EFFECTS OF THE INCLUSION OF YEAST CULTURE 
(SACCHAROMYCES CEREVISIAE PLUS GROWTH MEDIUM) 
IN THE DIET OF DAIRY COWS ON MILK YIELD 
AND FORAGE DEGRADATION AND FERMENTATION 
 PATTERNS IN THE RUMEN OF STEERS

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ABSTRACT 
The effects of including yeast culture (YC; Saccharomyces cerevisae plus growth medium; $5 \times 10^9$ organisms/g) in diets for ruminants was examined in two experiments. In Exp. 1, 32 multiparous Friesian dairy cows were fed between wk 7 to 12 of lactation one of four completely mixed diets based on either hay or straw plus rolled barley (mixed to give concentrate:forage ratios of either 50:50 or 60:40, respectively) with or without 10 g YC/d in a $2^3$ factorial design. Supplementation with YC increased DM intake of the cows by a mean of 1.2 kg/d ($P \leq 0.062$) and increased milk yield by 1.4 liters/d (corrected to 4% butterfat; $P \leq 0.05$. There was an interaction ($P < 0.05$) between diet composition and YC addition; effects of YC were greatest in diets containing 60:40 (concentrate:forage) ratio. In Exp. 2, three steers were fed a diet of 50% hay and 50% rolled barley (DM basis). Hay was available for the major part of the day but barley was fed in two meals/d. Addition of YC to the diet increased ($P < 0.05$) ruminal pH for 4 h after the barley meal. This elevation in pH probably was due to a reduction ($P \leq 0.01$) in the concentration of L-lactate in the ruminal liquor of steers given YC (1.43 vs 3.55 mM; $P \leq 0.01$). Peak ruminal L-lactate concentration (7.75 mM) in the controls coincided with time of minimum pH values (2 h after the meal of barley); this peak was absent in steers given YC. YC had no effect on the concentration of VFA in ruminal liquor, but the ratio of acetate to propionate was reduced ($P \leq 0.01$) from 3.3:1 to 2.8:1 in steers given YC. The extent of DM degradation of hay incubated in the rumen of steers fed the hay and rolled barley diet was increased ($P < 0.05$) in the presence of YC at 12 h of incubation, but degradation was similar in all treatment groups after 24 h of incubation. Presence of yeast culture in the rumen had effects on ruminal stoichiometry. An increased rate of forage degradation may have increased forage intake and productivity of these dairy cows. 

Key Words: Ruminants, Rumen Fermentation, Yeasts, Probiotics 


Introduction 
Fungal microorganisms nor normally encountered in the rumen, in particular the yeast Saccharomyces cerevisiae, may multiply and exhibit growth in the rumen or in rumen-

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2Mention of commercial products or sources in this paper does not constitute endorsements by the ARS. 
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simulating continuous cultures and confer beneficial effects on cellulolysis and growth or productive capacity of the host animal (Wiedmeier et al., 1987; Dawson and Newman, 1988; Harrison et al., 1988). Dawson (1987) reported that Saccharomyces cerevisiae multiplied when introduced into rumen simulators, although at some point extensive cell lysis probably occurs with extrusion of the cell contents (Bruning and Yokoyama, 1988). Because certain strains of Saccharomyces cerevisiae are facultative anaerobes, their growth in the rumen is not totally unexpected.
TABLE 1. COMPOSITION AND CHEMICAL ANALYSES OF DIETS OFFERED TO DAIRY COWS IN EXP. 1.

<table>
<thead>
<tr>
<th>Ingredient composition</th>
<th>50:50 Concentrate:forage</th>
<th>60:40 Concentrate:forage</th>
<th>Commercial dairy concentrate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Straw-based, %</td>
<td>Hay-based, %</td>
<td>Straw-based, %</td>
</tr>
<tr>
<td>Hay</td>
<td>—</td>
<td>50.0</td>
<td>—</td>
</tr>
<tr>
<td>Ammonia straw</td>
<td>50.0</td>
<td>—</td>
<td>40.0</td>
</tr>
<tr>
<td>Rolled barley</td>
<td>35.2</td>
<td>35.0</td>
<td>43.8</td>
</tr>
<tr>
<td>Beet pulp</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Soybean meal</td>
<td>2.0</td>
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<td>2.0</td>
</tr>
<tr>
<td>Fishmeal</td>
<td>4.0</td>
<td>4.0</td>
<td>4.8</td>
</tr>
<tr>
<td>Molasses</td>
<td>6.0</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Protected fat</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Urea</td>
<td>.8</td>
<td>1.0</td>
<td>.85</td>
</tr>
<tr>
<td>Limestone</td>
<td>.5</td>
<td>.5</td>
<td>.7</td>
</tr>
<tr>
<td>Hiphos b</td>
<td>1.38</td>
<td>1.38</td>
<td>1.35</td>
</tr>
<tr>
<td>Sodium sulfate</td>
<td>.12</td>
<td>.12</td>
<td>.10</td>
</tr>
<tr>
<td>Chemical composition</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ruminally degradable nitrogen/MJ</td>
<td>1.37</td>
<td>1.36</td>
<td>1.39</td>
</tr>
<tr>
<td>Energy content, MJ of ME/kg DM</td>
<td>10.02</td>
<td>10.45</td>
<td>10.59</td>
</tr>
</tbody>
</table>

