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Review Article

ROLE OF DIGESTION MODIFIERS AS FEED ADDITIVES IN RUMINANTS- A REVIEW

KUMAR SUSHIL*[1], SINGH NARENDER[2], SIHAG SAJJAN [1]AND SIHAG ZILE SINGH[1]

[1]Department of Animal Nutrition, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, 125004, India
[2]Livestock Production Management, Lala Lajpat Rai University of Veterinary and Animal Sciences, Hisar, 125004, India
*Corresponding Author: Email-chahar53@gmail.com

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Abstract- In the interest of animal health as well as economic animal production, feed additives are increasingly being given to animals, such as enzymes, buffers, probiotics, prebiotics etc. Animal feed additives are used worldwide for their varying range of advantages. Some of the feed additives cover the needs of essential nutrients while others increase the growth performance, feed intake and therefore optimize the feed utilization by the animals leading to economical livestock production. Feed additives can also positively affect technological properties of the feed and animal product quality as well. The health status of dairy animals with high growth and production performance need due consideration while choosing a feed additive. In many countries use of feed additives which impose high risk to the consumers or environment, like antibiotics, hormone etc. is banned in ruminant diets. Therefore, ruminant feed industry is becoming more interested in other valuable alternatives feed additives which could be accepted preferable by the consumers without any health risk. Probiotics, prebiotics, enzymes and ionophores etc. can be seen as alternative feed additives for modifying the digestion kinetics in the ruminant animals leading to accelerated production efficiency.

Keywords- Ruminant, Feed Additives, Probiotics, Prebiotics, Enzymes.

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Introduction

The constant effort to produce human food from animal sources more efficiently and at lower cost has stimulated continued search for new additives which will increase the efficiency, rate of growth and level of production of animals. These widespread efforts have led to the use of a range of feed additives which are ingredients or combination of ingredients to be used in micro quantity in animal nutrition. Although, these feed additives are not nutrients and cannot be considered as dietary essential to the animal, they have been reported to improve the efficiency of feed acceptance, nutrient utilization, growth and health of the animals. Ganai*et al.* [1] reported improvement in IVDMD, IVOMD and IVNDFD on supplementation of yeast to bajra straw and bajra straw-based complete feed. In today's ever increasing economic climate, commercial livestock feed companies are trying to help alleviate feed cost with the main focus on examining the benefits of adding feed additives to ruminants' rations. Kumar *et al.* (2015) [2] reported that incorporation of anaerobic fungal (Neocallimastix sp.) in complete feed for Murrah male buffalo calves significantly increased nutrient digestibility that enhances feed efficiency and body weight gains. The main objective of any industry is to maximize profit and from the standpoint of live production in ruminant production the nutritionist is faced with this heavy task. Currently, ruminant nutritionists are at battle with several issues when formulating diets to minimize cost while still meeting the animals' requirements to allow for maximal performance. One of the biggest issues at hand has been the price of feed ingredients. One way for reducing the cost of feed is by increasing the utilization of the nutrients in the feed by animals. This can be achieved by using feed additives in the diet of animals that modify the digestion kinetics of various feed components resulting in enhanced nutrient utilization like probiotics, prebiotics, enzymes, buffers, acidifiers and ionophores etc. In this review, we will focus on the application of digestion modifiers as feed additives and discuss the theory behind these compounds and their benefits while implementation in food animals.

Are the Feed Additives really needed ?

The response from the animal in term of production or growth due to feed additives application and economic return to the farmer are the chief factors which determine the need of use of feed additives in dairy animal ration. The response from the animal can be increase in milk production, increase feed intake, improved digestion, improved growth rate or improvement in health.

Probiotics (also known as Direct Fed Microbials) as feed additives

The probiotics are the live microorganisms which modify the digestion process. The probiotics can be broadly classified into 4 types, for example:

a) Bacterial vs Non-bacterial probiotics: with the exception of certain yeast and fungal probiotics (*S. cerevisiae*), most of the micro-organisms used are bacteria [3].
b) Spore forming versus non-spore forming bacteria as probiotics: in constrast to the previously used probiotics, the modern probiotics are based on the spore forming bacteria which sustain comparatively longer in animal system [4].
c) Multi-species (multi-strain) probiotics versus Single-species (single-satrain) probiotics.
d) Allochthonous probiotics versus Autochthonous probiotics: micro-organisms which are normally not present in GIT of animals (allochthonous) includes yeasts, while the micro-organisms normally present as indigenous inhabitants of GIT (autochthonous) include *Lactobacillus* and *Bifid bacterium*.

