The effects of live yeast supplementation to dairy cows during the hot season on production, feed efficiency, and digestibility

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ABSTRACT

The current study examined the effects of live yeast (LY) supplementation to dairy cows during the summer season on milk production, feed efficiency and ration digestibility. Forty-two dairy cows (14 primiparous and 28 multiparous) were fed either a control lactating diet or supplemented with 1 g of LY (*Saccharomyces cerevisiae*, Biosaf, Lesaffre) per 4 kg of dry matter consumed. The LY amounts were adjusted twice a week. Four rumen samples were taken from 30 cows in 2-h periods and ammonia concentrations were determined. Fecal grab samples from 30 cows were collected during 3 consecutive days, to determine the apparent digestibility of diets. The daily dry matter intake in the LY group was 2.5% greater compared with the control group (24.7 and 24.1 kg, respectively). The daily average milk yield of the LY group was greater by 1.5 kg (4.1%) compared with the control group (37.8 vs. 36.3 kg, respectively). There were no significant differences in the milk fat and protein percentages, but fat yield was greater in the LY group than in the control. The fat-corrected milk 4% was 2.0 kg (6.1%) greater in the LY group than in the control group (34.8 vs. 32.8 kg, respectively). The efficiency of using dry matter to produce 4% fat-corrected milk was 3.7% greater in the LY group compared with the control group. The ruminal ammonia concentrations after feeding were greater in the control group than in the LY group (151.9 vs. 126.1 mg/l, respectively). No differences were observed among groups in the total tract apparent digestibility of dry matter and other diet components. The pH values in the rumen that were determined in a companion trial using 4 fistulated cows tended to be higher in cows that were supplemented with LY than in the control (6.67 vs. 6.54, respectively). It may be concluded that LY supplementation to dairy cows during the hot season improved the rumen environment in a way that increased the dry matter intake and in consequence enhanced the productivity and efficiency.

Key words: live yeast, feed efficiency, hot season

INTRODUCTION

The use of yeast products in dairy cattle nutrition has become widespread over the last 20 yr. However, most of the research has focused on yeast culture and less on live yeast (LY). The overall results of yeast products supplementation on dairy cows performance are inconsistent. In some reports yeast culture increased DMI (Erasmus et al., 1992; Wohlt et al., 1998; Dann et al., 2000), whereas in others no effect of yeast on intake was observed (Kung et al., 1997; Soder and Holden, 1999; Schingoethe et al., 2004). Similarly, the effects of yeast on production have been variable. In some reports greater milk production was reported (Piva et al., 1993; Wohlt et al., 1998), but others reported no response in milk yield with yeast culture supplementation (Putnam et al., 1997; Soder and Holden, 1999; Schingoethe et al., 2004).

Several benefits of yeast product supplementation to ruminant nutrition have been demonstrated: an increase in nutrient digestibility, alteration of the proportion of volatile fatty acids produced in the rumen, reduction in ruminal ammonia, and increase of ruminal microorganism population (Chaucheyras-Durand et al., 2007). However, the mechanism of action of yeast products is not completely described. Yeast culture provides various growth factors, pro-vitamins, and other stimulants to bacteria growth in the rumen (Wiedmeier et al., 1987; Newbold et al., 1995; Miller-Webster et al., 2002).

Live yeast was also reported as beneficial to small ruminant nutrition and production (Abd El-Ghani, 2004; Stella et al., 2007). It was demonstrated in dairy cattle that LY supplementation contributes to rumen environment by enhancing the pH (Bach et al., 2007). Jouany (2001) proposed a mechanism in which LY contribute to the rumen environment; live yeast cells cannot survive in an anaerobic environment because they use oxygen for sugar and other nutrient metabolism (Jouany, 2001, 2006). It was also proposed that LY act as balancers of the ruminal fluid redox potential, hence maintaining optimal fermenting conditions for the rumen bacterial microflora, which is an obligate anaerobic environment.

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The end metabolites of the yeast could be used by bacteria and the removal of oxygen creates better condition for multiplication and development of anaerobic cellulolytic bacteria (Jouany, 2006).

The beneficial effects of yeast products depend on lactation stage (Wohlt et al., 1998), diet characteristic (Piva et al., 1993) and environmental condition (Schingoethe et al., 2004; Chaucheyras-Durand et al., 2007).

