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The Use of Live Yeast Products as Microbial Feed Additives in Ruminant Nutrition

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ABSTRACT

Various feed additives are in widespread use in diets of ruminants to modulate rumen metabolism which ultimately may enhance nutrient utilization and animal performance. Yeast products such as *Saccharomyces cerevisiae* and *Aspergillus oryzae* are often utilized in ruminants to improve nutrient utilization, rumen fermentation characteristics, milk production and daily gain. Yeast additives may exert positive effects on digestibility especially fiber components, probably by stimulating the cellulolytic microbial populations in the rumen. Rumen fermentation characteristics such as increased total volatile fatty acids, stabilization of rumen pH and decreased lactate concentration might be observed due to yeast supplementation. The increase in feed utilization and improvement of rumen fermentation along with increased dry matter may also enhance milk production and animal performance. Although, the favourable responses of yeast inclusion are usually moderate in ruminant nutrition, these responses are not always observed. The discrepancies of responses of yeast inclusion as a feed additive in different experiments might be attributed to dose, type of diets, strains of yeast, physiological stage and feeding systems. Therefore, yeast products should be added in diets by taking consideration of various interaction factors to achieve the consistent beneficial responses of yeasts in ruminant nutrition.

Key words: Live yeast, nutrient utilization, rumen fermentation, performance, ruminants

INTRODUCTION

During the past decades, scientists have shown greater interests in manipulating the microbial ecosystem of the rumen in order to improve the production efficiency. Most recently, ruminant nutritionists and rumen microbiologists are exploring various alternative solutions to the growing concerns over the use of antibiotics and other growth promoters in the animal feed industry. Digestion processes in the rumen can be manipulated by the addition of direct feed microbials to enhance feed digestion, to improve the performance of animals, to boost the health status of animals (Newbold *et al*., 1996; Robinson and Erasmus, 2009; Desnoyers *et al*., 2009). A number of microbial feed additives are used in both ruminants and non-ruminant for these purposes. Yeast products such as *Saccharomyces cerevisiae* and *Aspergillus oryzae* appear to be more useful in manipulating rumen metabolism. As a result, the use of *S. cerevisiae* as a microbial feed additive has increased during the past 20 years. However, the response of yeasts is not consistent on the nutrient utilization, rumen fermentation and production which depends upon several factors. This study reviews the response of yeast products and the factors determining their effects in ruminant nutrition.

EFFECT ON NUTRIENT UTILIZATION

Addition of yeast in diets of ruminants resulted in both positive and no effects on different nutrient digestibilities. Yoon and Stern (1996) reported that, Organic Matter (OM) and Crude Protein (CP) digestibility increased when they were fed with yeast culture (*S. cerevisiae*) (57 g day^{-1}) along with a basal diet containing 32.5% corn silage, 17.5% alfalfa hay, 35.3% corn grain and 12.7% soybean meal. Harris *et al.* (1992) and Kholif and Khorshed (2006) also noted a positive effect of yeast supplementation on digestion of Acid Detergent Fiber (ADF), Neutral Detergent Fiber (NDF), cellulose, hemicellulose and crude fiber. Wiedmeier *et al.* (1987) reported that Dry Matter (DM) and hemicellulose digestibility was increased on addition of yeast culture (90 g day^{-1}) and *A. oryzae* (2.63 g day^{-1}) along with a basal diet in non-lactating cows. Nutrient digestibility increases due to yeast supplementation which might be attributed to the stimulation of growth of rumen microbial populations (Harrison *et al.*, 1988). It has been suggested that yeasts may scavenge available oxygen on the surfaces of freshly ingested feeds to maintain metabolic activity thus deceasing redox potential in the rumen (Chaucheyras-Durand *et al.*, 2008). This change creates better conditions for the growth of strict anaerobic cellulolytic bacteria, stimulates their attachment to forage particles (Roger *et al.*, 1990) and increases the initial rate of cellulolysis. In addition, *S. cerevisiae* may provide growth factors, such as organic acids or vitamins, thereby stimulating ruminal populations of cellulolytic bacteria (Chaucheyras *et al.*, 1995). An increase in the number of total bacteria (Koul *et al.*, 1998), cellulolytic bacteria (Wiedmeier *et al.*, 1987; Harrison *et al.*, 1988; Koul *et al.*, 1998) and proteolytic bacteria (Yoon and Stern, 1996) was observed when the yeast culture was used as a feed supplement in ruminants.

