grains alone.

Table 1. Diet composition (% as fed) of basal diet

Item	% as fed
Corn silage	54.0
Alfalfa hay	11.8
Steam rolled corn	10.7
Potatoes	5.1
Canola meal	4.6
Soybean meal	3.9
Whole cotton seed	3.0
Beet pulp	1.8
Corn distiller's grains	1.2
Molasses	0.9
Limestone	0.8
Flour waste	0.6
Ground corn	0.6
Buffer	0.40
Salt	0.21
MgO	0.13
Urea	0.07
Vitamin and trace mineral mix[1]	0.04
Rumensin	0.0033

[1]Trace mineral mix contained 15.41% Ca, 0.04% P, 0.13% Mg, 0.11% K, 3.38% S, 0.05% Na, 0.2% Cl.

Measurements

Milk yield was recorded every 12 d by Dairy Herd Improvement personnel (Burlington, WA), and 24-h composite milk samples were collected from 3 milkings for fat and protein analyses. Pen feed intakes and refusals were recorded daily. Feed was sampled weekly for nutrient analysis of acid AIA, CP, NDF, ADF, ADL, Ca, P, and K (Dairyland Laboratories, Arcadia, WI; Table 2). Body weights were recorded at the beginning and end of each period. Fecal grab samples of approximately 200 g and urine samples of approximately 200 mL were collected twice during the last 2 wk of each period from 20 to 25 cows per treatment. Samples were pooled for chemical analysis (Dairyland Laboratories, Arcadia, WI). Fecal samples were analyzed for AIA, CP, NDF, ADF, ADL, Ca, P, and K. Urine samples were analyzed for Na, K, Cl, total N, ammonia N, and creatinine.

Manure fiber particle size was determined via wet sieving at the USDA Dairy Forage Research Center, Madison. Approximately 30 g of wet feces was refluxed in NDF solution for 60 min and then the residue was sieved through the apertures. Sieve sizes included 9.5, 6.7, 4.75, 3.35, 2.36, 1.18, 0.6, 0.3, 0.15, 0.075, and 0.038 μm. Residues were collected from each sieve onto preweighed filter paper, dried at 60°C in a forced air oven, and weighed.

Table 2. Chemical composition of experimental diets[1]

Item	Control	Yeast culture
DM, %	51.0	51.9
	% of DM	
CP	17.4	17.7
ADF	22.6	22.4
NDF	37.7	36.7
Lignin	4.7	4.7
Ash	7.9	8.1
Ca	0.88	0.84
P	0.35	0.36
Mg	0.43	0.46
K	1.51	1.51

[1]Experimental diets were control (no supplemental yeast culture) and yeast culture (56 g/d of Diamond V XP yeast culture).

Table 3. Summary of production responses from feeding yeast culture to Holstein dairy cows[1]

Item	Control	Yeast culture	SE	*P* <
Milk, kg	41.9	42.0	0.29	NS
Milk fat, %	3.61	3.69	0.02	0.02
Milk fat, kg/d	1.49	1.53	0.14	0.08
Milk protein, %	3.21	3.19	0.007	0.03
Milk protein, kg/d	1.33	1.32	0.10	NS
3.5% FCM,[2] kg/d	42.4	43.0	0.34	NS
Pen DMI, kg/d	26.2	26.4	ND[4]	—
BW change, kg/d	0.18	1.14	0.05	0.001
Milk potential BW gain adjusted 3.5% FCM potential,[3] kg/d	43.0	46.8	ND	—

[1]Experimental diets were control (no supplemental yeast culture) and yeast culture (56 g/d of Diamond V XP yeast culture).

[2]FCM = 3.5% fat corrected milk.

[3]The milk potential from BW gain was calculated as 1 kg of body tissue = 4.92 Mcal of energy (NE_L) = 7.1 kg of milk (Parker, 1994).

[4]ND = not determined.

