EXOGENOUS ENZYMES IN RUMINANT NUTRITION: A REVIEW

Ibrahim, R.S. [1]*, Idris ,A.I. [2], Aminu, M.U. [3], Abbas, M.W. [4], Mustapha, H. [1] and Nasiru, A. [1]

1 Department of Animal Science, Faculty of Agriculture, Bayero University Kano.
2 Department of Animal Production Technology, Audu Bako College of Agriculture, Dambatta,Kano State.
3 Department of Fisheries and Aquaculture, Bayero University Kano.
4 Institute of Grassland Science, School of Life Sciences, Northeast
Normal University, Changchun, China.
*Corresponding author: rukayyashafiu65@gmail.com; +2348065094620

ABSTRACT
The ability of ruminant to transform plant biomass that is unfit for human consumption into meat and milk is vital for both agriculture and society, however, the digestibility of plant cell walls has a significant impact on how well this mechanism works. Exogenous enzymes added to ruminant diets may increase the digestibility of plant cell walls and, consequently, feed utilization efficiency. The objective of the study was to review exogenous enzymes in ruminant nutrition. These include different exogenous enzymes product types, sources, benefits, different methods of application and the possible modes of action, it also reviewed methods of evaluating enzyme activity and characterization of exogenous enzymes into three main categories as fibrolytic, amylolytic and proteolytic. It further shows the sources of these exogenous enzymes which are mainly four bacterial species, three fungal species and some yeasts. Supplementation of exogenous enzymes in ruminant nutrition shows beneficial effects on feed utilization, growth and production performance in ruminant animals though future studies are highly recommended with emphasis on mode of action of these products so that on farm efficacy of ruminant enzyme technology can be assured.
Keywords: Ruminant, Exogenous enzymes, Forage, Digestibility

INTRODUCTION

Ruminant animals particularly in tropical developing nations are fed on crop residues and unimproved native pasture, leading to challenges in meeting their nutritional requirements, such as high feed costs and poor-quality feed resources (Sujani and Seresinhe, 2015), these challenges are intensified during the dry season when feed availability diminishes (Smith, 2023). Forages during dry season are fibrous, lignified, low in digestible protein, energy, minerals and vitamins leading to poor digestibility and significant weight losses of the animals as less than 65% of the fibrous plant cell walls are efficiently digested in the total digestive tract of animal (Van de Vyver and Useni, 2012). Exogenous fibrolytic enzymes have drawn a lot of attention in animal feed as a way to optimize nutrient use as it aid in breakdown of complex polysaccharides like cellulose and hemicellulose, thereby enhancing utilization of energy and other nutrients (Kholif and Patra, 2024), they are frequently given to monogastric animals to improve diet digestibility and utilization of nutrients, they are also added into the feed of ruminant animals to improve digestion of feedstuffs such as silage. They are exogenous enzymes are biological catalysts added to speed the rate of chemical reaction, the enzymes have gained popularity as a less expensive way to increase feed efficiency in recent years (Krause *et al.,* 2003), since they do not require chemical treatments, their application in the processing of feed may be advantageous. Supplementation of these enzymes has the potential to lower feed costs by improving nutrient utilization and lessen the environmental impact of animal production by reducing nutrient excretion.

Types, sources, and benefits of exogenous enzymes

Exogenous enzymes used in ruminant nutrition can be characterized into three main categories: fibrolytic, amylolytic and proteolytic enzymes. In addition to major categories of enzymes, phytase which is extensively used in monogastric feeding is also becoming popular in ruminant feeding. Enzyme products are derived primarily from four bacterial (*Bacillus subtilis, Lactobacillus acidophilus, L. plantarum,* and *Streptococcus faecium, spp.*), three fungal (*Aspergillus oryzae, Trichoderma reesei,* and *Saccharomyces cerevisiae*) species (Muirhead, 1996), and some yeast (Table 1). The benefit of using exogenous enzymes is to break down anti-nutritional factors, to increase the availability of starches, proteins and minerals enclosed within fiber-rich cell walls, to break down specific chemical bounds in raw materials which are not usually broken down by the animals' endogenous enzymes.

Application of enzymes

There are several enzyme application methods widely used but the most effective method is yet to be recognized. The application methods vary from a pretreatment of the feed for a period of time before feeding (e.g., silage making), to application at the time of feeding (application to the hay, in Totally Mixed Rations (TMR), concentrate), even the direct application to the rumen. (Hvelplund et al., 2009).

