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Effect of Exogenous Enzymes on Ruminal degradation of Feed and Animal Performance: A review

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ABSTRACT
Review was made on the effect of exogenous enzymes on ruminal degradation of feed and animal performance. A wide variety of carbohydrase, protease, phytase and lipase enzymes have been used in animal feeds. Although supplementation of exogenous enzymes to ruminants has shown to increase digestibility of poorly digested feeds and improves animal performance in terms of weight gain and milk yield, the effect is not consistent to different researches. The inconsistent results from studies can be contributed to a number of factors, including diet composition, type of enzyme preparation, complement of enzyme activities, and amount of enzyme provided, enzyme stability, and method of application. Among the different methods of enzyme application, pre-ingestion treatment of feed results in a better intake, digestibility and animal performance. Similarly supplementation of enzymes to the total mixed ration brings enhanced performance of animals. Even while the appropriate level of enzyme supplementation to different types of feeds is not specified, several studies have shown that applications of high levels of enzymes to forages or diets produce less desirable responses than low levels. The better understanding of the production techniques, enzyme activity, mode of enzyme action and application techniques of commercial non starch polysaccharidase enzymes can help the scientific community for competent utilization of these biotechnological products for efficient utilization of the available feed resources.

Key words; exogenous enzymes, supplementation , Animal performance

1. INTRODUCTION

In many animal production systems feed is the biggest single cost and profitability can depend on the relative cost and nutritive value of the feeds available. Often, the limiting factor when formulating rations is the animal's ability to digest different constituent parts of the feed raw materials, particularly fibre. Not all compounds in animal feed are broken down by animals own digestive enzymes, and so some potential nutrients are unavailable to the animal (McDonald et al., 2010).

The exogenous enzyme have shown promise at hydrolyzing plant cell walls (Bhat & Hazlewood, 2001) and revealed new opportunities to improve feed utilization in animal nutrition (Sheppy, 2001). The exogenous enzymes, like other feed enzymes, are of natural origin and non-toxic. They are mostly commercial products of microbial fermentation on safe, simple and inexpensive solid agricultural and agro industrial residues (Bhat, 2000). Therefore, the supplementation of animal feeds with enzymes to increase the efficiency of digestion can be seen as an extension of the animal's own digestive process (Sheppy, 2001). All sort of enzymes, which are responsible for degrading or hydrolyzing the complex carbohydrates, proteins or fats, are organic, containing up to 98% cellular complex protein, having polypeptide binding (Altaf-ur-Rahman et al. ,2007). They speed up or catalyse reactions by binding to their substrate and 'stabilize' the entire reaction process through to product formation, so that far less activation energy is required to move the reaction forwards (Sheppy, 2001). The enzymes, which are naturally secreted by the body cells of living beings, are also termed as endogenous, while the enzymes, which are synthesized artificially and are administered to the farm animals as a non nutrient feed additives are also called as exogenous enzymes (Mikulski, 1999).

The importance of using feed enzymes is to enhance availability of nutrients that are locked within cell wall components. Some nutrients are not as accessible to the own digestive enzymes of the animal, others are bound up in a chemical form that the animal is unable to digest them (Sheppy, 2001). The exogenous enzymes subsequently decrease the variability in nutrient availability from feed ingredients and also supplement the digestive enzymes of the animal. Thus, enzymes can be strategically utilized to enhance the uniformity of animal performance (e.i. daily growth rate, egg production or milk production) from such intrinsically variable feed ingredients (Pariza & Cook, 2010). Improving diet utilization with exogenous enzymes can enhance overall production efficiency, reduce cost of animal protein production and reduce the environmental impact of animal agriculture (Pariza & Cook, 2010).

For many years, researchers were discouraged from using enzymes to enhance the utilization of ruminant diets because of perceptions that the hydrolytic capacity of the rumen could not be enhanced by supplemental enzymes, and concerns that such enzymes would be ineffective due to ruminal proteolysis (McAllister et al., 2001). These concerns have been disproved by several recent studies that have demonstrated that fibrolytic enzyme supplementation enhances the productivity of livestock, and several fibrolytic enzyme products are currently commercially available (Adesogan, 2005). Adding fibrolytic enzymes to ruminant diets has been the topic of many studies (Beauchemin et al., 2003) because digestion of fiber is usually never maximized in the rumen. Therefore the aim of this paper is to review the effects of exogenous enzymes on ruminal fermentation of feed and animal performances.