In a separate evaluation, a mixture of feces from cows in each treatment group plus water was sieved through a screen with 3.2 mm holes on 4.8 mm diagonal offset to replicate a manure solids separator on the dairy operation where the feeding study was conducted. One liter of water was mixed with 450 g of feces to imitate the dilution of feces with urine and flush water (Nennich et al., 2005, 2006), and poured through the screen. Solids on the screen and liquid passing through the screen were collected for analysis of solids, N, ammonia N, P, and K (Dairyland Laboratories, Arcadia, WI) to estimate nutrient flows through a manure separator.

Diet digestibility was estimated from TMR and fecal AIA for CP, NDF, ADF, ADL, Ca, P, and K (Van Keulen and Young, 1977).

Milk potential from BW gain was calculated based on the relationship between body tissue and NE_L [Parker (1994); 1 kg of body tissue = 4.92 Mcal of NE_L = 7.1 kg of milk].

Urine volumes were estimated using multiple models and subsequently used to calculate urine and fecal N excretion (see Table 6). Statistics were not run on the estimates since DMI was on a group basis. One model (Kohn et al., 2002) used BW and milk urea N (15.0 and 15.3 mg/dL for control and cows receiving yeast culture, respectively) to estimate urine N excretion. Fecal N excretion was estimated by subtracting milk N, retained N, and urine N from intake N.

Table 4. Diet digestibility of experimental diets[1]

Item	Control	Yeast culture
Apparent DM digestibility,[2] %	59.5	59.5
NDF in feces, %	60.9	56.4
Apparent NDF digestibility, %	34.6	37.8

[1]Experimental diets were control (no supplemental yeast culture) and yeast culture (56 g/d of Diamond V XP yeast culture).

[2]Digestibility was estimated with the use of AIA in feeds and feces.

Statistical Analysis

Milk yield and composition, and body weights were analyzed using the GLM procedure of SAS (SAS, 1999). The model included cow, period, and diet effects. The PDIFF option was used for mean separation when differences were detected as significant ($P < 0.05$) or tended to be significant ($P < 0.20$). All results are reported as least square means.

RESULTS AND DISCUSSION

Production responses from feeding yeast culture are summarized in Table 3. Cows receiving yeast culture had a greater milk fat content ($P < 0.02$) and tended ($P < 0.08$) to have a greater milk fat yield. Milk protein content was lower ($P < 0.03$) for cows receiving yeast culture; however, milk protein yield was similar between treatments. Shaver and Garrett (1997) observed an increase in milk production, a decrease in milk fat content, no change in milk fat yield, reduced milk protein content, and higher protein yield in 11 commercial Wisconsin dairy herds fed yeast culture. A field study conducted in China (Zillin, 1996) demonstrated an increase in milk fat yield when yeast