Table 1: Cellulase and xylanase producing microorganisms and optimum conditions for the production

Enzyme and microorganism	Optimum pH	optimum temperature (°C)
Cellulase		
Bacillus subtilis	5.5	60
Cellulomonas uda	5.5-6.5	45-50
Pseudomonas fluoresences	7.0	35
Bacteroides cellulosolvens	6.4	39
Clostridium josui	6.8	60
Xylanase		
Penicillium canescens	7.0	30
Streptomyces sp	7.2	28
Aspergillus niger	5.0	28

(Sadhu and Maiti, 2013) (modified)

Mode of enzyme action

Pre consumption effects: Applying exogenous enzymes in liquid form to dry forage is more effective than to wet silage, as silage may contain enzyme inhibitors (Nsereko *et al.,* 2000). Dry feeds like hay that contains low supports carbohydrate hydrolysis, which releases sugars that enhance microbial growth and reduce colonization lag time. Enzyme activity depends on substrate type and enzyme binding, with effectiveness improving when enzymes are applied to a significant portion of the diet.

Ruminal effects: Contrary to what was first thought, exogenous enzymes have been demonstrated to be more stable in the rumen environment (Morgavi *et al.,* 2000). However, non-glycosylated enzymes have the potential to withstand ruminal proteolysis; nevertheless, their ability to stay in the rumen could be contingent upon the microbiological source from which they originated (Fontes *et al.,* 1995). Differences in the stability of enzymes could be a factor in the uneven production responses that are seen when ruminant diets contain enzymes. Exogenous enzymes supplemented to ruminant diets typically speed up feed digestion without significantly increasing its overall pace. Excessive exogenous enzyme supplementation may compete with ruminal microorganisms for fiber binding sites, and enzymes must complement rather than replace natural ruminal activity to optimize digestion and intake.

Post ruminal effects: It was initially reported by Hristov *et al*. (1998) that about 30% of xylanases are active in bovine intestinal digesta and may bypass ruminal fermentation. These results supported earlier pig investigations and in vitro reports (Fontes *et al.,* 1995). Some enzymes may escape rumen and boost digestion ability in the intestine in order to break down polysaccharides, depending on the dosage (Chesson, 1994). The abomasum is a significant barrier that prevents active exogenous enzymes from entering the intestine, according to Hristov *et al*. (1998). Morgavi *et al.* (2001) conducted a follow-up investigation which proved that certain exogenous enzymes are able to withstand ruminal fermentation and the abomasal environment and can even continue to function temporarily in the small intestine.

Production responses in ruminants

Ruminant rations supplemented with exogenous enzymes had drew a considerable research attention with the successful stories in livestock industry and it is steadily growing up to date. Following content shows newer research findings using exogenous enzymes, separately on ruminant species.

Effect of exogenous enzymes inclusion on feed intake and digestibility: Most of the previous studies showed that exogenous fibrolytic enzymes have no effect on nutrient intake with few studies showing variable effects. Feng et al. (1996) reported that intake of DM was increased by fibrolytic enzyme with dry forages, but not fresh forages. Salem *et al.* (2011) in their study revealed that Addition of enzymes improved nutrients digestibility in small ruminant. The improvement was better in goats than in sheep. Goats had the lowest total dry matter intake, which is associated with an improvement in nutrient digestibility and average daily gain more than sheep. Hristov *et al.* (2000) reported that exogenous polysaccharide degrading enzymes could potentially improve nutrient digestion of post ruminally, not only by modifying the feed but also enzyme resistance to proteolysis. Kung *et al.* (2000) reported that treatment of feeds with enzymes just prior to feeding can improve digestibility via several different mechanisms including direct hydrolysis, enhanced microbial attachment, changes in gut viscosity, complementary actions with ruminal enzymes, changes in the site of nutrient digestion and improvements in palatability and changes in patterns of feed consumption could also occur.

CONCLUSION

Supplementation of exogenous enzymes to ruminant diets shows beneficial effects on feed utilization, growth and production performance in ruminant animals though some debatable issues need to be further revised. Therefore, studies are highly recommended with emphasis on mode of action of these products so that on farm efficacy of ruminant enzyme technology can be assured.

REFERENCES

Chesson, A. (1994). Manipulation of fibre degradation: An old theme revisited. In: Biotechnology in the feed industry. *Proceedings of All tech's Tenth Annual Symposium*, Loughborough, UK. p. 83–98.