*On DM basis.

bTo supply the following in grams/kilogram: Ca, 200; P, 150; NaCl, 100; Mg, 50; in milligrams/kilogram: Cu, 1,500; Co, 150; Mn, 4,400; Zn, 1,800; I, 80; Fe, 6,000; Se, 16; and in IU/kilogram; vitamin A $5 \times 10^{5}$; vitamin D, $1 \times 10^{5}$; vitamin E, 500.

Beneficial effects from the inclusion of yeast culture in diets for dairy cows have been reported, although little scientific evidence supports these claims. Experiments have been equivocal with respect to the responses obtained. Increases in fat-corrected milk yield of 5% were obtained from cows given totally mixed rations and supplements of either Saccharomyces cerevisiae (Harris and Lobo, 1988) or Aspergillus oryzae (Kellens et al., 1988), whereas no effect was obtained in two experiments using supplements of Saccharomyces cerevisiae (Arambel and Kent, 1988; Quinonez et al., 1988). Diet composition may have influenced these results.

We conducted two experiments to assess the effects of including yeast culture (YC) in diets for ruminants.

Materials and Methods

The effects of the addition of YC (Saccharomyces cerevisiae plus growth medium; $5 \times 10^{6}$ organisms/g) in diets for ruminants was examined in two experiments. The yeast, though produced commercially, was a flocculent strain of Saccharomyces cerevisiae obtained from the National Collection of Yeast Culture in Nutfield, Surrey, U.K. and is referred to as strain 1026. Viable cell counts on the culture are those reported by the manufacturer and were estimated using both the methylene blue staining method (Lindgren, 1949) and slide culture technique (Gilliland, 1959). In Exp. 1, the effects of addition of YC to complete diets for dairy cows on milk yield and composition was tested; in Exp. 2, effects on ruminal metabolism were monitored in three cannulated steers. All experiments described in this paper using live animals were carried out under license from authorities granted by the Secretary of State under the Cruelty to Animals Act 1876/Animals (Scientific Procedures) Act 1986.

Experiment 1

Diet Formulation. Four complete diets were formulated using concentrates (based on rolled barley, soybean meal, and fishmeal) and forage (timothy and rye grass hay mixture or ammonia-treated wheat straw, variety Norman) with the concentrate:forage ratio either at 50:50 or 60:40 on a DM basis (Table 1). Weighed amounts of hay or treated straw were milled through a 400-mm screen, mixed in a mixer.
trailer with the required amounts of the concentrate, and stored until required for feeding. All diets were sampled weekly and composited monthly for chemical analyses.

Animals and Management. Based on previous milk yield, 32 multiparous Friesian dairy cows were allocated to nutritional treatments (excluding YC) 3 d before calving in a randomized $2^3$ factorial design, with eight cows on each level and type of forage. The cows calved over a period of 9 d and were offered one of the four complete mixed dairy diets, but the YC was not included in the diets, within 3 d of calving. All animals were housed in separate cubicles in a dairy barn, with water available constantly; cows were exercised regularly. Feed was available separately ad libitum to each individual with weighed amounts of fresh feed offered daily; once every 7 d the feed hoppers were emptied and refused feed was recorded, allowing weekly estimations of feed intake. The cows were milked twice daily; all cows received in addition to the above diets 0.5 kg of a commercial dairy concentrate (Table 1) and individual milk yields of all cows were recorded daily throughout lactation. Samples of milk were removed from analysis from morning and afternoon milkings once every week. All animals were weighed once every 7 d.