In contrast to positive effect of yeast on digestibility, Doreau and Jounay (1998) reported no alteration of total and ruminal digestibilities of OM by the addition of *S. cerevisiae* but ruminal dry matter content increased when lactating dairy cows were fed with 50 g of premix containing 0.5 g of *S. cerevisiae* (6×10^8 CFU g^{-1} of premix) along with a diet containing 60% corn silage and 40% concentrates. Enjalbert *et al.* (1999) reported that, feeding of non lactating cows with yeast culture (0.5%) along with basal diet containing corn silage, wheat grain and protein concentrate did not change the degradation of DM, NDF or ADF from hay suspended in nylon bags or coefficients of degradation kinetics. Putnam *et al.* (1997) also in a study with early lactating Holstein cows reported no effect of supplementation of yeast culture (10 g day^{-1}) on ruminal digestibility. In sheep, Kawas *et al.* (2007a) revealed that the yeast addition to the finishing diets for lambs had no effect on DM, NDF or non-fibrous carbohydrates digestibility. Harrison *et al.* (1988) reported that, there is no significant improvement in apparent nutrient digestibilities on addition of yeast culture in lactating cows fed with 40% corn silage and 60% concentrate (DM basis). Rate of disappearance of cellulose *in vitro* was lower in cows receiving yeast. Arambel and Kent (1990) reported that, no significant differences in digestibility were observed for CP, ADF and NDF in early lactating dairy cows supplemented with 90 g day^{-1} of yeast culture *S. cerevisiae* along with basal diet. However, Sauvant *et al.* (2004), in a review, observed a tendency toward increase in OM digestibility (+0.5%) due to supplementation of yeast.

Different factors influence the response of yeast cells in ruminants such as dose, diets, strains and physiological conditions. A particular dose of yeast culture may be required after which there may not be further effects on digestibility in a particular feeding condition. For example, Fadel El-seed *et al.* (2004) reported that, supplementation of *S. cerevisiae* culture (0, 2.5, 5 g day^{-1}) in Nubian kids diet increased OM digestibility by 12.1 and 10.1% and NDF digestibility by 13.3 and 10.5% for 2.5 and 5 g day^{-1} yeast culture, respectively, compared with the control diet.

El-Waziry and Ibrahim (2007) reported that, digestibilities of DM, NDF and ADF of berseem hay were increased when the basal diet (berseem hay) was supplemented with *S. cerevisiae* (22.5 g day^{-1}), whereas, supplementation of 11.25 g day^{-1} had no effect in sheep. Degradation rate of NDF and ADF was enhanced by the addition of *S. cerevisiae* at both levels of supplementation. Shorter lag time was noticed in the digestion of NDF and ADF at both levels of *S. cerevisiae* supplementation. Ahmed and Salah (2002) performed an experiment by feeding two levels of yeast culture (control, 4, 8 g yeast/day) to sheep and reported that digestion coefficients of DM improved at both levels of yeast used in comparison with control whereas, CP digestibility was significant only between control and the group fed with 8 g yeast/day. Wohlt *et al.* (1998) reported that, the digestibility of CP and ADF was significantly improved by the addition of 10 or 20 g of yeast per day to early lactating cows fed with diets based on corn silage. The CP digestibilities with 0, 10 or 20 g of yeast per day were 78.5, 80.8 and 79.5% and ADF digestibility with 0, 10 or 20 g of yeast day^{-1} were 54.4, 60.2 and 56.8%, respectively. DM and fiber digestibilities were similar for all cows in control and yeast supplemented diet.

Again, type of diets may determine the effect of yeast on digestibility. Tang *et al.* (2008) studied the effects of yeast culture on *in vitro* fermentation characteristics of rice straw, wheat straw and maize stover and reported that supplementation of yeast culture (0, 2.5, 7.5 g kg^{-1} straw DM) increased the *in vitro* DM digestibility for each type of straw. Mir and Mir (1994) studied the effect of adding yeast culture (*S. cerevisiae,* 5×10^9 live organisms/g of growth medium) at 10 g/steer daily to three diets consisting of 75% alfalfa silage and 25% barley, 96% corn silage and 4.0% soybean meal or 75% dry-rolled barley and 25% alfalfa hay in steers in separate trials for over 2 years and reported that the coefficients of digestibility of the diets for DM, CP, ADF, NDF did not differ due to inclusion of yeast, except for the high-grain diet in the second year, in which Yeast supplementation increased DM and CP digestibility.