Feng, P., Hunt, CW., Pritchard, G.T., and. Julien. W.E. (1996). Effect of enzyme preparations on in situ and in vitro degradation and in vivo digestive characteristics of mature cool-season grass forage in beef steers. *Journal of Animal Science*. 74: 1349-1357.

Fontes, C. M. G. A., Hall, J., Hirst, B. H., Hazlewood, G. P., and Gilbert. H. J. (1995). The resistance of cellulases and xylanases to proteolytic inactivation. *Applied Microbiology and Biotechnology*. 43:52–57.

Hristov, A. N., McAllister, T. A., and Cheng, K.J. (1998). Stability of exogenous polysaccharide-degrading enzyme in the rumen. *Animal. Feed Science and Technology*. 76:161–168.

Hristov, A. N., McAllister, T. A., and Cheng, K.J. (2000). Intraruminal supplementation with increasing levels of exogenous polysaccharides degrading enzymes: Effects on nutrient digestion in cattle fed a barley grain diet. *Journal of Animal Science*. 78: 477-487.

Hvelplund, T., Weisbjerg, M.R., Hindrichsen, I.K. and Madseen, J. (2009). The effect of adding exogenous enzymes at ensiling on nutrient availability in different forages. Proceedings of the TSAP Conference, September, 2009, Mwanza, Tanzania, pp: 1-7.

Kholif, A. E., and Patra, A. K. (2024). Dietary Applications of Exogenous Enzymes to Improve Nutrient Utilization and Performance in Ruminants. *Feed Additives Supplements for Ruminants,*1-28.

Krause, D. O., Denman, S. E., Mackie, R. I., Morrison, M., Rae, A. L., Attwood, G. T., and McSweeney, C. S. (2003). Opportunities to improve fiber degradation in the rumen: microbiology, ecology, and genomics. *FEMS Microbiology Reviews,27*(5), 663-693.

Kung, L.,Treacher,R.J, Nauman, G.A., Smagala, AM., Endres, K.M. and Cohen, M.A. (2000).The effect of treating forages with fibrolytic enzymes on its nutritive value and lactation performance of dairy cows. *Journal of Dairy Science*. 83: 115-122.

Morgavi D.P., Beauchemin K.A., Nsereko V.L., and Rode, L.M. (2000). Synergy between ruminal fibrolytic enzymes and enzymes from Trichoderma longibrachiatum in degrading fibre substrates. *Journal of Dairy Science.* 83: 1310- 1321.

Morgavi, D.P., Beauchemin, K.A., Nsereko, V.L., Rode, L.M., McAllister, T.A., Iwaasa, A.D., Wang, Y., and Yang, W.Z. (2001). Resistance of feed enzymes to proteolytic inactivation by rumen microorganisms and gastrointestinal proteases. *Journal of Animal Science.* 79: 1621-1630.

Muirhead, S. (1996). Direct Fed Microbial, Enzyme and Forage Additive Compendium, 3rd edition. *The Miller Publishing Company, Minetonka, Minnesota*, 391.

Nsereko, V.L., Beauchemin, K.A., Morgavi, D.P., Rode, L.M., Furtado, A.F., McAllister, T.A.,, Iwaasa, A.D., Yang, W.Z. and Wang. Y. (2000). Effect of a fibrolytic enzyme preparation from Trichoderma longibrachiatum on the rumen microbial population of dairy cows. *Canadian Journal of Microbiology.* 48: 14-20.

Salem, A.Z.M., El-Adawy, M., Gado, H., Camacho, L.M., Gonzalez-Ronquillo, M., Alsersy H., and Borhami, B. (2011). Effects of exogenous enzymes on nutrients digestibility and growth performance in sheep and goats. *Tropical and Subtropical Agroecosystem*.14: 867-874.

Smith, J., and Brown, A. (2023). Impact of Seasonal Feed Availability on Livestock Productivity. *Journal of Agricultural Research, 15*(3), 123-135.

Sujani, S., and Seresinhe, R. (2015). Exogenous enzymes in ruminant nutrition: A review. *Asian Journal of Animal Sciences,9*(3), 85-99.

Van de Vyver, W., and Useni, B. (2012). Digestion and microbial protein synthesis in sheep as affected by exogenous fibrolytic enzymes. *South African Journal of Animal Science, 42*(5), 488-492.