At the end of wk 6 of lactation, YC was added to the diet of four cows in each treatment group. Within each dietary treatment group, cows were paired according to milk yield during wk 6; one cow in each pair was allocated randomly to receive YC. The YC culture was top-dressed, in a premix, to the diet. All cows remained on the experiment until the end of wk 12 of lactation.

The YC culture was mixed in a horizontal mixer with rolled barley such that 250 g of the mixture contained 10 g of yeast culture. From the beginning of wk 7 of lactation, all cows received either 250 g of YC/d or 250 g of the barley premix alone, according to treatment.

The digestibility of the diets was measured with two cows on each diet $\times$ YC treatment; measurements were made as each cow finished the experiment at the end of wk 12 of lactation. The cows were kept in metabolism stalls for periods of 7 d, during which total collections of urine and feces were made. Samples were obtained from each daily collection (10% of daily total) and stored at 1°C for later analysis.

Experiment 2

The aim of this experiment was to determine the effects on ruminal metabolism and on degradation of a forage using the nylon bag technique (O'rskov and McDonald, 1970) when YC was added to two contrasting diets given to young steers. The diets were either a high-forage diet of hay or a mixture of forage plus barley fed in such a manner as to induce a negative associative effect (i.e., in order to depress cellulolysis the barley was ground and fed in two meals rather than in a complete diet) (Williams, 1983/84).

Animals and Management. Three Friesian steers, each weighing approximately 200 kg, that 1 yr earlier, under general anesthesia and using full aseptic techniques, had been fitted with ruminal cannulas, were individually penned and given diets of either hay plus rolled barley or hay alone. The diets were given to the steers without or with a supplement of 7.5 g of YC/d, giving a total of four diet-supplement treatments. Each treatment was given to the steers for a minimum of 35 d.

The YC supplement was top-dressed onto the morning feed. Half of each steer's daily allowance of feed was given at 0700 and the remainder at 1600. The same amount of feed was given to all three steers at a level estimated to be 90% of their ad libitum intake. Measurements were made over the last 14 d of each 35-d period. At the time that the experiment was designed, no information was available with respect to cross-contamination between animals in adjacent pens given live yeast cultures. For this reason all three steers were given the same treatment at the same time; the period-treatment sequence was hay plus barley, hay plus barley plus YC, hay alone, and, finally, hay plus YC.

Diets. The hay was a mixture of timothy and rye grass; each steer was given an allowance of 4 kg/d. The barley was rolled and, when given with the hay, each steer received a daily allowance of 2 kg barley plus 2 kg hay.

Ruminal Metabolism and Degradability Estimations. Recordings of ruminal metabolism and degradation estimations were made in all steers given the four dietary combinations. Ruminal pH was determined on samples drawn from the rumen via the ruminal cannula on six occasions at 2-h intervals on two consecutive days. The pH was recorded immediately with a pH electrode; the ruminal liquor was strained.
through a double thickness of cotton gauze and duplicate samples were stored at 1°C for future chemical analyses. The degradation of samples of hay was determined with duplicate nylon bags in each steer, on two separate days for each incubation period, yielding six estimates of the degradation of the material at any one time (Ørskov et al., 1980).

**Chemical Methods.** Milk was analyzed for N by the method of Davidson et al. (1970), fat by the Gerber method (Ling, 1949), and total solid by oven drying (AOAC, 1984).

Volatile fatty acids were determined by gas-liquid chromatography\(^4\) using a 1.5-mm × 4-mm i.d. glass column packed with 10% SP 1200 and 1% H\(_3\)PO\(_4\) on Chromosorb WAW, 80/100 mesh;\(^5\) the column was operated at 125°C. Peak areas were integrated using an SP 4200 integrator.\(^6\) The concentration of L-lactate in ruminal fluid was estimated by the automated method of Hochella and Weinhouse (1965) using porcine L-lactate dehydrogenase. Total hexose sugars (mono-, oligo-, and any soluble polysaccharides) were determined as glucose by the anthrone colorimetric procedure (Southgate, 1976). The sample was heated in 67% (vol/vol) H\(_2\)SO\(_4\) to convert all oligosaccharides to monomeric hexose units, and color was developed by the action of glucose with thiourea and anthrone. The DM concentration of feeds and feces was estimated by drying to constant weight at 100°C. Ash was determined by heating at 500°C and N by the method of Davidson et al. (1970).