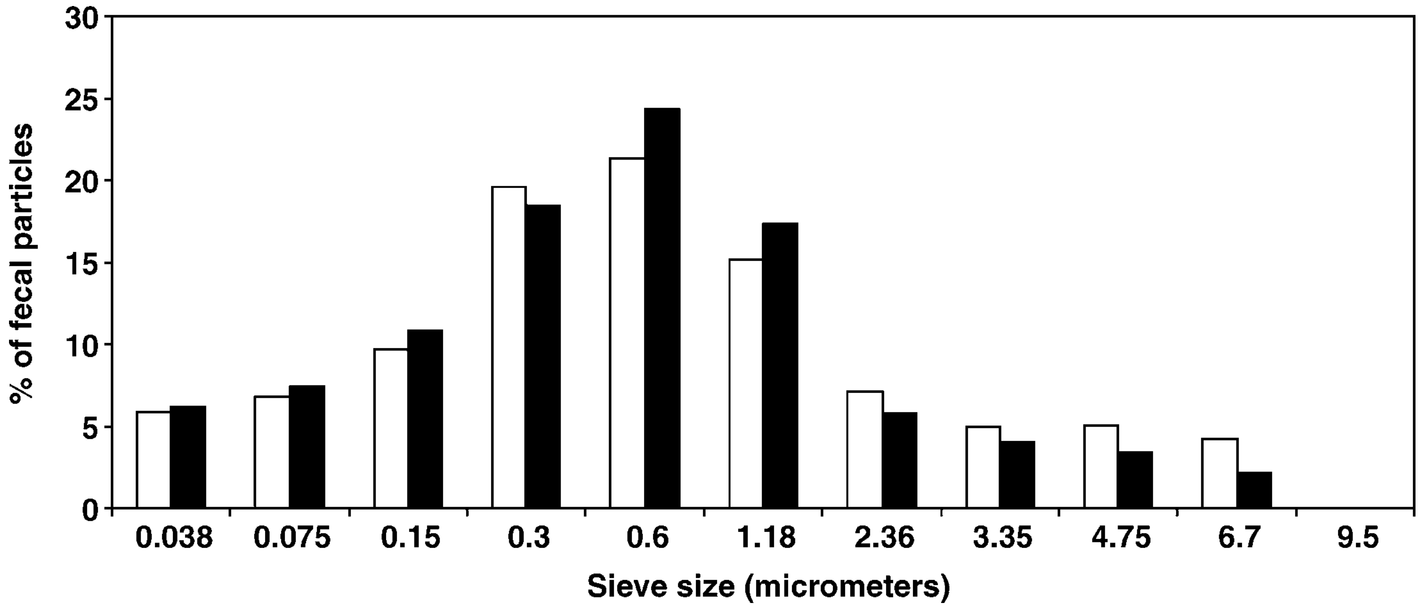

Figure 1. Fecal NDF particle size distribution after wet sieving. Open bars are feces from control cows; closed bars are feces from cows fed yeast culture.

culture was supplemented. Factors affecting milk fat and protein content of cows fed yeast culture are not clear but may be related to increased fiber digestibility.

Milk yields were similar between treatments. However, there was a trend for an increase ($P < 0.19$) in 3.5% FCM. Field studies in North Carolina (Garrett, 1997) and the Midwest (Belknap and Yoon, 2001) observed an increase in milk yield or FCM.

Cows receiving yeast culture showed numerically greater DMI (0.13 kg/d), an increase ($P < 0.001$) in BW gain, and no change in estimated microbial protein production (estimated with milk allantoin). As observed in the current study, the China field study (Zillin, 1996) observed an increase in ADG when cows were fed yeast culture. The increased BW gain was used to calculate an equivalent amount of milk that could be produced from the gain in BW when cows were fed the yeast culture (Parker 1994). This calculation resulted in an estimated 3.8 kg more 3.5% FCM when compared with cows not receiving the yeast culture (Table 3). Similarly, Schingoethe et al. (2004) observed a 7% increase in feed efficiency (kg of energy-corrected milk/kg of DMI) when yeast culture was fed to mid-lactation cows in heat stress.

Apparent DM digestibility was not different among treatments (Table 4). Harrison et al. (1988) supplemented yeast culture to ruminally fistulated, lactating cows and did not observe any differences in total tract apparent digestibilities despite an increase in cellulolytic bacteria concentration. Miller-Webster et al. (2002) supplemented diets with yeast culture and observed a tendency for increased DM digestion.

Neutral detergent fiber percent in feces (60.9 and 56.4%, respectively; Table 4) was numerically higher in control cows compared with cows fed yeast culture, which agrees with the apparent NDF digestibilities; control cows had lower NDF digestibility compared with cows fed yeast culture (34.6 and 37.8 respectively; Table 4). The greater NDF digestibility and smaller percentage of NDF in feces would indicate that less total solids could be removed via a manure separator.

The result of wet sieving of feces is summarized in Figure 1. The accumulative percent of particles retained on progressive sieves was greater for feces from cows not receiving yeast culture. Similarly, cows fed yeast culture had 6% less long fiber particles in manure compared with control cows (Belknap and Yoon, 2001). Therefore, fecal

Table 5. Fecal nutrient distribution after sieving[1]

Nutrient location	% distribution	
	Control[2]	Yeast culture[2]
N		
Screen	12.0	12.9
Liquid	88.0	87.1
P		
Screen	8.5	8.4
Liquid	91.5	91.6
K		
Screen	2.6	2.6
Liquid	97.4	97.4

[1]Feces (450 g feces mixed with 1 L water) passed through a screen with 3.2 mm holes on 4.8 mm diagonal offset.

