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Yeasts as Dietary Additives to Manipulate Ruminal Fermentation: Effect on Nutrient Utilization and Productive Performance of Ruminants

*Oscar Ruiz Barrera, Jaime Salinas-Chavira
and Yamicela Castillo Castillo*

Abstract

There is considerable interest in the use of microbial additives such as yeasts in the nutrition of ruminants. The prohibition of the antibiotics as growth promoters in animal feeds increased the interest to investigate the effects of yeasts as natural additives on the gastrointestinal ecosystem and animal productive behavior. The effect of yeast-based preparations on the rumen environment and on the growth performance of ruminants has been well documented and has generated considerable scientific attention in the last two decades. However, the precise action modes by which the yeast cultures improve nutrient utilization and livestock production are still under study. Therefore, the objective of this chapter is to deepen into the action mechanisms of the yeasts at the ruminal level and at the productive level for their use as additives in animal feeding.

Keywords: ruminants, probiotics, natural additives, feeding, growth

1. Introduction

The yeasts are not part of the ruminal ecosystem, and their presence is mainly due to the ingestion in feeds and water. Marrero [1] and Castillo-Castillo et al. [2] showed that supplementing ruminant feeds rich in yeasts, they survived for longer time in the rumen and improved the conditions that favored the dry matter (DM) use by microorganisms that inhabit in it. These results corroborate the approach made by Galves [3] that when certain allochthonous microorganisms are deposited in a new habitat with nutrients, they survive and are able to use part of the resources of the environment in which they were deposited; in this case, the yeasts use the little oxygen existing in rumen and favor the conditions of anaerobiosis [4] that facilitate or potentiate the growth of other anaerobic microorganisms as the cellulolytic bacteria.

Research reports where yeasts are a natural alternative to manipulate ruminal microbial fermentation and animal productivity are shown below. Yeasts have

shown to improve the digestibility of DM and neutral detergent fiber (NDF) [5], feed consumption [6], milk production [7], and live weight gain [8]. However, not all yeast cultures have been shown to modify ruminal metabolism or improve animal productivity [9, 10]. These inconsistencies could be related to the type of yeast strain used [11], the specificity of the different commercial additives [12], or to the diet composition [13]. The objective of this review was to deepen into the mechanisms of action of the yeasts as well as their effects at the ruminal level and at a productive level for their use as animal feed additives.

2. Yeasts

Yeasts are unicellular microorganisms that ferment carbohydrates, and they are reproduced by budding. Most commercial yeast-based products contain a mixture of varying proportions of living cells of *Saccharomyces cerevisiae* and dead cells. Products with a predominance of living cells are sold as live yeasts, while those containing more dead cells with the growth medium are sold as yeast cultures [14]. Examples include Yea-SACC (Alltech Inc.), Levucell SC-20 (Lallemand Animal Nutrition), and Yeast Cultivation Diamond V (Diamond V, Mills Inc.). Yeast cultures are foods generally considered as safe (GRAS) denomination given by the Food and Drug Administration (FDA) (USA).

3. Mechanisms of action of yeasts in the rumen

One of the proposed action modes is that living yeasts through their aerobic respiration allow the elimination of the small percentage of oxygen (1%) that enters to the rumen when the animal ingests their feeds, thus facilitating the growth of the most anaerobic microorganisms as cellulolytic bacteria and fungi [4, 15].

Another proposed mechanism of action is that yeast cultures provide vitamins (specifically thiamin), glucans, mannano-proteins, and organic acids, which stimulate the growth of microorganisms that digest fiber and use lactic acid [16–18].

An additional effect is that yeast cultures are rich in organic acids (mainly malic acid) that stimulate the growth of *Selenomonas ruminantium*. This ruminal bacterium consumes the lactic acid produced in the rumen and therefore contributes to the stabilization of the pH in rumen, which favors the growth of cellulolytic microorganisms [17].