**Statistical Analyses.** In Exp. 1, all treatment effects were tested using wk 1 to 6 of lactation to adjust by covariance for differences that occurred among treatment groups, up to the start of the experiment on wk 7. Differences between treatments were tested by ANOVA with the four dietary treatments and plus or minus YC as main effects using the between-animal variation as the test statistic. Fat-corrected milk yield was calculated using the formula of Gaines and Overman (1938) in which milk yield was adjusted to 4% butter fat = [milk yield × .04] + [fat yield (kilograms/day) × 15].

We would have preferred to run 2 in a switchback design; however, constraints on animal use made it possible to carry out the measurements only with vs without the addition of YC, omitting the final switch back from YC to control. In the absence of a final period, the effects of time and test periods of measurement could not be taken into account, and period and treatment were confounded. However, because our aim was to determine the effects of YC on ruminal fermentation parameters, all external conditions were the same over each period of measurement, so it is highly unlikely that animal effects between the two measurements with or without YC (which were essentially 28 d apart) would have influenced the ruminal responses.

Degradation curves of the hay were plotted using the method of Ørskov and MacDonald (1970) and differences between degradation values were tested by ANOVA.

**Results**

**Experiment 1**

Fat-corrected milk yields from wk 1 to 6 of lactation, before the addition of YC to the diets as well as the effects of YC on milk yield and milk composition from wk 7 to 12 are shown in Table 2. Covariate analysis was used to adjust for differences at the beginning of the experimental period (wk 7) in milk yield, total protein production, fat-corrected milk yield, and dry matter intake (covariate adjustment \(P ≤ .001\) in each instance); the adjusted values for all criteria are given in Table 2. The composition of the diet had an effect on certain responses to the addition of YC to the diet (interaction \(P < .05\)). Although the effect of the addition of YC on fat-corrected milk yield was significant overall (\(P ≤ .05\)), an interaction between diet and YC (\(P ≤ .061\)) was detected; effects occurred only in diets containing the high level of concentrate (60:40 concentrate:forage ratio). Examination of the uncorrected milk yields and composition also indicated that the responses of the cows differed due to the type of forage given. With treated straw in the diet, inclusion of YC had no effect on milk yield, but butter fat concentration tended to increase; with hay as the source of roughage, milk yield tended to increase but percentage of butterfat tended to fall when YC was fed. Only the increase in milk yield by cows given the 60:40 concentrate:hay diet plus YC was significant.

\(^4\)PU 4500 chromatograph, Philips Scientific Ltd., Cambridge, UK.
\(^5\)Supelco, Inc., Bellefonte, PA.
\(^6\)Spectra Physics Ltd., St. Albans, UK.
TABLE 2. EFFECTS OF YEAST CULTURE (YC) IN THE DIET OF DAIRY COWS ON MILK YIELD, MILK COMPOSITION, PAT-CORRECTED MILK YIELD, AND DRY MATTER INTAKE.

<table>
<thead>
<tr>
<th>Diet composition</th>
<th>50:50 Concentrate:forage</th>
<th>60:40 Concentrate:forage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Straw</td>
<td>Hay</td>
</tr>
<tr>
<td>Control</td>
<td>YC</td>
<td>Control</td>
</tr>
<tr>
<td>No. of cows</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Weeks 1 to 6 of lactation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milk yield, kg/d</td>
<td>19.3</td>
<td>21.5</td>
</tr>
<tr>
<td>Fat-corrected milk yield, kg/d</td>
<td>3.64</td>
<td>3.64</td>
</tr>
<tr>
<td>Butterfat, %</td>
<td>4.1</td>
<td>4.1</td>
</tr>
<tr>
<td>Total protein, %</td>
<td>3.6</td>
<td>3.6</td>
</tr>
<tr>
<td>Dry matter intake, kg/d</td>
<td>710.9</td>
<td>692.2</td>
</tr>
<tr>
<td>Dry matter intake, %</td>
<td>18.1</td>
<td>18.1</td>
</tr>
</tbody>
</table>

*Yields adjusted for differences occurring at the start of the trial; adjustments were made using yields over wk 1 to 6 of lactation.

Daily milk protein production was altered by a significant diet × treatment interaction. Daily milk protein production was increased only in cows given the high-concentrate diet plus YC. No effect of YC treatment on production of total milk solids was detected.

There was no significant effect of YC on the live weight changes of cows, although there was a tendency for the live weight gains by cows given the supplement of YC to be greater (+13.5 kg) than that by control cows (+8.7 kg).

