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CASE STUDY: Multiple-Study Analysis of the Effect of Live Yeast on Milk Yield, Milk Component Content and Yield, and Feed Efficiency

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ABSTRACT

A data set with dietary information and production responses was compiled from 14 research trials conducted internationally (160 observations representing 1,615 cows) that tested the effect of dietary inclusion of live yeast (Saccharomyces cerevisiae CNCM I-1077). Diet and feed analysis data for each study were entered into CPM (Cornell, Penn, Miner) Dairy 3.0.8 to estimate dietary nutrient parameters. Mean milk yield was 31.56 kg (SD = 6.45) with 3.75% milk fat (SD = 0.34) and 3.02% true protein (SD = 0.15). Mixed model analysis was conducted with CPM nutrients as main effects. Number of cows per treatment was included as a weighting factor, and experiment was included as a random effect. Live yeast significantly improved ($P < 0.0001$) 3.5% FCM yield (35.54 vs. 34.58 kg/d for live yeast and control) with the effect being greater for cows <100 DIM (36.06 vs. 34.93 kg; $P < 0.01$) but still highly significant for cows >100 DIM (33.81 vs. 32.83 kg; $P < 0.005$). Feed efficiency (kg 3.5% FCM/kg DMI) was improved ($P < 0.001$) with live yeast (1.75 vs. 1.70 for live yeast and control). There was no overall effect ($P > 0.10$) of live yeast on DMI. Although milk fat and protein content were slightly lower with the inclusion of live yeast, both milk fat yield (1.28 vs. 1.25 kg/d; $P < 0.01$) and milk true protein yield (1.02 vs. 1.00 kg/d; $P < 0.0001$) increased with live yeast.

Key words: feed efficiency, live yeast, milk component, milk yield

INTRODUCTION

Over many years, researchers have conducted in vitro as well as in vivo research with live yeast (*Saccharomyces cerevisiae*) to provide mechanistic insights into its actions in the ruminant animal and to test production responses. The addition of live yeast to the diet of gnotobiotically reared lambs showed that it accelerated the establishment of rumen cellulolytic bacteria, enhanced the activity of fiber-digesting enzymes, and tended to increase in situ DM degradation of wheat straw (Chaucheyras-Durand and Fonty, 2001). Further work with conventional newborn lambs by this research group showed that live yeast also promoted protozoal establishment in the rumen and stimulated growth of cellulolytics. Due to the oxygen scavenging of live yeast, it lowered redox potential (Chaucheyras-Durand and Fonty, 2002). Mosoni et al. (2007) also found that live yeast increased cellulolytic bacteria populations in sheep. Guedes et al. (2008) found that live yeast increased fiber digestion by 24% with low-quality corn silages; however, with high-quality silages, there was no improvement in fiber digestion.

Continuous culture research with the addition of live yeast to the diet decreased ammonia, increased bacterial nitrogen production, and increased efficiency of microbial protein synthesis (Moya et al., 2007). Live yeast has also been shown to increase rumen pH and reduce rumen pH variation (Moya et al., 2007; Thrunel et al., 2007;

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Guedes et al., 2008). In a study with loose-housed dairy cows, live yeast addition to the diet reduced the time with rumen pH less than 5.6 from 4 h/d to 1.3 h/d and increased average rumen pH from 5.49 to 6.05 (Bach et al., 2007). Chaucheyras-Durand et al. (2005) found that in vitro cell numbers of the lactic-acid-producing bacteria *Streptococcus bovis* were reduced by 47-fold with live yeast present, likely due to a competition for glucose uptake under anaerobic conditions. Lactate-utilizing organisms (*Megasphaera elsdenii*) were also stimulated by this strain of live yeast (Chaucheyras et al., 1996). It is likely that the positive effects observed on rumen pH by this strain occur as the result of both inhibition of the growth of lactate-producing bacteria and stimulation of the growth of lactate-utilizing bacteria, thus leading to an overall decrease in lactate accumulation.