Jouany *et al.* (1998) in a study with two probiotics, *S. cerevisiae* and *Aspergillus oryzae* in defaunated and refaunated sheep found that apparent digestibility of the plant cell walls was similar in defaunated sheep, but was increased with the addition of *S. cerevisiae* (+16%) in refaunated sheep. Simultaneously, the effect of *S. cerevisiae* or *A. oryzae* on in situ ADF digestion was either not significant or negative in defaunated animals, whereas, it became positive in refaunated rumen after a residence time of 12 h.

Sometimes, the response of yeast culture on the digestibility depends upon the type of strain of cultures (Newbold *et al.*, 1995). For instance, Miller-Webster *et al* (2002) conducted a study to evaluate the effect of two different yeast cultures on rumen microbial metabolism. The treatments were (a) control lactation ration, (b) yeast culture 1 (YC1, Diamond-V XP) and (c) yeast culture 2 (YC2, A-Max), both fed at an equivalent of 57 g day^{-1}. The results showed that both yeast culture products increased DM digestion, propionic acid production and protein digestion compared with the control. YC1 demonstrated an increase in molar percentage of propionic acid, a reduction in acetic acid and a lower mean nadir (daily low) pH compared with YC2. Ruminal cultures treated with YC digested more protein and contributed less bypass N than control. Supplementing YC2 resulted in a tendency for higher microbial N kg^{-1} DM digestion than YC1. YC1 resulted in production of rumen microbes containing less protein than YC2. All these results confirm that several factors might influence the variability observed between experiments and that many other experimental parameters might have to be tested in such databases to determine more precisely the conditions in which yeasts are the most effective (Desnoyers *et al.*, 2009).

EFFECT ON RUMEN FERMENTATION

Yeast supplements showed effect on conflicting results on rumen fatty acid concentration. Williams *et al.* (1991) and Corona *et al.* (1999) reported that, steers and sheep supplemented with 7.5 and 3 g, respectively, of a yeast culture containing *S. cerevisiae* per day had lower total Volatile Fatty Acid (VFA) concentration and molar proportion of butyric acid, respectively. In contrast, many reports indicated that total ruminal VFA concentration and molar proportions of acetic, propionic and butyric acid were generally unaffected by yeast cultures (Wiedmeier *et al.*, 1987; Erasmus *et al.*, 1992; Mir and Mir, 1994; Yoon and Stern, 1996; Putnam *et al.*, 1997; Pinos-Rodriguez *et al.*, 2008). However, Koul *et al.* (1998) reported that, total ruminal VFA increased in buffalo calves fed 5 g yeast culture containing *S. cerevisiae* per day compared to controls (132.2 versus 122.4 mmol L^{-1}, respectively). In addition, Dolezal *et al.* (2005) reported increased VFA production with increasing doses of yeast culture containing *S. cerevisiae* strain SC-47. Furthermore, Harrison *et al.* (1988) found decreased molar proportion of acetic acid and acetate to propionate ratio and increased molar proportion of propionic acid in the rumen fluid of Holstein cows supplemented with 114 g day^{-1} of a yeast culture containing *S. cerevisiae*.