These results suggest strongly that the increased milk yield occurred as a result of an increase in feed intake. Dry matter intake was increased by 1.2 kg/d (P ≤ .002) in cows given YC (Table 2). For DMI, no YC × dietary interaction was detected. Intake was increased on all dietary treatments; however, only for diets with the 60:40 concentrate:forage ratio was intake increased substantially (2.3 vs .9 kg DM/d).

The DM digestibility coefficient of all four diets without YC was 63%; with YCh it was 64%. There was no effect either of diet composition or of inclusion of yeast culture on the DM digestibility of the diets; it is unlikely that effects would have been detected with only two cows on any one diet × YC treatment.

**Experiment 2**

Each meal of barley was rapidly consumed by the steers; little remained 30 min after the meal was offered. Consumption of hay tended to be spread throughout the day.

The molar concentration of VFA in the ruminal liquor of the steers given the hay plus barley diet tended to be lower in steers given YC; mean molar concentrations from the three steers with six sampling times over a period of 12 h were 73 vs 78 mM in ruminal fluid (SD = 16.9) from steers given diets with vs without YC, respectively. In both groups, molar concentrations peaked between 2 and 3 h (84 and 88 mM with or without YC, respectively) after the barley meal and declined thereafter. However, the mean acetate:propionate ratio was reduced (P ≤ .01) from 3.3:1 to 2.8:1 (SD = .144) in steers given YC compared with the controls (Figure 1). Levels of butyrate tended to be lower in steers given YC (mean molar proportions, 6.96 and 8.58 meq/liter in steers given YC and controls, respectively; SD =
Yeast culture had no effect on the proportions of valerate or the branched-chain VFA.

The pH of ruminal liquor in steers is shown in Figure 2; each point is the mean ± SE of values obtained for the three steers. On the 2 d and following each meal of barley, the presence of YC in the feed reduced (\(P \leq .05\)) the depression in ruminal pH, which occurred immediately after barley was given and persisted for 4 h. There was no difference between values recorded with vs without YC from 4 h after the barley was given until the start of the next feeding cycle.

Levels of L-lactic acid in the rumen of steers are shown in Figure 3; each point represents the mean ± SE of values obtained for the three animals. The presence of YC resulted in an overall lower (1.43 vs 3.55 mM; \(P \leq .01;\) SD = 2.35) level of lactic acid in the ruminal liquor; YC prevented a peak in lactic acid concentration, which occurred 2 h after the meal of barley.

The concentration of total oligosaccharides composed of hexose units was low in ruminal liquor but was increased (\(P < .001\)) by the addition of barley to the diet compared with feeding hay alone (.97 vs .28 mg/ml). Although the values tended to be lowest immediately before and at 7 h after a meal of barley compared with 2 h after the meal, it was difficult to identify a consistent time pattern in the concentrations of oligosaccharides in ruminal liquor (Figure 4). However, addition of YC to the diet reduced (\(P \leq .001\)) the mean level of hexose units (1.37 vs .58 mg/ml ruminal liquor; SD = .099).

The curves for degradation of hay incubated in the rumen of the steers with or without YC and their coefficients plotted according to the method of Ørskov and MacDonald (1970) are shown in Table 3. Supplementation of the basal hay diet with barley reduced (\(P \leq .01\)) the rate constant of the hay. Addition of YC increased (\(P < .05\)) the amount of hay degraded in 12 h but it had no effect at longer incubation time periods. The effect was most marked when the diet contained both barley and hay; however, the interaction was not significant. There was a tendency for lag time to be reduced by the addition of YC with both the hay and hay plus barley diets.

**Discussion**

The presence of YC (*Saccharomyces cerevisiae* plus growth medium) in complete diets fed to dairy cows increased feed intake; this may be responsible for the increased fat-corrected milk yield. Responses were greatest in cows fed the diet containing the higher level of rapidly fermentable carbohydrate. The
results obtained with the steers indicated that the presence of YC altered ruminal fermentation patterns and ruminal pH.