2. COMMON FEED ENZYMES

So far over 3000 different enzymes have been discovered. Enzymes, as with all proteins, are made from chains of amino acids (Sheppy, 2001). Enzymes are naturally occurring biocatalysts produced by living cells to bring about specific biochemical reactions. In the context of feed additives for ruminants, enzymes are employed to catalyse the degradative reactions by which substrates (i.e. feedstuffs) are digested into their chemical components (e.g. simple sugars, amino acids, fatty acids). These are in turn used for cell growth, either by ruminal microorganisms or by the host animal (McAllister et al., 2001). Currently, enzymes are mainly produced with the help of micro-organisms, particularly from fungi and bacteria. This is generally speaking more economical than isolating enzymes from plant or animal source materials. In addition, micro-organisms are able to synthesise a very broad spectrum of hydrolytic enzymes which the animal organism is largely not able to produce itself. As many micro-organisms are adapted to cope with extreme living conditions (temperature, pH, osmolarity) microbial enzymes are in this respect often more stable than enzymes originating from plants and animal. Moreover, microbial enzyme preparations can also be better standardised, which is a further advantage (Bühler et al., 2000).

A wide variety of carbohydrase, protease, phytase and lipase enzymes find use in animal feeds (McCleary, 2001). Although enzyme products marketed for livestock number in the hundreds, they are derived primarily from only four bacterial (Bacillus subtilis, Lactobacillus acidophilus, L. plantarum and Streptococcus faecium) and three fungal (Aspergillus oryzae, Trichoderma reesei and Saccharomyces cerevisiae) species (Muirhead, 1996). Cellulases and xylanases are produced by a wide range of bacteria and fungi, including aerobes, anaerobes, mesophiles, thermophiles and extremophiles. Aerobic fungi and bacteria generally produce extracellular cellulases and hemicellulases (Bhat et al., 2001)

Furthermore, most of the commercially available enzyme products that have been evaluated as ruminant feed additives are produced for non feed applications; cellulases and xylanases are used extensively in the food, pulp and paper, textile, fuel, and chemical industries (Bhat and Hazlewood, 2001). Several fibrolytic enzyme products evaluated as feed additives in ruminant diets were originally developed as silage additives (Feng et al., 1996).

2.1. Carbohydrases

Carbohydrases are to any of a group of enzymes that promote hydrolysis or synthesis of a carbohydrate. Carbohydrases facilitate the breakdown of dietary carbohydrates such as starches, fibers, and sugars (Bregendahl, 2007). Smaller saccharides found in the diet, and those resulting from starch digestion, are broken down into their component monosaccharides by intestinal brush border enzymes such as glucoamylase, sucrase, isomaltase, and lactase. Fibers, like starches, are polysaccharides but their internal beta-glycosidic bonds cannot be hydrolyzed by human pancreatic or intestinal enzymes (see figure above). Fibers are therefore non-digestible by humans, but they can be partially broken down by microorganisms within the gastrointestinal tract that produce the enzymes necessary to cleave the internal bonds. Supplemental fiber-digesting carbohydrases such as cellulase and hemicellulase can also effectively break the beta-glycosidic bonds in fibrous foods making them easier to digest (Wolfson et al., 2002).

Carbohydrases break down carbohydrates into simpler sugars. The two main fibre-degrading enzymes used in animal feed are xylanase and β-glucanase. Xylanases break down arabinoxylans, particularly prevalent in grains and their by-products. β-glucanases break down β-glucans that are particularly prevalent in barley and oats and their by-products. Amylases break down starch in grains, grain by- roducts and allows the use of less cooked grain in the diet, with resultant benefits in feed cost reduction (Barletta, 2010). Amylases and proteases are rarely fed in isolation and are more commonly found as part of an enzyme admixture, perhaps involving xylanases, glucanases, proteases and phytases. It has recently been demonstrated that the efficacy of such enzymes is inextricably linked to the digestibility of the diet to which they are added (Cowieson, 2010).