The summary of various published by Robinson (2010) indicated that yeast supplementation resulted in an average increase in pH (1.6%), an overall increase in total rumen VFA (5.4%) and an overall decrease in lactate concentration (8.1%). The meta-analysis study of Desnoyers *et al.* (2009) suggests that, yeast supplementation increased rumen pH and VFA concentration (2.1 mmol L^{-1}) and tended to decrease rumen lactate concentration. Sauvant *et al.* (2004), in a review, did not observe any influence of yeast supplementation on rumen pH or VFA concentration and only observed a tendency toward increase in OM digestibility (+0.5%). The yeasts are able to limit the decrease in rumen pH that is usually linked to an increase in VFA (Desnoyers *et al.*, 2009). Furthermore, yeasts were able to limit lactic acid production or accumulation in the rumen (Chaucheyras-Durand and Fonty, 2002; Desnoyers *et al.*, 2009) probably *S. cerevisiae* can compete with other starch utilizing bacteria for fermentation of starch (Lynch and Martin, 2002) leading to the prevention of lactate accumulation in the rumen (Chaucheyras *et al.*, 1995). It should be noted only few strains of yeast have the ability to stimulate both the beneficial fiber digesting bacteria and the bacteria associated with lactate utilization (Newbold *et al.*, 1996). No influence of yeast is generally observed on the acetate-to-propionate ratio (Sauvant *et al.*, 2004; Desnoyers *et al.*, 2009). The rumen fermentation characteristics associated with yeast supplementation are influenced by the dietary characteristics (Desnoyers *et al.*, 2009). The proportion of concentrate in the diet interacted with the effects of yeast supplementation. The influence of yeast supplementation on rumen parameters is greater when using high-concentrate diets (Erasmus *et al.*, 1992; Kung *et al.*, 1997; Jouany, 1999; Desnoyers *et al.*, 2009) or with diets or feeding systems that reduced cellulolysis the most (Williams *et al.*, 1991). Yeast effect on rumen VFA appeared to be greater in high-concentrate or high-NDF diets than in intermediate ones (Desnoyers *et al.*, 2009). The increased effect in high-NDF diets is certainly caused by an increase in cellulolysis or the number of cellulolytic bacteria (Harrison *et al.*, 1988). Crude protein is often the least significant interfering factor, showing that there might be fewer interactions between yeasts and nitrogen than between yeasts and concentrates or NDF (Desnoyers *et al.*, 2009).

EFFECT ON INTAKE AND PERFORMANCE

Many studies have reported positive effect of yeast on DM intake. Erasmus *et al.* (1992) reported that, when lactating dairy cows were fed with ration supplemented with yeast culture (10 g day^{-1}) there was greater DM intake in treatment group than in control. Stella *et al.* (2007)

investigated the effects of live *S. cerevisiae* (CNCM I-1077) supplementation to Saanen dairy goats in early lactation. Treated animals received 0.2 g day^{-1} yeast supplement (Levucell SC20) corresponding to 4×10^9 CFU day^{-1} *S. cerevisiae*, beginning week 3 of lactation and lasting 15 weeks. Body Condition Score (BCS) was not affected by the treatment but treated animals had greater DM intake (2.71 versus 2.35 kg day^{-1}). Putnam *et al.* (1997) in a study with early lactating Holstein cows reported higher DM intake in yeast culture supplemented (10 g day^{-1}) cows than that of non-supplemental group. Feeding of yeast cultures has been shown to beneficially modify rumen metabolism which might increase DM intake. Fibrous components that are fermented and passed from the reticulo-rumen more slowly, have greater filling effect in the rumen over time (Allen, 1996). Increased digestibility of NDF might decrease rumen filling effect which can lead to an enhancement in feed intake (Fadel El-seed *et al.*, 2004).

Several studies showed increased Average Daily Gain (ADG) of animals due to addition of yeast products in diets. Lesmeister *et al.* (2004), Haddad and Goussous (2005) and Kawas *et al.* (2007b) reported an increase in ADG with yeast supplementation in lambs, goats and calves. Fadel El-seed *et al.* (2004) reported that supplementation of *S. cerevisiae* culture at dose levels of 2.5 and 5 g day^{-1} in the diet of Nubian kids increased ADG by 20.8 and 16.3 g day^{-1}, respectively than unsupplemented kids (5.5 g day^{-1}). However, no additional benefits gained when adding high level of yeast supplement. Growth of kids increased linearly with *Saccharomyces* supplementation from day 30 onward till the end of the experiment (Pal *et al.*, 2010). The improved performance might be due to supplementation of yeast culture in the diet which increased digestion, particularly fiber fraction of the diet, therefore, improved feed intake (Newbold *et al.*, 1996). However, yeast products did not always improve the performances of the animals. Titi *et al.* (2008) reported that, yeast supplementation digestibility of feeds with no effect on ADG and DM intake in kids and lambs. Pinos-Rodriguez *et al.* (2008) reported that, SC supplementation increased DM intake but had no effect on ADG in dairy calves. Many factors such as diet, viable cell numbers of SC, dose of SC, strain of SC, type of forage fed have been suggested for the discrepancies of responses among the studies (Cabrera *et al.*, 2000; Kawas *et al.*, 2007b; Pinos-Rodriguez *et al.*, 2008).