Mode of action of Probiotics

1. Modification of microbial population of the gut thus promoting favorable micro flora
2. Increase in digestion and absorption of nutrients
3. Production of antimicrobial substances
4. Alteration in gene expression in pathogenic micro-organisms
5. Improvement in innate gut immunity through restitution of intestinal barrier function.

Role of Probiotics in ruminants' ration

To minimize the gaseous losses duirng the fermentation process and therefore, improving the efficiency of feed utilization and overall performance of the dairy animals, manipulation of rumen is being given more and more emphasis by the ruminant nutritionists. For this purpose, probiotics like, Yeast has commonly been used [5], which effects the microbial population dynamics in rumen and breakdown of nutrients. The improved performance of animals due to probotics application is oftenly due to the improved digestibility. Bacterial population in the silage is also a good source of probiotics to the ruminants [6]. Boyd *et al.* (2011) [7] used a combination of *L. acidophilus* and *P. freudenreichii* and found that digestibility of crude protein and fibre improved significantly in Holstein cows. The meta-analysis of the application of yeast probiotics in ruminants by Desnoyers *et al.*(2009) [8] demonstrated that live yeast significantly increased rumen SCFA and increased rumen pH.Higher the proportion of concentrate and neutral detergent fibre in the diet, the better is the digestibility of organic matter resulting from the live yeast supplementation. The increased cellulose degradation and microbial protein production due to yeast-based probiotics in ruminants is mainly due to the increased number of the cellulolytic bacteria [9][10].Similarily, increase in the number of rumen bacteria in cross bred cattle fed *S. cerevisiae* probiotic has been reported by Ding *et al.*(2014)[11]. Feeding with high non-structural carbohydrates e.g. starch and low fibre diet lowers the ruminal pH [12] leading to accumulation of SCFAs and unbalanced buffering of rumen [13]. The condition is referred to as SARA when the pH drops below 5.6 [14] leading to loss of appetite, diarrhea, dehydration, debilitation, impaired rumen motility and impaired fibre digestibility. Lactic acidosis is the more severe form of ruminal acidosis where the pH drops below 5.2 due to accumulation of lactate [15]. Probiotics have also been found to effective in alleviating the acidosis. Lettat*et al.*, (2012)[16] studied the effect of application of *Propionibacterium, L. plantarum* and *L. rhamnosus*strain as probiotics and found them to be effective in pH stabilizing and prevention of acidosis in sheep. It was hypothesized that stability in ruminal pH was achieved by the probiotics modulating rumen microbes so that their capacity to hydrolyse cellulose was increased and lactic-acid producing bacteria were inhibited. Similar effects were observed with *Megasphaeraelsdenii*by Prabhu*et al.* (2012) [17] and Kung and Hession (1995) [18] in preventing lactic acid accumulation during *in vitro* fermentation. Similarly, yeast *S. cerevisiae* decreased the lactic acid concentration in the rumen of lactating Holstein cows [19, 20], which may prevent ruminal acidosis. But, prolonged establishment of probiotic bacterial species in rumen has constantly been a challenge for the ruminant nutritionists. Chiquette *et al.* (2007) [21] fed *Ruminococcus flavefaciens* bacterium with *S. cerevisiae* to examine the establishment of the inoculated bacteria in rumen. In a similar study by Klieve *et al.* (2012) [22], *Ruminococcus bromii* was inoculated with *Megasphaera elsdenii* as an alternative starch-utilizerin steers.