Yeasts also produce changes in the bacterial flora by competition and growth stimulation, increasing the growth, and activity of the acetogenic populations that compete with the methanogenic ones by the use of the metabolic hydrogen [16]. This decreases the energy losses in the animal caused by the methane formed in rumen, which decreases the negative effect of this greenhouse gas on the environment [19].

4. Effect of the addition of yeasts in the ruminal fermentation

Yeast cultures based on *Saccharomyces cerevisiae* have been widely used in the diet of ruminants to improve digestibility and DM utilization [14].

The yeast products available in the market vary widely depending on the strain of *S. cerevisiae* used and the number and viability of the cells. Some products guarantee a high number of live yeast cells, while other products are sold as yeast cultures, which contain living cells and the medium where they grew [14].

Interestingly, it has been observed that not all strains of *S. cerevisiae* are capable to stimulate digestion in the rumen [11, 12]. For example, yeast culture “Diamond-VXP” and “A-Max Concentrate” generated different values of ruminal pH and molar concentration of total and individual VFA [12]. These differences were not related to the number of viable cells in the preparation or to the differences in metabolic activity [11].

In vitro and in vivo studies found no effect of yeasts on ruminal pH [4, 20–24]. However, results where pH decreased were reported by Williams [6] when they supplemented *S. cerevisiae* (10 g/d) in steers consuming barley hay. Lynch and Martin [25] also found a decrease in pH at adequate values for ruminal cellulolysis when they studied the in vitro effect of a *S. cerevisiae* culture on the fermentation of Bermuda hay and alfalfa hay.

On the other hand, regarding to the concentration of ammonia-nitrogen (N-NH₃), Lila et al. [22] and Erasmus et al. [20] showed that the inclusion of yeast does not affect the levels of this compound. Contrary to the above, Lattimer et al. [21] reported a decrease in the N-NH₃ concentration when they evaluated the effect of a yeast culture on the in vitro fermentation of a high fiber diet. Also, Moallem et al. [26] reported a decrease in ruminal N-NH₃ from dairy cows supplemented with yeast.

Other effects of yeasts include increase in metabolites as VFA [12, 18], decrease in lactic acid concentration [22], reduction of methane production [22, 25], increase in growth of cellulolytic bacteria and fungi [4, 16, 22] as well as acetogenic bacteria [16], and increase in fiber degradability [12, 22].

5. Use of yeasts in animal feeding

The use of feed additives is important in the feeding of ruminants. Yeast proteins have a high nutritional value, characterized by a balanced amino acid profile with a high content of lysine and threonine, which gives it an extraordinary potential for use as a supplement to animal diets, since these could be deficient in these amino acids [27].

The yeast of *Saccharomyces cerevisiae* as an additive in animal nutrition has been extensively investigated; however, the results obtained are variable and not very repeatable, possibly due to the great diversity of diets offered to the animals in study, the different strains of yeasts, and the different doses supplied to the animals. It is pointed out that *S. cerevisiae* increases feed consumption, milk production, feed conversion, and daily gain of weight, in response to increases in the amount and activity of the total anaerobic and cellulolytic bacteria that modify the concentration of volatile fatty acids, ruminal pH, and ammonia-nitrogen; however, the results are not consistent, so it is recommended to differentiate *S. cerevisiae* yeast strains that promote the use of the neutral detergent fiber of the ration [28].