Wohlt *et al.* (1991) reported that, in cows fed supplemental yeast (10 g day^{-1}) (5×10^9 CFU of *S. cerevisiaelg*) along with a basal diet containing corn silage: grain (1:1 on DM basis) and hay (0.9 kg day^{-1}) resulted in greater DM intake during the first 6 week of lactation and a higher average milk yield through week 18 of lactation compared with control cows. The meta-analysis indicates that DM intake and milk production were increased by yeast supplementation (Desnoyers *et al.*, 2009) but a significant increase may occur in early lactation (Wohlt *et al.*, 1991; Dann *et al.*, 2000). Dawson and Tricarico (2002) analyzed the results gained from 22 studies with Yea-Sacc®1026 in lactating dairy animals. He found an average increase in milk production of 7.3% in yeast-supplemented animals. Responses to supplementation were variable and ranged from 2-30% increase in milk production. Yeast culture can also influence on the persistence of lactation after the production peak of dairy cows (Alonzo *et al.*, 1993). Jouany (1999) reported an average increase in milk production of 7.3% for yeast-supplemented animals from analysis of 22 experiments. Robinson and Erasmus (2009) summarized the data from 19 experiments and noted that response of yeast product was modest on DM intake (1.8%), milk yield (3%) and milk fat yield (4.4%). However, Sauvant *et al.* (2004) only observed a tendency toward increased milk yield but no effect on DM intake in their meta-analysis. Yeast supplementation generally has a very little influence on milk composition, only milk fat content tended to increase by yeast supplementation but this result was only observed for the qualitative effects of yeast supplementation (Desnoyers *et al.*, 2009; Robinson, 2010; Sauvant *et al.*, 2004).

EFFECT ON METHANE PRODUCTION

While there are many studies on rumen fermentation and animal performance, limited information are available on the effect of microbial feed additives (live cells) such as *S. cerevisiae* and *A. oryzae* on methane (CH_4) production and most of all are *in vitro*. Addition of *S. cerevisiae* to an *in vitro* system reduced the CH_4 production by 10% initially, though, this was not sustained (Mutsvangwa *et al*., 1992). Lynch and Martin (2002) reported a 20% decrease in CH_4 production after a 48 h of incubation of mixed rumen microorganisms in the presence of alfalfa and a live yeast product. *A. oryzae* has been found to reduce CH_4 production to the extent of 50% (Frumholtz *et al*., 1989) which was directly related to a reduction in the protozoal population (45%). In some experiments, *A. oryzae* and *S. cerevisiae* increased CH_4 production (Martin *et al*., 1989; Martin and Nisbet, 1990) while Mathieu *et al*. (1996) reported that *S. cerevisiae* addition did not affect CH_4 release *in vivo*. Mwenya *et al*. (2004) reported that a yeast culture containing *Trichosporon sericeum* (4 g day^{-1}) reduced CH_4 production by 10% in sheep fed on a roughage based diet. It is suggested that yeast culture might stimulate the acetogens to compete or to co-metabolize hydrogen with methanogens thereby, reducing CH_4 emissions (Chaucheyras *et al*., 1995; Mwenya *et al*., 2004). These conflicting results on CH_4 production is likely due to strain difference of yeast culture and type of diets. This suggests that more research is required before it can be concluded that yeast cultures decrease CH_4 production *in vivo*.

CONCLUSION

Yeast supplementation in ruminants shows moderate beneficial effects on nutrient utilization, rumen fermentation characteristics, milk production and daily gain. Addition of some strains of yeasts in diets may also decrease methane production in ruminants. Yeasts influence positive effects on nutrient digestibility especially fiber components, probably by stimulating the cellulolytic microbial populations. Improvement of rumen fermentation characteristics such an increase in total volatile fatty acids, stabilization of rumen pH and a decrease in lactate concentration might be observed due to yeast supplementation. The improvement in feed utilization and rumen fermentation along with increased DM intake due to yeast addition may also result in increased milk yield and animal performance. But all these responses of yeasts in ruminant nutrition are always not observed. The discrepancies of responses of yeast inclusion as a feed additive in different experiments might be attributed to dose, type of diets, strains of yeast, physiological stage and feeding systems. Therefore, to obtain the consistent beneficial effects of yeasts in ruminant nutrition, yeasts should be added in diets by taking consideration of various interaction factors.

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