One would expect the positive responses to yeast observed in vitro to translate into positive in vivo milk yield and component responses. Several in vivo studies have been conducted with live yeast over the last decade. The objective of the current work was to determine if live yeast affected milk yield, milk component content and yield, and feed efficiency across multiple experiments with varying diets.

Table 1. Experiments used for the multiple-study analysis

Experiment	Number of treatment means reported	Number of cows per treatment	Days on treatment	Mean DIM	Mean milk, kg
Brazil, 2002[1]	16	9	24	198	18.73
Brazil, 2008[2]	4	10	28	157	28.93
Estonia, 2004[3]	4	88	100	54	33.25
France, 2001[4]	16	20	70	213	30.49
France, 2003[5]	6	31	70	120	30.53
Germany, 2001[6]	22	18	70	49	38.35
Italy, 2003[7]	30	27	56	84	33.16
the Netherlands, 2004[8]	3	29	42	166	32.36
UK, 2001[9]	40	23	102	89	29.13
UK, 2003[10]	10	40	99	144	35.16
USA, 2003[11]	2	93	35	121	37.96
USA, 2003[12]	2	100	60	158	41.90
USA, 2004[13]	2	100	60	219	39.42
USA, 2005[14]	4	42	70	98	42.38

[1]University of Sao Paulo, Brazil, Santos et al. (2002).

[2]Lavras University, Brazil, Bitencourt (2008).

[3]Tallin University, Estonia, Rihma et al. (2004).

[4]Central Soya, France, Boucher (2001).

[5]Agricultural College of Toulouse, France, Haimoud-Lekhal and Chevaux (2003).

[6]Technische Universitat Munchen, Germany, Ettle and Schwarz (2002).

[7]Universita degli Studi de Milano, Italy, Dell'Orto et al. (2003).

[8]Nutreco Ruminant Research Centre, Boxmeer, the Netherlands, Nielen (2004).

[9]Brookmount Farm, Bangor, Northern Ireland, Bell (2001).

[10]Kemble Farms Ltd., Gloucestershire, UK (Kemble Farms Ltd., 2003).

[11]ADM Alliance Nutrition Inc., Maryland, Brown and Cecava (2003).

[12]FARME Institute Inc., Homer, NY, Siciliano-Jones (2003).

[13]FARME Institute Inc., Homer, NY, Siciliano-Jones (2004).

[14]Spruce Haven Farm and Research Center, Auburn, NY, Nocek (2005).

MATERIALS AND METHODS

A data set with diet information and production responses was compiled from 14 well-documented research trials with dairy cows conducted internationally (160 observations representing 1,615 cows) that tested the effects of dietary inclusion of live yeast (Levucell SC, Lallemand Animal Nutrition, Milwaukee, WI; *Saccharomyces cerevisiae* CNCM I-1077; 10×10^9 cfu/d) on DMI, milk yield, milk component content and yield, 3.5% FCM yield, and feed efficiency (kg 3.5% FCM/kg DMI). The product was either presented in a microencapsulated form and added to a pelleted concentrate or used in a noncoated form and in most cases mixed with a supplement or TMR before being fed. A description of the database including number of treatment means reported for each study, number of cows per treatment, days on treatment, mean DIM, and mean milk yield for each study is presented in Table 1.