2.2. Protease

Proteases catalyze the hydrolysis of proteins into smaller fragments known as peptides. Dietary protein digestion begins in the stomach where the acid-stable protease, pepsin, initiates the cleavage of peptide bonds within proteins to produce large polypeptide fragments. These polypeptides enter the small intestinal tract where pancreatic and intestinal proteases and peptidases cleave peptide bonds until only small peptide units and individual amino acids remain (Bregendahl, 2007).

Proteases are protein-digesting enzymes that are used in livestock nutrition to break down storage proteins in various plant materials and proteinaceous anti-nutrients in vegetable proteins. Proteases can help break down storage proteins, releasing bound energy-rich starch that can then be digested by the animal. Two major proteinaceous anti-nutrients are trypsin inhibitors and lectins. Trypsin inhibitors can inhibit digestion as they block the enzyme trypsin, which is secreted by the pancreas and helps break down protein in the small intestine. Lectins are sugar-binding proteins that have also been shown to reduce digestibility. Proteases can be used to reduce the levels of trypsin inhibitors and lectins, thus improving protein digestibility (Barletta, 2010). Although livestock are able to digest the majority of dietary protein, approximately 10% on average of dietary protein escape the small intestine undigested. Hence, addition of exogenous proteases may increase the animals' utilization of dietary protein. Improved protein digestibility has been reported when proteases were added to the diet (Hong et al., 2002; Omogbenigun et al., 2004), but inclusion of proteases probably does not improve energy digestibility or availability (unless the additionally digested amino acids are broken down for energy rather than being used for protein synthesis).

2.3. Phytase

Phosphorus is a mineral required by all animals for maintenance, growth, and production. Most feed ingredients of plant origin contain sufficient phosphorus to meet the animals' daily phosphorus requirement; however, a large proportion of the phosphorus is contained in phytate (Bregendahl, 2007). This phosphorus compound represents the main storage form for phosphorus in plant seeds and can only be broken down by phytases. In the past, dairy cows were often fed diets containing P levels markedly higher than the recommendations for P supply. The most common explanation for this oversupply is the perception that high-P diets improve reproductive performance. In addition, the recommendations for adequate P supply differ from nation to nation (CVB, 2005; Schlegel, 2011). Consequential the proportion of excreted P, which is not used to meet the requirements of the cow, increases. Moreover, natural P sources used as mineral feedstuffs become more and more limited in the future (Rodehutscord, 2008). One way to increase the P-absorption and to reduce faecal P is the supply of exogenous phytase to the diets (Knowlton et al., 2007).

In ruminants, phytase is secreted intracellular by ruminal bacteria (Yanke et al., 1998) and phytate hydrolysis also occurs in the lower gastrointestinal tract (small intestine with duodenum, jejunum, ileum) of ruminants. However, for P to be absorbed from the small intestine, the phytate hydrolysis must occur in the rumen. Garikipati and Kincaid (2004) figured out a positive effect of the influence of exogenous phytase in dairy cows. However, data regarding the intake of Phosphorus and the use of exogenous phytase are inadequate. Kincaid et al. (2005) reported that exogenous phytase could have an influence on the faecal P-excretion of dairy cows.

3. ENZYMES IN RUMINAL FERMENTATION OF FEEDS

Enzymes are added to animal feed to increase its digestibility, to remove anti-nutritional factors, to improve the availability of components, and for environmental reasons (Walsh et al., 1993). The majority of carbohydrates found in feed ingredients can be divided into two groups based on the animal's ability to digest them: Starch and non-starch polysaccharides (NSP). Whereas starch is readily digested by animals, the carbohydrates classified as NSP are not. The NSP group includes cellulose, hemicellulose, gums, b-glucans, pectins, and others that often serve a structural function in the plant (Bregendahl, 2007). Not only are the NSP themselves indigestible (and therefore contain no usable energy for the animal, diluting the dietary energy content), but they may also prevent digestion of otherwise digestible carbohydrates (and other nutrients) in part by encapsulation, thereby preventing physical access by digestive enzymes.
Some exogenous enzymes are resistant to degradation in the rumen and have the potential to increase the digestibility of feeds, and in turn improve animal performance (Klingerman et al., 2009). Carbohydrases addition in the feed reduces the non starch polysaccharide -induced viscosity of the digesta and in turn improving general nutrient digestibility and energy availability (Bregendahl, 2007). Similarly, because of its hydrolytic action, supplemental α-amylase increases the availability of starch hydrolysis products in the rumen and alter the ruminal fermentation process (Tricarico et al., 2008). Additions of exogenous proteases increase the animals' utilization of dietary protein. Improved protein digestibility has been reported when proteases were added to the diet (Hong et al., 2002; Omogbenigun et al., 2004). Most lipids in ruminants are digested efficiently without the addition of exogenous lipases.