Baioomy [29], in a study carried out with lactating sheep, mentioned that supplementation with live yeasts of *S. cerevisiae* has a significant effect on the development and metabolism of animals during the lactation period. In view of the above, it is recommended to include live yeast (Yea Sacc1026) in the animal diet in an amount of 6 g animal⁻¹ day⁻¹. On the other hand, Sotillo et al. [30] in dairy goats found that the addition to the diet of 0.08 g kg⁻¹ of dry matter of the additive Yea-Sacc® TS (*S. cerevisiae*) causes a 7% increase in milk production and an increase in the percentage of fat in it. In turn, there is an increase in the level of urea in milk and an improvement in body condition. There was also a decrease in somatic cell count values, indicative of a better health status of the animals. It is necessary to consider that the effects of the yeasts can be variable, depending on several factors related to the animal (species, physiological

stage, consumption, etc.) and/or diet (composition of the diet, mode of distribution, etc.) [31, 32]. However, the concentration of viable cells, the type of yeast, and the used dose are also of great importance in this variability [33]. In this regard, little research has been conducted to determine the effects of different doses of the microbial additive, and the doses used differ only in a narrow range, from 2 to 5 times [33, 34].

6. Other non-*Saccharomyces* strains of yeasts with potential commercial use as probiotics

A joint project carried out by Cuban and Mexican researchers has developed additives based on native yeasts adapted to their local conditions, showing a good potential to be utilized as growth enhancers in ruminants and could be economically competitive in the international market. Several studies have been conducted to examine the potential use of these non-saccharomyces yeasts on animal nutrition [35, 36]. Additionally, Marrero et al. [37] studied the effects of the addition of two strains, Levazoot 15 (*Candida norvegensis*) and Levica 25 (*Candida tropicalis*), and found that both yeasts stimulated ruminal fermentation of oat straw and alfalfa, although it was better when the Levazoot 15 was inoculated. In recent study, Castillo-Castillo et al. [2] demonstrated the fermentative capacity of Levazoot 15, which showed greatest gas production than the yeast-free control and positively affected the in vitro ruminal fermentation parameters of alfalfa and oat straw. Based on these results, the Levazoot 15 yeast strain could be potentially used as an additive for ruminants consuming high-fiber diets. In another study, Ruiz et al. [38] showed that the same strain of yeast did not affect the ruminal cellulolytic bacterial counts. However, the treatment with yeast cultures positively influenced the cellulolytic fungal populations in rumen after 4 h of incubation. Methane production did not exhibit any trends across the fermentation times. A significant reduction in methane production was only observed at 8 h by the yeast treatment; at other time points, there were noticeable numerical decreases, although not statistically significance. In addition, Levazoot 15 strain also increased volatile fatty acid (VFA) concentration such as acetic, propionic, butyric, valeric, and isovaleric acids and enhanced the in vitro dry matter digestibility (IVDMD). In accordance, Ando et al. [39] with different strains of *Candida utilis* studied the in vitro degradation of grain and forage; the results showed that the microorganisms not only increased fibers degradability but also improved the utilization of the lipids. Finally, in a related study reported by Angulo-Montoya et al. [40], *C. norvegensis* Levazoot 15 strain preferred glucose as an energy source than other carbohydrates such as sucrose and lactose for its growth. In this study, only manganese was used as trace element, and the addition of vitamins in the culture medium was not required. This yeast used tryptone as a nitrogen source and did not denote sodium requirements.

7. Conclusions

The results in the use of yeast as feed additives are not conclusive; however, in rumen, they stimulate the growth and activity of total and cellulolytic bacteria, improving fiber digestion, synthesis of microbial protein, enhances feed intake and growth performance of ruminants. Yeasts also use ruminal oxygen, facilitating the growth of obligate anaerobes. In addition, yeasts may stimulate the bacteria that consume the lactic acid produced in rumen and may contribute to modulate the pH in rumen, reducing the risks of acidosis, and it can contribute significantly to the reduction of production of methane in the rumen.

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Author details

Oscar Ruiz Barrera¹, Jaime Salinas-Chavira² and Yamicela Castillo Castillo^{1*}

¹ Facultad de Zootecnia de la Universidad Autónoma de Chihuahua, Mexico

² Facultad de Medicina Veterinaria y Zootecnia de la Universidad Autónoma de Tamaulipas, Mexico

*Address all correspondence to: ycastillo75@yahoo.com

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