Diet Descriptions

Diet and feed analysis data for each experiment were entered into CPM (Cornell, Penn, Miner) Dairy 3.0.8 (School of Veterinary Medicine, University of Pennsylvania, Kennett Square, PA) to estimate total diet nutrient parameters. Amounts of each ingredient consumed and the analyzed nutrient description of each ingredient were entered into the model. The nutrient analysis of every ingredient was not available for all studies; in those cases, CPM-Dairy 3.0.8 feed dictionary nutrient analyses were used. Diet nutrient parameters from each study [protein fractions A, B_1, B_2, B_3, and C (% DM); long-chain fatty acids (% DM); methionine (% metabolizable protein); lysine (% metabolizable protein); fermentable NDF (% DM); fermentable starch (% DM); and fermentable soluble fiber (% DM)] were summarized into an Excel spreadsheet. The protein fractions have been described previously by Sniffen et al. (1992). Protein fraction A is NPN. Protein fraction B_1 is borate-phosphate buffer soluble peptides and true protein. Protein fraction B_2 is protein that is insoluble in borate-phosphate buffer but soluble in boiling neutral detergent solution. Protein fraction B_3 is protein that is insoluble in boiling neutral detergent but soluble in boiling acid detergent solution. Protein fraction C is that protein which remains insoluble after boiling in acid detergent solution.

In Table 2, mean production and diet characteristics of the 14 research trials are reported. The range in production and diet nutrient parameters appeared to be sufficient to assess the effect of live yeast supplementation on milk yield and milk component responses.

Table 2. Production and diet characteristics[1] of the 14 live yeast trials used for the multiple-study analysis

Characteristic	Mean	SD	Minimum	Maximum
Milk, kg	31.56	6.45	15.70	43.18
Milk fat, %	3.75	0.34	2.76	4.50
Milk CP, %	3.25	0.16	2.92	3.73
Milk true protein, %	3.02	0.15	2.71	3.47
DMI, kg	19.22	3.67	11.01	27.20
NE_l, Mcal/kg	1.73	0.11	1.49	1.88
CP, % DM	17.32	1.93	13.90	22.20
RUP, % CP	32.65	2.43	28.60	44.70
Soluble protein, % CP	34.13	7.81	20.94	47.56
Protein fraction A, % DM	4.39	1.83	0.66	7.75
Protein fraction B_1, % DM	1.46	0.77	0.62	3.72
Protein fraction B_2, % DM	8.89	2.37	4.84	12.39
Protein fraction B_3, % DM	1.70	0.94	0.52	3.56
Protein fraction C, % DM	0.87	0.23	0.57	1.36
Methionine, % metabolizable protein	2.00	0.13	1.76	2.27
Lysine, % metabolizable protein	6.64	0.29	5.85	7.05
Ether extract, % DM	4.54	1.30	3.10	6.50
Long-chain fatty acids, % DM	3.51	1.26	2.30	5.80
NDF, % DM	34.91	5.04	26.80	42.40
Fermentable NDF, % DM	13.72	4.51	5.66	23.15
Forage, % DM	55.34	13.66	36.35	87.84
Nonfiber carbohydrates, % DM	38.81	5.06	27.60	48.00
Sugar, % DM	5.46	2.33	3.30	10.80
Starch, % DM	22.82	8.39	3.40	36.50
Fermentable starch, % DM	18.97	6.70	2.87	27.77
Soluble fiber, % DM	6.92	2.33	2.00	13.40
Fermentable soluble fiber, % DM	6.01	2.18	1.70	12.24

[1]Determined using CPM-Dairy 3.0.8 (School of Veterinary Medicine, University of Pennsylvania, Kennett Square, PA).

Statistical Analysis

Mixed model analysis was conducted using JMP statistical software (SAS Inst. Inc., Cary, NC) with CPM nutrient parameters as main effects with no interactions. Production responses were analyzed with the following variables included in the models: control vs. treatment; DMI (kg); DIM category (<100 vs. >100 DIM); control 3.5% FCM yield categories (<33 kg vs. >33 kg); protein fractions A, B_1, B_2, B_3, and C (% DM); long-chain fatty acids (% DM); methionine (% metabolizable protein); lysine (% metabolizable protein); fermentable NDF (% DM); fermentable starch (% DM); and fermentable soluble fiber (% DM). The nutrient fractions and DMI were continuous variables. Category effects (DIM and control 3.5% FCM yield) incorporated interaction with treatment. Number of cows per treatment was included as a weighting factor, and experiment was included in the models as a random effect. The DMI response to live yeast supplementation was analyzed separately with the same nutrient variables and categories included in the model as described previously.