Dry matter intake of the complete diet by the cows was increased by 1.2 kg/d of the complete diet when YC was added. Energy balance of the cows was calculated (energy value for fat-corrected milk = 5.3 MJ of ME/liter; 34 MJ of ME/kg of BW gain of the cow and 63 MJ of ME/d for the maintenance requirement of a cow weighing 600 kg) based on estimates by the Ministry of Agriculture, Fisheries and Food, Department of Agriculture and Fisheries for Scotland and Department of Agriculture for Ireland (MAFF, 1984). Based on the overall treatment means in Table 2, after accounting for the maintenance requirement and changes in live weight during the treatment period, cows given YC required an extra 11.4 MJ of ME/d to provide the extra milk and live weight gain. The ME value of the complete diets (9.3 MJ of ME/kg of DM) was estimated from the mean DM digestibility of the four diets (63%) and equations given in
TABLE 3. EFFECTS OF THE ADDITION OF YEAST CULTURE (YC) ON THE DEGRADATION OF HAY INCUBATED IN THE RUMEN OF STEERS GIVEN DIETS OF HAY ALONE OR HAY PLUS ROLLED BARLEY

<table>
<thead>
<tr>
<th>Incubation time, h</th>
<th>Dry matter loss (%) from nylon bags</th>
<th>Probability level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control YC</td>
<td>Control YC</td>
</tr>
<tr>
<td>12</td>
<td>28.9</td>
<td>31.0</td>
</tr>
<tr>
<td>24</td>
<td>34.0</td>
<td>36.3</td>
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<td>36</td>
<td>49.4</td>
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<tr>
<td>48</td>
<td>58.8</td>
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</tr>
<tr>
<td>Intercept</td>
<td>-19.0</td>
<td>-9.8</td>
</tr>
<tr>
<td>Potential degradation</td>
<td>65.9</td>
<td>59.2</td>
</tr>
<tr>
<td>Rate constant</td>
<td>.0263</td>
<td>.0185</td>
</tr>
</tbody>
</table>

*Coefficients obtained from degradability curves plotted using the method of Ørskov and McDonald (1979).

MAFF (1984). The additional DMI provided 11.1 MJ of ME/d extra for cows given YC; this equates well with the additional energy required for milk and weight gain. No other physiological effect need be proposed to explain the effects of YC. Similar results were obtained when the same YC was fed to dairy cows given either a complete diet of barley plus grass silage or a diet of barley plus silage fed separately (Bax, 1988). Small but consistent increases in feed intake and milk yield were obtained in cows given the silage diets plus YC compared with controls, but responses were greatest when the components were fed separately; with both diet combinations, the extra energy consumed in the feed was sufficient to account for the increased milk yield.

The effects of starch and sugars in the diets of ruminants and the constraints that they impose on forage digestion (i.e., negative associative effects) have been reported extensively. Stewart (1977) demonstrated that the activity of cellulolytic bacteria was depressed by a reduced ruminal pH. The presence of starch and sugars in the rumen depresses ruminal pH and impairs the degradation of forage (Williams, 1983/84). Part of this effect is due specifically to the presence of the rapidly fermentable carbohydrates (Mould and Ørskov, 1983/84); the negative effect is intensified as the level of feeding is raised above 1.5 times maintenance (Byers et al., 1982). In Exp. 1 the effect of YC was greatest with the 60:40 concentrate to forage ratio compared with the 50:50 ratio; and in the experiment of Bax (1988) the effect was greatest when the concentrate allowance was given in two meals rather than as a complete diet. These responses to YC seem to be greatest with the diet or feeding system that would compromise cellulolysis the most. This would suggest that the action of YC may be related partly to the alleviation of negative associative effects influencing cellulose digestion.

After the barley meal was given, the minimum ruminal pH was approximately .5 pH unit higher when the diet contained YC;

![Graph](image)