However, when using high lignocellulolytic ingredients (agricultural wastes), the results have been variable and inconsistent in terms of fibre digestibility (Wang et al., 2004; Colombatto et al., 2007; Gallardo et al., 2010) because the potential of exogenous enzymes depends mainly on the dose and type of substrate. Intraruminal dosing of exogenous enzymes did not affect apparent digestibility of DM, crude protein (CP) or neutral detergent fiber (NDF) but reduced rumen pH and the activity of key endogenous fibrolytic enzymes and also increased the soluble DM fraction and effective DM degradability (Hristov et al., 2000).

3.1. Mechanism of enzyme Action

The mode of actions of exogenous enzymes in ruminant systems is not conclusive (Beauchemin et al., 2004). This is due to the lack of understanding the relationship between enzymatic activities and the improvement in forage utilization (Eun et al., 2007). Previous works on this topic showed that exogenous enzymes can act to improve feed utilization in ruminants either through their effects on the feed before consumption or through their enhancement of digestion in the rumen and/or in the post-ruminal digestive tract (McAllister et al., 2001). The exogenous enzymes are most effective when applied in liquid form onto dry feed prior to ingestion (Kung et al., 2000; Beauchemin et al., 2003). This may partially digest feed or weaken cell wall barriers that limit microbial digestion in the rumen. The direct action of exogenous enzymes before feed consumption can cause a release of reducing sugars arising from partial solubilisation of cell wall components. This may therefore increase available carbohydrates in the rumen required to shorten the lag time needed for microbial colonization and also enhance the rapid microbial attachment and growth (Forsberg et al., 2000). Direct-fed enzyme application is often accompanied by increased feed intake, which is attributable to increased palatability due to sugars released by pre-ingestive fiber hydrolysis, post-ingestive enzyme effects such as an increased digestion rate or extent of digestion or increased passage rate. These factors reflect an increase in the hydrolytic capacity of the rumen which indirectly reduces gut fill, and hence enhances feed intake (Adesogan, 2005). Moharrery et al. (2009) also reported that pre-treatment of forage with fibrolytic enzymes can solubilize some fiber and improve digestibility at short incubation times. It appears that effective enzymes work best by removing structural barriers which retard microbial colonization of digestible fractions (Colombatto et al., 2003) to increase rate of degradation.

Another important advantage for treating feed with exogenous enzymes prior to ingestion is the improvement of the enzyme binding to feed particles, in contrast to its direct infusion in the rumen. This was thereby reported to increase the resistance of exogenous enzymes to proteolysis in the rumen (Morgavi et al., 2001; Beauchemin et al., 2003). Within the rumen, exogenous enzymes could act directly on the feed or could indirectly stimulate digestive activity through synergistic effects on ruminal microorganisms.

Exogenous enzymes applied to feed are relatively stable in the rumen (Morgavi et al., 2001). Thus, it is likely that exogenous enzymes survive for a considerable amount of time in the rumen where they probably maintain activity against target substrates. Enzyme application to diets at feeding is attractive because the fermentable substrates released by enzyme action can be directly fermented by ruminal bacteria, thereby releasing energy for the host animal. However care is needed to ensure an even distribution of the small quantity of enzyme that is typically added (Adesogan, 2005). At the levels typically used in feeding studies, enzymic activities provided by exogenous enzymes represent only 5–15% of the enzymic activities normally present in the rumen (Wallace et al., 2001). However, this estimate disregards the synergy that occurs between exogenous enzymes and rumen microbial enzymes (Morgavi et al., 2000a). Synergy between exogenous enzymes and rumen microbial enzymes can be defined as the enhanced effect of these two entities acting cooperatively.