RESULTS AND DISCUSSION

Live yeast improved ($P < 0.0001$) milk yield by 1.15 kg/d (34.19 vs. 33.04 kg/d for live yeast and control, respectively; Table 3). A meta-analysis conducted by Desnoyers et al. (2009) concluded that the addition of yeast (with no differentiation between live yeast vs. yeast culture) improved milk yield by 1.2 g/kg BW (or 0.75 kg more milk for a 625-kg cow).

Table 3. Multiple-study analysis of the effect of live yeast supplementation on milk yield, 3.5% FCM, feed efficiency, and milk components

Item	Control	Live yeast	*P*-value	R^2
Milk yield, kg/d	33.04	34.19	<0.0001	0.95
3.5% FCM, kg/d	34.58	35.54	<0.0001	0.93
Feed efficiency, kg 3.5% FCM/kg DMI	1.70	1.75	0.0006	0.96
Milk true protein content, %	3.03	2.99	0.0013	0.79
Milk true protein yield, kg/d	1.00	1.02	<0.0001	0.94
Milk fat content, %	3.80	3.75	0.0326	0.76
Milk fat yield, kg/d	1.25	1.28	0.0080	0.90

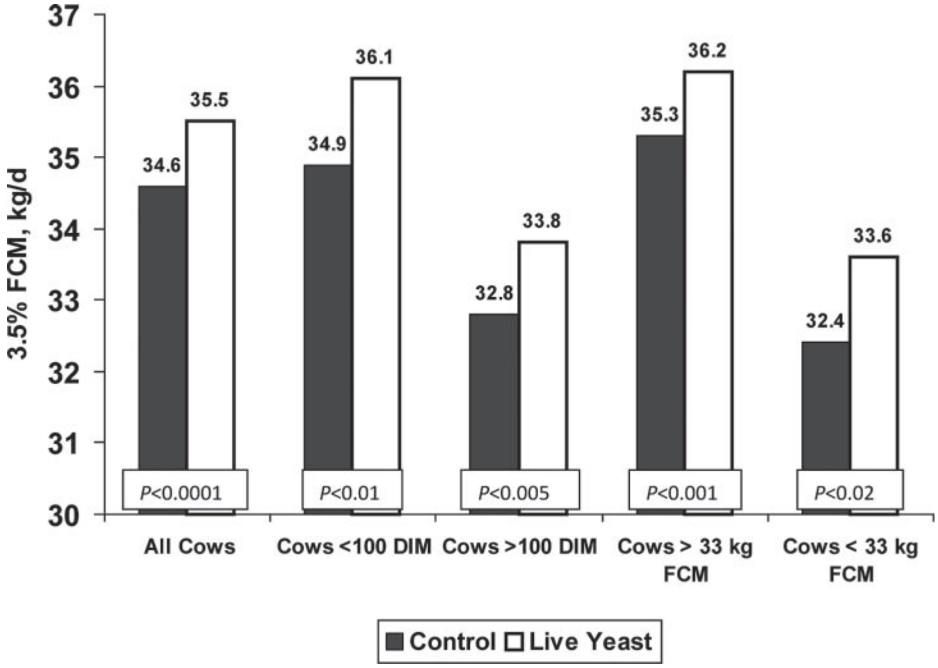

Figure 1. Effect of live yeast supplementation on yield of 3.5% FCM (kg/d) in all cows and according to DIM category (<100 or >100 DIM) and 3.5% FCM of control cows (<33 kg or >33 kg).