The objectives of the current study were to examine the effects of LY supplementation to dairy cows during the hot season on milk yield and composition, feed efficiency and apparent digestibility of diet and nutrients.

MATERIALS AND METHODS

Cows and Treatments

The experiment protocol of the study was approved by the Volcani Center Animal Care Committee and was conducted at the Volcani Center experimental farm in Bet Dagan, Israel. Twenty-eight multiparous and 14 primiparous Israeli-Holstein cows that averaged 114 ± 54 DIM were group housed in shaded loose pens with adjacent outside yards, equipped with a real-time electronic individual feeding system. Each station was equipped with individual identification system (I.D. tag, S.A.E. Kibbutz Afikim, Israel) that allowed each cow to enter a specific station with the feed intake being automatically recorded.

The experiment commenced in mid-July and continued until mid-October, which is the typical hot season in Israel. After 10 d of adaptation to the diets and the electronic feeding system, the cows were assigned to 2 groups of 21 cows each to begin treatments; 7 primiparous and 14 multiparous cows in each treatment group. The cows were stratified on the basis of the average milk production during the pre-treatment period, DIM, parity, and BW. The treatments were as follows: 1) Control: cows were fed a basal diet (Table 1) and supplemented with 100 g of ground corn grain per d per cow; 2) LY: cows were fed the basal diet and supplemented with 1 g of LY (Biosaf, Lesaffre Feed Additives, Lille, France) per 4 kg of DM consumed, premixed with 100 g of ground corn grain. Biosaf is made of small granules with a core of LY from the *Saccharomyces cerevisiae* SC47 strain. According to the manufacturer's information, the quantity of yeast given by 1 g of product was 10^{10} cfu, therefore the cows were offered 10^{10} cfu per 4 kg of DM consumed. The yeast was offered in a dry protected form that guarantees high recovery rate. The supplemented amounts of LY were adjusted twice a week, according to the previous 3 to 4 d individual intake of each cow.

Table 1. Lactating cow diet ingredients and chemical composition of formulated TMR

Ingredient	Amount, % of DM ¹
Corn grain, ground	23.7
Barley grain, rolled	6.5
Sunflower meal	3.8
Soybean meal	6.2
Gluten feed	7.9
Cottonseed	3.3
Wheat silage	20.2
Dried distillers grain	5.3
Molasses	1.7
Vetch hay	6.5
Oat hay	5.3
Wheat bran	4.6
Whey	2.6
Calcium bicarbonate	0.4
Soybean oil	0.2
Limestone	0.9
Vitamins and minerals ²	0.1
Chemical composition	
NE _L , Mcal per kg of DM ³	1.75
CP	16.5
RUP	5.1
ADF	16.0
Crude NDF ⁴	31.7
NDF-forage ⁵	17.2
Ether extracts	4.4
Ca	0.9
P	0.4

¹The DM was 64.0%

²Contained (per kg of DM) 20,000,000 IU of vitamin A; 2,000,000 IU of vitamin D; 15,000 IU of vitamin E; 6,000 mg of Mn; 6,000 mg of Zn; 2,000 mg of Fe; 1,500 mg of Cu; 120 mg of I; 50 mg of Se; and 20 mg of Co.

³Calculated using NRC (2001) recommendations.

⁴NDF from forage and nonforage sources.

⁵NDF from forage sources.

Daily individual intake was recorded. The cows were fed once a day at 1200 h at 107% of the expected intake, which was adjusted according to the previous day's intake. The supplements were individually hand-mixed into the upper third of the TMR. The feed efficiency was determined by calculating the kilograms of milk or FCM (4%) yield per kilogram of DM consumed for each cow in each treatment group.

The cows were cooled 5 times a day during the study period in the holding pen of the milking parlor. Each cooling period lasted 30 min and each cycle consisted of 30 s of showering and 4.5 min of ventilation without showering.

The cows were weighed automatically 3 times daily after each milking with a walking electronic scale. Body condition score (1–5 scale; Edmonson et al., 1989) was determined weekly by one technician. Cows were milked 3 times daily and milk production was recorded electronically. Milk samples were collected every 10 d from 3 consecutive milkings and analyzed for milk fat, protein, lactose, urea, and somatic cell counts, which

were determined by infrared analysis (IDF, 2000) at the laboratories of the Israeli Cattle Breeders Association (Caesarea, Israel).