Although most of the benefits of using enzyme supplements in ruminant diets are probably due to ruminal effects, the possibility of post ruminal effects cannot be discounted (Beauchemin et al., 2006). Exogenous enzymes may remain active in the lower digestive tract, contributing to the post-ruminal digestion of fibre, or they could indirectly improve nutrient absorption in the lower tract by reducing viscosity of intestinal digesta (McAllister et al., 2001). In the small intestine, exogenous enzymes appear to survive for a sufficient period of time with sufficient effects on substrate particles when applied to wet feeds and concentrate premix (Beauchemin et al., 2004). Administering large quantities of enzymes directly into the rumen can significantly increase cellulase activity in the small intestine. An exogenous enzyme supplemented in this manner flow mainly with the fluid phase of ruminal contents (Hristov et al., 2000) and at these elevated feeding levels a portion of the cellulases even escapes inactivation by the low pH and pepsin in the abomasum. As biological silage additives, enzymes (cellulases, xylanases, hemi-cellulases, pentosanases and amylases) are used to release water-soluble carbohydrates from forage polysaccharides and are often applied together with inoculants containing lactic acid bacteria (Davies, 2004).

3.2. Level of enzyme supplementation in ruminants

Enzymes can be added to feed in one of two ways. One option is to reformulate the feed to reduce feed costs and at least maintain animal growth, egg production and feed conversion; for example, replace some wheat, barley or maize with lower-cost, higher-fibre by-products and/or reduce the added fat level in the diet. The second option is to add the enzyme to the standard feed formulation and achieve improved animal growth, egg production and feed conversion giving enhanced efficacy of production by improving the efficiency of feed utilization.

Responses to enzyme application level have been somewhat variable, with quadratic responses most commonly observed (Beauchemin et al., 2003). However, there are some inconsistencies on effects of exogenous enzyme levels on ruminal fermentation kinetics. Some research has shown that efficiencies of forage utilization were increased at increasing levels of exogenous enzymes (Miller et al., 2008) whereas others suggest that exogenous enzymes produced better results at a particular level, rather than showing a dose response (Jalilvand et al., 2008). The inconsistent results from those studies can be contributed to a number of factors, including diet composition, type of enzyme preparation, complement of enzyme activities, amount of enzyme provided, enzyme stability, and method of application (Yang et al., 2007). Several studies have shown that applications of high levels of enzymes to forages or diets produce less desirable responses than low levels (Adesogan, 2005). For instance, Beuchemin et al. (2000) found that a high level of enzyme application was less effective than a low level at increasing total tract digestibility. Excessive enzyme application blocks binding sites for enzymes or may prevent substrate colonization (Beauchemin et al., 2003).

4. PRODUCTION RESPONSE OF RUMINANTS TO ENZYME APPLICATIONS

According to Sheppy (2001), there are four main reasons for using enzymes in animal feed: 1) to break down anti-nutritional factors; 2) to increase the availability of starches, proteins and minerals enclosed within fiber-rich cell walls; 3) to break down specific chemical bounds in raw materials which are not usually broken down by the animals' own enzymes, thus releasing more nutrients, and. 4) to supplement the enzymes produced young animals. A number of studies have been published in the past decade to examine the potential role of exogenous feed enzymes in ruminant diets (Beauchemin et al., 2006). On the other hand beauchemin and Holtshausen (2011) reported as the primary objective of using feed enzyme additives in ruminant diets is to decrease the cost of producing meat and milk. Most of the research on ruminant enzymes has focused on fibrolytic enzymes to improve fi bre digestibility, because increasing fibre digestibility can increase the intake of digestible energy by the animal. As a result, less feed is required to produce 1 kg of milk or liveweight gain or, alternatively, more milk or weight gain results per kilogram of feed consumed by the animal.