Yield of 3.5% FCM was increased ($P < 0.0001$) by 2.8% with live yeast supplementation (35.54 vs. 34.58 kg/d for live yeast and control, respectively; Table 3). Figure 1 shows the effect of live yeast supplementation on yield of 3.5% FCM in all cows and according to DIM category (<100 or >100 DIM) and 3.5% FCM of cows on the control diet (<33 kg vs. >33 kg 3.5% FCM). The effect of live yeast on 3.5% FCM was slightly greater ($P < 0.01$) for cows <100 DIM (36.06 vs. 34.93 kg/d for live yeast and control, respectively) than for cows >100 DIM (33.81 vs. 32.83 kg/d for live yeast and control, respectively; $P < 0.005$). The response of 3.5% FCM to live yeast supplementation was slightly higher for lower-yielding cows: cows producing less than 33 kg 3.5% FCM on the control diets responded with 1.2 kg more ($P < 0.02$) 3.5% FCM (33.63 vs. 32.44 kg/d for live yeast and control, respectively), whereas cows producing more than 33 kg of 3.5% FCM on the control diets increased ($P < 0.001$) 3.5% FCM yield by 0.9 kg (36.23 vs. 35.32 kg/d for live yeast and control, respectively).

The overall effect of live yeast on DMI (kg) was not significant ($P = 0.13$), with control cows consuming 20.35 kg/d and cows supplemented with live yeast consuming 20.53 kg/d. This result is contrary to that of Desnoyers et al. (2009), who concluded that yeast supplementation increased DMI (+0.44 g/kg BW; 0.275 kg/d for BW of 625 kg).

Feed efficiency was improved ($P < 0.001$) by 2.9% with live yeast (1.75 vs. 1.70 for live yeast and control, respectively; Table 3). The live yeast effect on feed efficiency was greater (+0.10) for lower producing cows (<33 kg 3.5% FCM/d) than for higher producing cows (+0.04, >33 kg 3.5% FCM/d; Figure 2). Moallem et al. (2009) increased efficiency of producing 4% FCM by 3.7% with the addition of live yeast to the diet.

Milk fat content was slightly lower ($P = 0.03$) with live yeast supplementation (3.75 vs. 3.80% for live yeast vs. control, respectively; Table 3). However, milk fat yield was higher ($P = 0.01$) when live yeast was added to the diet (1.28 vs. 1.25 kg/d for live yeast vs. control, respectively).

Live yeast supplementation slightly reduced ($P = 0.001$) milk true protein content (2.99 vs. 3.03% for live yeast vs. control, respectively; Table 3). However, due to higher milk yield with live yeast supplementation, yield of milk true protein was higher ($P < 0.0001$; 1.02 vs. 1.00 kg/d for live yeast vs. control, respectively).

Previous research has shown that production responses to supplemental live yeast can be diet dependent. Guedes et al. (2008) improved fiber digestibility with supplemental live yeast more with low-quality corn silage than with high-quality corn

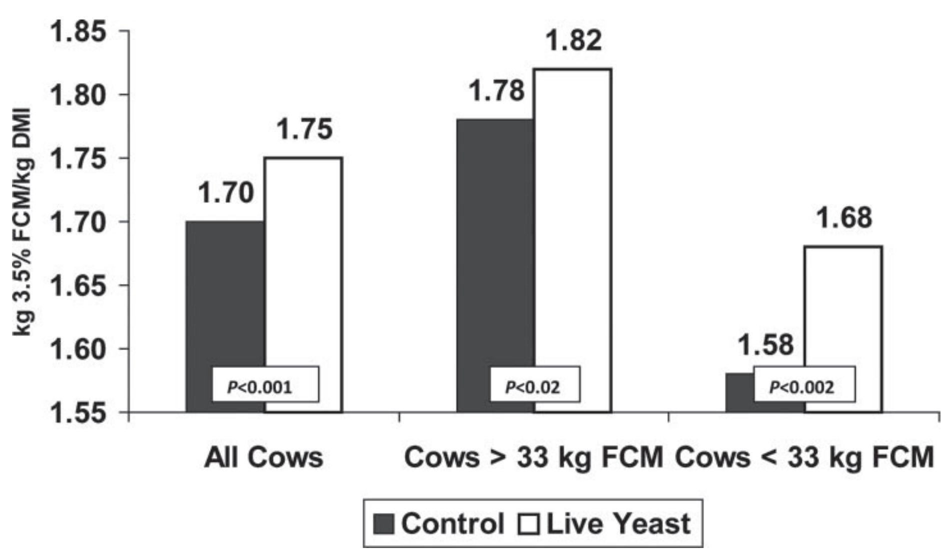

Figure 2. Effect of live yeast supplementation on feed efficiency (kg 3.5% FCM/kg DMI) in all cows and according to initial 3.5% FCM production (<33 kg or >33 kg 3.5% FCM).