[2]Experimental diets were control (no supplemental yeast culture) and yeast culture (56 g/d of Diamond V XP yeast culture).

Table 6. Estimated N excretions using different models

Item	Equation used	N excretion (g/d) Control[1]	Yeast culture[1]
N intake (g/d)	= (% CP × DMI)/6.25	736	755
Milk N (g/d)	= (Milk true protein/6.38) × 1.17	247	245
Estimated N retention (g/d)	= 5 g N/ADG (kg)	1.0	5.7
Estimated N excretion (g/d) based on estimated urine volumes[2]			
Nennich et al., 2006	= [Na intake × 0.062 (± 0.016)] + [MUN[3]× 0.43 (± 0.21)] + 11.4 (± 3.8)	219	226
Valadares et al., 1999	= [29 mg × kg BW/mg/dL urine creatinine]/10 × 1.038	294	280
ASAE, 2005	= (kg milk × 0.114) + (kg BW × 0.016) + (g/milk g milk fat × 97.709) + (g/milk g MTP[4] × 353.280) + (g/DM CP × 62.036) − 16.389	228	232
Bannink et al., 1999	= 0.1153 × (0.0098) intake Na (g/d) + 0.0577 × (0.0021) intake K (g/d)	310	321
Estimated N excretion (g/d)			
Kohn et al., 2002	= 0.026 × BW (kg) × MUN (mg/dL)	266	264
Average estimated urine N (g/d)		263	265
Estimated fecal N (g/d)	= intake N − milk N − retained N − urine N	225	240
Estimated total N excretion (g/d)	= intake N − milk N − retained N	488	504
Estimated total N excretion			
Nennich et al., 2005	= [DMI × Dietary CP (g/g of DM) × 84.1 (± 3.7)] + [BW × 0.196 (± 0.026)]	521	524
ASAE, 2005	= (milk × 2.03) = (DIM × 0.159) + (DMI × CP × 70.138) + (BW × 0.193) − 56.632	515	517

[1]Experimental diets were control (no supplemental yeast culture) and yeast culture (56 g/d of Diamond V XP yeast culture).

[2]Urine N = (urine volume/1.038) × urine N (mg/L)/1,000.

[3]MUN = milk urea N.

[4]MTP = milk true protein.

fiber particles are smaller when cows are fed yeast culture. This observation is consistent with the apparent NDF digestibility, which further supports that fewer solids could be removed by a separator.

Nutrient distributions of fecal screenings through a lab model manure solids separator are summarized in Table 5. Nutrients remaining on the screen were substantially less compared with the liquid fraction. There was no difference in distribution between cows fed yeast culture and control cows.

Estimated N excretions are summarized on Table 6. Nitrogen intake was numerically higher for cows fed yeast culture compared with control cows as a result of a higher percentage of CP in the TMR and a numerically greater DMI. Milk N was similar between treatments. Nitrogen retention was estimated using the NRC (2001) equation for protein retention. Cows fed yeast culture retained a greater amount of N due to the higher ADG.

Urinary N excretion was similar between treatments. Urinary N excretion ranged from 226 to 321 and 219 to 310 g/d for cows receiving yeast culture and control cows, respectively. Estimated fecal N excretion was lower in control compared with cows fed yeast culture. Total N excretion (intake – milk – retained N) was higher in cows receiving yeast culture compared with control cows. Total N excretion (Nennich et al., 2005; ASAE, 2005) estimated by the models was greater for cows receiving yeast culture and was likely related to the increase in DMI when cows were supplemented with yeast culture.

IMPLICATIONS

Feeding yeast culture improved milk fat production, tended to increase 3.5% FCM, increased BW gain, and numerically increased DMI and fiber digestibility. Distribution of fecal particles suggests more manure solids may pass the manure solids separator to the manure lagoon and therefore reduce the amount of manure solids collected with the separator.

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