4.1. Production Response in Cattle

Supplementing diets with enzymes has been shown to improve feed efficiency and daily gain of feedlot cattle (Galyean et al., 2000). Beauchemin et al. (2000) reported an 11% improvement in feed conversion ratio resulting from a 5% decrease in feed intake from enzyme treated ration associated with a 6% increase in body weight gain. En earlier study of the same author of reported a 10% improvement in the feed conversion ratio of steers fed dry forages resulting from improved digestibility of enzyme-supplemented ration. In a 9.5, 14.25, and 19.5 grams enzyme supplementation in Holstein beef cattle, the crossponding values of weight gains (in gram) found respectively to be 651, 801 and 583. Using moderate level of enzyme (14.25 ml/10Kg alfalfa) increased average daily gain and dry matter intake 23.1 and 4.3 percent respectively compared to control (Atrian and Shahryar, 2012). A number of studies have examined the effects of exogenous enzymes on digestibility and milk production in dairy cows. In some studies, dietary addition of enzymes either to forages or concentrate portion increased milk production from 5 to 16% (Gado et al., 2009; Holtshausen et al., 2011) and in some others (Elwakeel et al., 2007; Bernard et al., 2010) no milk response was reported. Inconsistency of results may be due to differences in energy status of the cows, diet composition, type and activity of enzyme used and method of application (Yang et al., 2000).

As reported by Sutton et al.(2003), no differences were found between dietary concentrate or total mixed ration supplementation or rumen infusion of enzymes on DM intake digestibility or milk yield in dairy cows. This indicates post-ingestive supply of fibrolytic enzymes is no more effective than dietary supplementation for increasing feed intake, digestion and milk yield in cattle. Enzyme addition to the total mixed ration treatment reduced the ruminal acetate to propionate ratio, decreased concentrations of ruminal ammonia-N, tended to improve milk fat and protein concentrations. Enzyme addition to the concentrate tended to reduce milk yield and ruminal pH, and increase BW gain and milk protein concentration (Dean et al., 2013). Yang et al.(2000) also reported that application of fibrocystic enzymes to the concentrate instead of the total mixed ration increased total tract dry matter digestion and milk yield. The addition of amylase to a 26% starch total mixed ration increased milk production and dry matter intake of dairy cows (Klingerman et al., 2009).

The addition of exogenous fibrolytic enzymes (Fibrozyme containing active xylanase and cellulase) to the complete diets (total mixed ration) of dairy cows increases milk productivity by about 7% during the peri parturient and early lactation period and by as much as 13% during the first three weeks of lactation, and has a positive effect on feed conversion, especially in the first three weeks after calving (Bilik et al., 2009). Although the effect of fibrolytic enzyme supplement on percentage of milk components is not consistent observed a tendency for milk protein to increase without clear effects on the content of fat and other components. However for enzymes to be effective when added to the feed they must be active in the animal, stable during storage and be compatible with minerals, vitamins and other feed ingredients. Equally, they must be stable at the high temperatures reached during feed manufacture, safe and easy to handle and free-flowing to ensure thorough mixing throughout the feed(Barletta, 2010). Milk yield (4%) and the fat corrected milk were increased as a response to fibrolytic enzymes supplementation(15g/day) to lactating dairy cows fed total mixed ration (Shadmanesh, 2014).

4.2. Production response in small ruminant (sheep and goat)

Bala et al. (2009) observed an increase in milk yield of lactating goats supplemented with enzymes. The authors ascribed this to the improvement of the energy availability and the utilization of microbial digestible protein, estimated as purine derivatives and creatinine excreted in urine. The increased availability of nutrients to micro-organisms in the rumen was reported by Chakeredza et al. (2002) to improve the yield of fermentative end-products due to a change in the ratio of micro-organism biomass to the digestible energy in the rumen. The application of fibrolytic enzyme produced by Aspergillus spp. at low level (2 g/kgDM) to the concentrate portion of total mixed ration containing silage increases ruminal availability of slowly digestible carbohydrate and improve goat performance (Wahyuni et al.,2012). Enzyme addition increased the average daily gain by 51 and 69% in sheep and goats, respectively (Salema al., 2011). Addition of enzymes of ZADO® enzymes improved nutrients digestibility in sheep and goats. The improvement was better in goats than in sheep. Goats had the lowest total dry matter intake that associated with an improvement in nutrient digestibility and average daily gain more than sheep.