Table 4. Significant ($P < 0.05$) nutrient parameter estimates from the milk and milk component linear analysis

Item	Milk, kg	Milk true protein, %	Milk true protein, kg	Milk fat, %	Milk fat, kg
R^2	0.95	0.79	0.94	0.76	0.90
DMI, kg	1.92	−0.04	0.05	−0.09	0.03
Protein A, % DM	−0.96	0.08	—	0.18	—
Protein B_1, % DM	−2.42	—	—	0.37	—
Protein, B_2, % DM	1.72	—	0.04	—	0.05
Protein, B_3, % DM	7.46	—	0.21	—	0.17
Protein C, % DM	—	−0.58	−0.34	−1.08	−0.54
Long-chain fatty acids, kg	—	0.07	0.05	0.15	0.07
Methionine, % metabolizable protein	—	—	—	2.10	1.03
Lysine, % metabolizable protein	6.82	—	—	−0.98	—
Fermentable NDF, kg	1.41	−0.03	0.04	—	0.04
Fermentable starch, kg	0.94	—	0.03	—	—
Fermentable soluble fiber, kg	0.92	—	0.03	−0.17	—

silage. Because live yeast has been shown to increase rumen pH and reduce rumen pH variation (Bach et al., 2007; Moya et al., 2007; Thrunel et al., 2007; Guedes et al., 2008), greater production responses would also be expected with dietary factors that increase the incidence of subclinical rumen acidosis. The CPM-Dairy input data provide insight into the nutrient variance among the studies used to establish the response to live yeast. Including these nutrient parameters in the statistical analysis improved the prediction of responses to supplemental live yeast as evidenced by the R^2-values higher than 0.90 for all yield responses (Table 3).

Nutrient parameter estimates for each of the nutrient variables [DMI (kg); protein fractions A, B_1, B_2, B_3, and C (% DM); long-chain fatty acids (% DM); methionine (% metabolizable protein); lysine (% metabolizable protein); fermentable NDF (% DM); fermentable starch (% DM); and fermentable soluble fiber (% DM)] were generated for each dependent variable, including milk yield (kg), milk true protein content (%), milk true protein yield (kg), milk fat (%), and milk fat yield (kg) (Table 4). These relative numbers indicate which nutrients had the most positive or negative effect when predicting the dependent variable. Dry matter intake (kg), amount of protein fraction B_3 (% DM), and lysine (% metabolizable protein) had a greater positive effect on milk yield (kg) than did other diet nutrients. Methionine (% metabolizable protein) had a sizable effect on both milk fat content and yield of milk fat. Higher levels of soluble protein (A and B_1) had a negative effect on milk yield.

Live yeast increased 3.5% FCM yield and feed efficiency across multiple experiments with varying diets. The improvement in 3.5% FCM yield and feed efficiency, with the inclusion of live yeast without any effect on DMI ($P > 0.10$), could be a consequence of improved rumen function (Chaucheyras-Durand and Fonty, 2001; Bach et al., 2007). Increasing fiber digestion and controlling rumen pH should increase microbial yield due to increased substrate availability and improved function of the rumen microbial population.

IMPLICATIONS

The improvement in 3.5% FCM yield and feed efficiency, with the inclusion of live yeast, could be a consequence of improved rumen function. Further investigations should provide opportunities to design optimized diets with the inclusion of live yeast.

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