Digestibility Measurements

In the ninth week of the experiment, 9 fecal grab samples were collected during 3 consecutive days, 3 times daily, 2 h and 40 min apart, from 30 cows (15 cows from each treatment group). The fecal samples were dried at 60°C for 48 h in a forced air oven, then ground to pass through a 1.0-mm screen (Retsch S-M-100, Haan, Germany). Simultaneously, diet samples were collected, dried, and then ground. For in situ measurements (Dacron bags), 0.5 g of dried ground fecal sample from each cow (9 samples) were composited (total 4.5 g) and placed in Dacron bags (6 × 12 cm, 42 to 44 µm pore size; Emka, Petah Tikva, Israel). The in situ incubation of the fecal samples was determined in triplicate. An additional 3 Dacron bags were filled with diet samples, 4.5 g each, for in situ analysis. The Dacron bags were incubated in a rumen cannulated cow at the same time, and removed after 8 d. After removal, the bags were washed in a washing machine, dried (60°C for 48 h) and weighed. The indigestible neutral detergent fiber (**I-NDF**) was used as a marker for the apparent total-tract digestibility analysis and the residuals were determined for I-NDF (Lippke et al., 1986; Arieli et al., 1996; Voelker et al., 2002). The fecal and ration samples were analyzed for DM, protein, NDF, ADF, and ash content. The digestibility of DM, protein, NDF, ADF, and ash were determined as follows (Bondy, 1987):

$$\text{Digestibility of DM} = 100 - \left[100 \times \left(\frac{\% \text{ I-NDF in Diet}}{\% \text{ I-NDF in Feces}} \right) \right]$$

Digestibility of nutrient =

$$100 - \left[100 \times \left(\frac{\% \text{ I-NDF in Diet}}{\% \text{ I-NDF in Feces}} \right) \times \left(\frac{\% \text{ Nutrient in Feces}}{\% \text{ Nutrient in Diet}} \right) \right]$$

The digested amounts of each chemical component of the ration were calculated individually by using the average individual DMI during the 3 d of feces sampling.

Rumen Samples

At the 10th week of the study, 5-mL rumen fluid samples were collected with a stomach vacuum from 30 cows (15 from each treatment group) at 1000, 1200, 1400, and 1600 h, which were 2 h before feeding, at

feeding, and 2 and 4 h postfeeding, respectively. The rumen samples were immediately mixed with 20% trichloroacetic acid (1:1 volume ratio) and frozen in -20°C until ammonia determination.

A companion trial was conducted using 4 rumen cannulated cows. In this trial 2 cows were supplemented daily with 5 g of LY that was inserted directly into the rumen via the fistula and mixed into the rumen content. Two other cows served as control. After a week of adjustment, rumen samples were taken via the fistula from the ventral sac every 2 d during a 24-d period (12 samples). The rumen samples were taken 1 h after feeding (at 0900 h) and pH values were immediately determined.

Chemical Analysis

Total mixed rations were sampled weekly and DM, CP, NDF, ADF, Ca, and P were determined. Feed samples were dried at 65°C for 24 h and then ground to pass through a 1.0 mm screen (Retsch S-M-100). The ground samples were dried at 100°C for 24 h and analyzed for N (AOAC, 1990; method 984.13), NDF and ADF content was determined with Ankom equipment (Ankom Technology, Fairport, NY; NDF, using α-amylase and sodium sulfite; Van Soest et al., 1991), Ca (AOAC, 1990; method 935.13), P (AOAC, 1990; method 964.06), and ether extracts (AOAC, 1990; method 996.06). Samples were dried at 550°C for 3 h for ash determination. The NE_L NRC (2001) values of feedstuffs were used. The RUP values of most of the feedstuffs were from Arieli et al. (1989). For feedstuffs that were not examined in Arieli et al. (1989), the NRC (2001) RUP values were used. Rumen ammonia concentrations were determined by the phenol procedure (Chaney and Marbach, 1962).