Figure 4. Concentrations of hexose-unit oligosaccharides in ruminal liquor of steers given diets of hay plus barley in the ratio 1:1 on a DM basis with (◇) or without (●) yeast culture. Vertical bars on each point represent ± SE.
this elevation probably was related to the elimination of a lactate peak and the reduction in concentration of lactic acid in the ruminal liquor. The maximum pH depression in steers given the un-supplemented diet occurred at the same time as the peak lactate concentration. A similar peak in lactic acid concentration was reported in cows fed a starch-based concentrate (Malestein et al., 1981); their peak concentration (6.5 mM) occurred 1 h after the concentrate was given, followed by a rapid decline to baseline levels. Recent studies with sheep fed a mixed diet of barley concentrate plus dried grass in a 1:1 ratio (fed continuously from belt feeders) have shown similar significant reductions in ruminal lactate concentrations and small elevations in ruminal pH when YC was added to the diet (Newbold et al., 1990). The fact that in Exp. 2 the pH modulation existed for only 4 h after the barley was given could explain why other authors have not detected an effect of YC on ruminal pH (Harrison et al., 1988). The effects of pH on the depression of cellulolysis is related not only to the absolute level of pH (Stewart, 1977), but also to the duration of time during which the pH is depressed (Istas and Ørskov, 1983). Improvements in cellulolysis as a result of elevated ruminal pH may increase the rate of forage digestion. In the presence of YC, the lag time for degradation of DM of hay tended to be reduced; this reduction occurred when the diet was based on either hay alone or hay plus rolled barley. These results have been confirmed by Chadema and Offer (1990); diets ranging in concentrate:forage ratios from 10:90 to 60:40 were fed to wether sheep with or without YC, and the degradation of hay in the rumen was measured. At every concentrate:forage ratio, the presence of YC increased the disappearance of hay organic matter incubated in the rumen for 24 h (P ≤ .05); however, YC had no effect when the bags were incubated for 48 h. These two sets of data indicate that YC increases the initial rate of degradation of fibrous materials in the rumen.

The beneficial effect of YC in increasing the voluntary intake of calves (Fallon and Harte, 1987; Hughes, 1988) also may be related to pH modulation via reductions in lactic acid concentration. Williams et al. (1985) reported that low ruminal pH from diets high in rapidly fermentable starch fed to young calves was a factor limiting appetite and that low pH was related to high levels of lactic acid in the developing rumen (Frost and Nevison, 1989).

Lactic acid is not used as a substrate by *Saccharomyces cerevisiae* for growth (Panchal et al., 1984); therefore, the major reduction in lactate concentration may result from the use of a lactate precursor, from the inhibition of lactate production, or from the stimulation of lactate use by other microorganisms. The reduction in concentration in ruminal liquor of total oligosaccharides, including such hexose-containing sugars as maltose and maltotriose, in the presence of YC (Figure 4) may be important because both these oligosaccharides enter the cell of *Saccharomyces* and related genera by the action of a permease, where they are converted to glucose and are substrates for yeast growth (Panchal et al., 1984). However, although active yeast fermentation should produce ethanol, no ethanol was detectable in ruminal liquor of steers given YC (P.E.V. Williams, unpublished data). The presence of short-chain sugars in ruminal liquor probably is the result of α-amylase activity on starch present in grain in the diet (Hungate, 1966). The reduction in concentration of these sugars in the presence of YC may be responsible for the fall in lactate that generally is considered to increase when sugars and other rapidly fermented feeds are added to the rumen (Hungate, 1966).

Harrison et al. (1988) concluded that the action of a similar yeast culture also containing *Saccharomyces cerevisiae*, but produced under different conditions, was to stabilize ruminal fermentation with less variation in ruminal ammonia and microbial numbers and lower standard errors on measurements of in vitro gas production and total VFA production. The present series of experiments tends to confirm that the addition of YC increases ruminal stability in terms of ruminal pH, lactate concentration, and acetate to propionate ratios.

The stabilization of the ruminal environment, and especially the elevation in ruminal pH, could be the reason for the increase in total anaerobic bacteria and, in particular, could explain the increase in cellulolytic bacteria seen when yeast cultures were added to diets for ruminants or to rumen simulators (Wiedmeier et al., 1987; Dawson and Newman, 1988; Harrison et al., 1988). In the present trial, the reduction in the acetate:propionate ratio, confirming other results (Harrison et al., 1988; Newbold et al., 1990),
indicates that YC had a major effect on fermentation stoichiometry in the rumen. It is not surprising that in this and other studies (Wiedmeier et al., 1987; Harrison et al., 1988) there was no major effect on the DM digestibility of the diet, because changes in bacterial numbers may influence the rate of fiber digestion and, hence, intake, but the digestibility of the diet is more related to the physicochemical structure of the forage and ruminal retention time (Hovell et al., 1986). The presence of YC would be unlikely to influence the cellular structure of the plant tissue.

Implications

Addition of a fungal culture containing live yeast cells to the diet of dairy cows may elevate milk yield, probably via stimulation of intake. The precise component of the fungal culture that affects metabolism in the rumen is unknown; however, the effect seems to be mediated via a reduction in ruminal lactate and an elevation in ruminal pH. The use of live fungal cultures can modify ruminal metabolism and increase milk production of dairy cows.

Literature Cited