5. LIMITATIONS OF ENZYMES UTILIZATION IN RUMINANT DIETS

Supplementing ruminant diets with exogenous enzymes has the potential to improve plant cell wall digestibility and thus the efficiency of feed utilization. Understanding the complexity of the rumen microbial ecosystem and the nature of its interactions with plant cell walls is the key to using exogenous enzymes to improve feed utilization in ruminants (Meale et al., 2014). The variability currently observed in production responses can be attributed to the array of enzyme formulations available, their variable activities, the level of supplementation, mode of delivery, and the diet to which they are applied as well as the productivity level of the host. Although progress on enzyme technologies for ruminants has been made, considerable research is still required if successful formulations are to be developed (Adesogan, 2005). Knowledge of the rumen microbial ecosystem and its associated carbohydrases could enhance the likelihood of achieving positive responses to enzyme supplementation. Ruminal conditions can cause a loss of fibrolytic enzyme activity, such that no responses in feed intake and milk production will be seen following enzyme application (Vicini et al., 2003). Not all exogenous enzymes are equally effective at digesting complex substrates in different feedstuffs. Feedstuffs are exceedingly complex structurally, and our lack of knowledge of the factors that limit the rate and extent of feed digestion impedes our engineering of enzyme preparations designed to overcome constraints to feed digestion. With some feeds, specific targets can be identified (McAllister et al., 2001).

6. SUMMARY AND CONCLUSION

The use of enzymes in animal nutrition has an important role in current farming systems. Feed enzymes can increase the digestibility of nutrients, leading to greater efficiency in feed utilization. Also they can degrade unacceptable components in feed, which are otherwise harmful or of little or no value. Another benefit is positive impact on the environment by allowing better use of natural resources and reducing on faecal nutrient level applied to land. For example, diets based on cereals such as barley, rye and wheat are higher in non -starch polysaccharides (NSPs), which can decrease the intestinal methane production when supplemented with NSP enzymes. Furthermore, proteases can substantially reduce the amount of non -protein nitrogen supplement in diets of animals, thereby reducing the excretion of urea into the environment.

Although positive responses in animal performance have been observed, results have been inconsistent. Characteristics of the ruminant digestive tract (e.g., complex microbial populations producing numerous endogenous enzymes) complicate elucidation of the mechanisms of exogenous enzyme action in ruminants. There is evidence that exogenous enzymes initiate digestion of feeds prior to consumption and that they can improve feed digestion in the rumen and lower digestive tract. Addition of exogenous enzymes to the total mixed ration was more effective than adding it to dietary components. Enzyme addition to the total mixed ration improved the ruminal utilization of energy and protein. Research on exogenous enzyme in ruminant diets reports on improvements of forage utilization, production efficiency and reduced nutrient excretion.

The net effect of exogenous enzymes on feed digestion is a combined result of direct hydrolysis of substrate, increased microbial attachment, stimulation of the rumen microbial population and synergistic effects with hydrolases of ruminal micro-organisms. Important progress has been made in using fibrolytic enzymes to increase meat and milk production from livestock. However more research is needed in the areas of determining the most critical activities for inclusion in commercial preparations, improving enzyme-feed specificity and developing practical guidelines that ensure the effectiveness of the enzymes.

In conclusion, enzyme efficacy in dairy cows is more likely to result if the following conditions are met:

- Only enzymes that exhibit high activity under ruminal pH and temperature conditions are used.
- Proper enzyme-substrate specificity is ensured i.e. activities of the specific enzymes in the enzyme preparation are appropriate for hydrolysis of the nutritional fractions in the feed or diet being investigated.
- Enzymes are uniformly applied to the total mixed ration rather than to individual components of the diet at feeding, or to the forage component at ensiling.

7. RECOMMENDATIONS

- New products designed for ruminants and for specific types of feed which increase the potential for profitable use of enzymes needs to develop. Promising enzyme technologies should be evaluated by producers on a case by case basis from independent research results until clearer animal performance and cost to benefit ratios emerge.

- The better understanding of the production techniques, enzyme activity, mode of enzyme action and application techniques of commercial non starch polysaccharidase enzymes can help the scientific community for competent utilization of these biotechnological products for efficient utilization of the available feed resources.

- Optimum level of exogenous enzyme supplementation to different ruminant animals needs to be determined.

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