Statistical Analysis

Continuous variables (milk, milk solids, DMI, and efficiency) were analyzed as repeated measurements using Proc Mixed (SAS Institute, 2000). Each variable was analyzed using the specific data of the pre-treatment period as covariate.

The model used was

$$Y_{ijkl} = \mu + T_i + L_j + C(T \times L)_{ijk} + \text{DIM}_{ijkl} + E_{ijklm},$$

where μ = overall mean; T_i = treatment effect, $i = 1$ to 2; L_j = parity, $j = 1$ or > 1 ; $C(T \times L)_{ijk}$ = cow_k nested in treatment_i and cow nested in parity_j; DIM_{ijkl} = day in milk as continuous variable; and E_{ijklm} = random residual.

Table 2. Least squares means of DMI, milk, milk solids, and feed efficiency

Variable	Treatments ¹		SEM	P <
	CTL	LY		
Cows, n	21	21		
DMI, kg/d	24.1	24.7	0.12	0.0001
Milk yield				
Milk, kg/d	36.3	37.8	0.4	0.007
FCM 4%, kg/d	32.8	34.8	0.3	0.0001
Milk solids concentration				
Fat, %	3.49	3.63	0.07	0.15
Protein, %	3.20	3.24	0.04	0.5
Lactose, %	4.86	4.91	0.02	0.02
Urea, g/dL	0.027	0.027	0	0.7
Milk solids yields (g/d)				
Fat	1,273	1,362	28	0.03
Protein	1,172	1,220	21	0.12
Lactose	1,810	1,887	37	0.15
Feed efficiency				
Milk per kg of DM	1.53	1.56	0.01	0.16
FCM 4% per kg of DM	1.36	1.41	0.01	0.03

¹Treatments: cows were fed either a control lactating diet (CTL) or supplemented with 1 g of live yeast (LY; *Saccharomyces cerevisiae*; Biosaf, Lesaffre Feed Additives, Lille, France) per 4 kg of DM consumed during the hot season.

The interactions treatment $\times$ parity, treatment $\times$ DIM, parity $\times$ DIM and treatment $\times$ parity $\times$ DIM were tested for each dependent variable. No treatment $\times$ parity interaction was significant and therefore they were excluded from the model. Whenever one or more of the other interactions that were tested for each dependent variable were not significant, they were excluded from the model and the model was rerun.

The pH values were also analyzed as repeated measurements using the Proc Mixed procedure of SAS Institute (2000). Other variables were analyzed using the GLM procedure. Least squares means and adjusted SEM are presented in Tables 2 and 3, and $P < 0.05$ was accepted as significant unless otherwise stated.

RESULTS AND DISCUSSION

In the current study, supplementation of LY to dairy cows during the hot season increased feed consumption, milk production, and feed efficiency. However, no increase in apparent digestibility of the diet was demonstrated in the LY group.

Five cows were substituted during the experiment due to health problems: 3 cows were removed from the study after contracting mastitis and 2 cows due to severe lameness. Because no treatment $\times$ parity effect was significant for any independent variable, the results for primiparous and multiparous cows are presented together.

Table 3. Apparent digestibility and digesta intake of diet components

Variable	Treatment ¹		SEM	P <
	CTL	LY		
Cows, n	15	15		
Apparent digestibility (%)				
DM	61.7	62.4	0.58	0.42
Organic matter	58.3	58.9	0.50	0.48
Protein	62.9	61.7	0.86	0.38
NDF	43.9	44.8	0.83	0.83
ADF	33.0	35.0	1.0	0.17
Apparent digestible intake (kg/d)				
DM	14.7	15.5	0.5	0.30
Organic matter	13.9	14.6	0.5	0.31
Protein	2.47	2.54	0.1	0.64
NDF	3.75	4.01	0.16	0.25
ADF	1.25	1.40	0.06	0.10

¹Treatments: cows were fed either a control lactating diet (CTL) or supplemented with 1 g of live yeast (LY; *Saccharomyces cerevisiae*; Biosaf, Lesaffre Feed Additives, Lille, France) per 4 kg of DM consumed during the hot season.

Figure 1. Least squares means of DMI of dairy cows fed either a control lactating diet (■) or supplemented with 1 g of live yeast (*Saccharomyces cerevisiae*; Biosaf, Lesaffre Feed Additives, Lille, France) per 4 kg of DM consumed (▲) during the hot season.

The maximal daily temperature during the study period averaged $31.2 \pm 1.6^{\circ}\text{C}$ and the average maximal relative humidity was $83.6 \pm 5.7\%$. The temperature-humidity index (THI) at morning (0600 h) averaged 69.4 ± 3.5 , and the THI at afternoon (1600 h) averaged 79.3 ± 2.1 . The temperature, relative humidity, and THI values during the study period were relatively stable and represent typical Israeli heat stress conditions during the summer season.

The average daily DMI in the LY group was greater by 0.6 kg/d (2.5%) than in the control ($P < 0.0001$; Table 2 and Figure 1). Enhanced DMI in response to LY supplementation was observed in dairy cows (Wohlt et al., 1998) and in dairy goats (Stella et al., 2007). Dann et al. (2000) observed greater DMI in dairy transition cows supplemented with yeast culture, whereas no differences were observed among these groups from 42 d in lactation. It was suggested by Arambel and Kent (1990) that yeast products might be more effective under stress as in the current study, rather than in normal conditions. However, the increased DMI was not observed in Schingoethe et al. (2004) in which dairy cows received a yeast culture supplement during the summer.

The average daily milk production was 1.5 kg/d greater in the LY group than in the control group (4.1%; $P < 0.007$; Table 2 and Figure 2). The interaction DIM by parity was significant ($P < 0.001$), which represents the usual differences in lactation curve between prim-

iparous and multiparous cows. Similar to DMI, the milk yield results in response to yeast products in other reports were variable. In a study conducted with early lactation dairy cows, greater milk yield was observed for cows fed LY (Wohlt et al., 1998; Kung et al., 1997) and similar results were reported in dairy goats (Stella et al., 2007). In a report by Piva et al. (1993) greater milk production was observed in cows fed yeast culture, but others reported no response in milk yield (Putnam et al., 1997; Soder and Holden, 1999; Schingoethe et al., 2004). In general, greater milk production in response to yeast products supplementation was accompanied by greater feed intake (Wohlt et al., 1998; Abd El-Ghani, 2004; Stella et al., 2007), whereas no response in production was accompanied by no effect on feed consumption (Putnam et al., 1997; Soder and Holden, 1999; Schingoethe et al., 2004). The mixed results in intake and production might be partially attributable to the different condition in which these studies were performed with respect to stage of lactation, diet characteristics, and season.

Milk solids percentage and yield are presented in Table 2. The average fat percentage was not different among groups, whereas the fat yield was 7% greater in the LY group than in the control ($P < 0.03$). The enhancement of fat yield was also observed in other studies in response to yeast culture supplementation and might be attributable to the increased milk production in the yeast-fed cows (Putnam et al., 1997; Wohlt et al.,

Figure 2. Least squares means of milk production (A) and FCM (4%) (B) of dairy cows fed either a control lactating diet (■) or supplemented with 1 g of live yeast (*Saccharomyces cerevisiae*; Biosaf, Lesaffre Feed Additives, Lille, France) per 4 kg of DM consumed (▲) during the hot season.

1998). No differences between groups were observed in protein percentage and yield. Greater lactose percentage was observed in the LY group than in the control group ($P < 0.02$). The lactose yield was numerically but not significantly greater in the LY group than in the control group (4.3%; $P < 0.15$). No differences were observed in milk urea concentrations among groups.

The average daily FCM 4% was greater by 2.0 kg/d in the LY group than in the control group (6.1%; $P < 0.0001$; Table 2 and Figure 2). Greater FCM yield in response to yeast supplementation was previously reported (Putnam et al., 1997; Wohlt et al., 1998). Feed efficiency as was defined by production of FCM 4% from DMI was 3.7% greater in LY than in control (Table 2; P

Figure 3. Least squares means of ammonia concentrations in the rumen of cows fed either a control lactating diet (■) or supplemented with 1 g of live yeast (*Saccharomyces cerevisiae*; Biosaf, Lesaffre Feed Additives, Lille, France) per 4 kg of DM consumed (▲) during the hot season.

< 0.03), which was also observed in Schingoethe et al. (2004) in cows fed yeast culture during the hot season.

The initial BW for the control and LY groups were 587.5 and 586.8 kg (Pooled SEM = 4.4) and 607.1 and 599.0 kg (pooled SEM = 4.5) at the end of the study period. The average increase in BW through the treatments period was 20.6 and 12.7 kg for the control and LY groups, respectively ($P < 0.3$; pooled SEM = 4.8). The initial BCS for the control and LY groups were 2.40 and 2.49 BCS units (pooled SEM = 0.08) and 2.66 and 2.74 BCS units (pooled SEM = 4.5) at the end of the study period, respectively. A moderate increase in BCS was observed along the study with no differences among groups; 0.27 and 0.26 BCS unit for control and LY groups, respectively (pooled SEM = 0.05).

The ammonia concentrations in the rumen are presented in Figure 3, and as shown there was a similar pattern of ammonia concentrations over time in both groups. However, the ammonia concentrations in the rumen from feeding and later samplings were 20% lower in the LY group than in the control group (151.9 vs. 126.1 mg/L, respectively; $P < 0.04$). Lower ammonia concentrations in response to yeast culture supplementation were reported in Harrison et al. (1988) and Erasmus et al. (1992). Lower ammonia concentrations were also observed with feeding LY in growing lambs (Chaucheyras-Durand and Fonty, 2001) and adult ruminants (Kumar et al., 1994). There are 2 parameters that could be influenced by yeast supplementation

and affect the ammonia concentration in the rumen: 1) increase or decrease the protein degradation in the rumen, and 2) increase the ammonia incorporation to microbial protein. In Erasmus et al. (1992), lower ammonia concentration was associated with increased incorporation of ammonia into microbial protein, which might increase the microbial flow to the duodenum. Erasmus et al. (1992) also reported numerically but not significantly greater flow of non-ammonia N and microbial N in yeast culture-fed cows. In an in vitro study by Chaucheyras-Durand et al. (2005), the proteolytic rumen bacteria activity was lowered by yeast supplementation, which might be the reason for lower ammonia concentrations in the rumen. It was concluded by Sniffen et al. (2004) that the diet balance between degradable and nondegradable protein is a key factor in the response to yeast supplementation.

The pH values that were collected from the cannulated cows in a companion trial tended to be higher in the LY cows than in the control; 6.67 and 6.54, respectively (pooled SEM = 0.03; $P < 0.1$). Higher pH values in response to yeast supplementation were also observed in Williams et al. (1991), Miller-Webster et al. (2002), and Bach et al. (2007). Bach et al. (2007) also observed differences in intermeal intervals between control and LY-supplemented cows, which may be associated with the changes in pH values.

No differences were observed in the apparent digestibility of DM, organic matter, protein, NDF, and ADF

(Table 3). However, numerically greater amounts of digested DM (5.4%), organic matter (5.0%), protein (2.8%), NDF (6.9%), and ADF (12%) were observed. The apparent digestibility of DM and other diet nutrients in response to yeast supplementation were variable. Greater apparent digestibility of DM or other nutrients in response to yeast culture supplementation were observed in several reports (Miranda et al., 1996; Wiedmeier et al., 1987; Williams et al., 1991), but not in others (Harrison et al., 1988; Putnam et al., 1997). It has been suggested that the live yeast's capacity to scavenge oxygen contributes to create anaerobic conditions in the rumen, which is favorable to most of the ruminal microorganisms (Chaucheyras-Durand et al., 2007). A few strains of *S. cerevisiae* that were added to rumen fluid in vitro increased the disappearance of O₂ (Newbold et al., 1996). This might contribute to increasing the bacterial population and digestibility of nutrients. However, in the current study although lower ammonia concentrations which may associated with increased rumen bacteria activity were observed in the LY cows, no increase in apparent digestibility of nutrients was demonstrated.

CONCLUSIONS

Live yeast supplementation to dairy cows during the hot season increased feed intake and milk yield. In addition, the feed efficiency for FCM 4% production was enhanced by the LY. Lower concentrations of ammonia in the rumen were observed in the LY group, which may indicate greater utilization of protein for the microflora synthesis and apparent increase in the rumen bacterial population. Although no differences in the apparent total tract digestibility were observed among groups in the current study, LY supplementation during the hot season increased the DMI, productivity, and efficiency.

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