Prebiotics as feed additives for ruminants

Certain organic compounds that cannot bedigested by the host animal, but specific microbes in the GITof animals can effectively utilize them for the good of host are called prebiotics. Schrezenmeir and De-Vrese (2001) [23] classify them as pharmaceutical grade nutrients. They contain nutrients that stimulate growth of beneficial intestinal micro flora in the animal's digestive tract and suppress harmful pathogenic bacteria from the body [24]. Some oligosaccharides like MOS, FOS, XOS and other organic compounds like inulin are "colonic food" for the beneficial microbes in the small and large intestine [25, 26]. The nutrients used as prebiotics may be a peptide, protein, fat, oligo or a polysaccharide [27]. According to Grela*et al.* (2013) [28] addition of prebiotics to dairy animal feed has inhibited the development of pathogenic microorganisms in the digestive tract with a decrease in the population of E. coli that are the main pathogens causing diarrhea in animals.These substances are produced by surface yeast cell walls.Prebiotics increase the microbial diversity in the host GIT leading to improved feed utilization [29]. In ruminants, the presence of a huge, dense pre-gastric microbial population in the rumen break down many of prebiotic compounds and presents enormous challenges to the implementation of prebiotics in these animals. Another factor working against prebiotic usage in ruminants is the large GIT volume [30]. This has limited the number of investigations regarding the use of prebiotics in ruminants; however, rumen-protective technologies may allow these compounds to be used in dairy animals [31].

Synbiotics: a synergistic approach to modify microbial ecosystem

Simultaneous use of probiotics and prebiotics together is known as "synbiotics" [32, 33]. These two products support each other in a highly targeted fashion, which has been reported the most likely approach to reduce pathogens in dairy animals [34]. Bomba*et al.* (2002) [35] showed a synergistic effect in reduction of food borne pathogenic bacteria populations in food animals when fed synbiotics.

Role of Enzymes as feed additives

These are natural biocatalysts which regulate different biochemical reaction in the living system. They can also be employed as feed additives for improving the deragation reaction during feed digestion. The enzymes produced by the rumen mirocbes work in a synchronous fashion for carbohydrate digestion. The capacity to solubilize in ruminal fluid, structural complexity and accessibility to the rumen microbes are the main factors that determine the efficiency of fermentation of the carbohydrates in rumen [36]. The ruminant nutritionists have started giving more emphasis on manipulating the rumen carbohydrate and protein digestion metabolism tomaximize the efficiency of degradation of feed. Cellulases, xylanases, β-glucanases, pectinases, amylases, proteases, phytases and enzymes that degrade specific plant toxins like tannases,arise from the diversity of the microbial population established in the rumen[37-39].

Exogenous fibrolytic enzymes like cellulases or xylanases have been extensively used innonruminant animals since long [40]. But, their use in ruminants has been started over 40 years ago only [41, 42]. Exogenous enzymes in ruminants alter feed utilization either through their effects on the feed before ingestion, or through improvement in the digestion in rumen or post-ruminally. But, the mode of action of exogenous enzymes in ruminants continues to be a major focus of the research in animal nutrition. Different feed types [43], application levels of enzymes [44], type of enzyme products [45] and enzyme application methods [46] are the different factors which effect the response from the animals and have been compared under controlled conditions with better feed efficiency outcome.

Although it was demonstrated that these enzyme preparations could increase milk production in cows fed total mixed rations, positive responses in milk production were highly dependent on the level of enzyme applied [47]. Beauchemin*et al.* (1998) [48] suggested that the efficacy of enzymes in ruminant ration is apparently dependent upon the method of its application.

Buffering agents as feed additives

Buffers are weak acids or alkalis that resist changes inpH.They are added to diets to complement the buffering effect of saliva and neutralizeruminal acidity thus reducing the risk of acidosis in cattle fedstarch-rich diets or acidic silages, and decrease the incidence of bloat. Buffers as feed additives include sodium bicarbonate, limestone, sodium bentonite, and magnesium oxide. The main mode of action of buffers involves increasing pH or resisting a changein pH. Higher pH values facilitate fiber digestion leading to increased acetate to propionate ratio in the rumen.Theyalso enhance water intake, ruminal fluid outflow, fibredigestion and milk fat synthesis. The cow has three primary means of buffering acid ingested or acid produced by rumen fermentation *viz.* buffer naturally occurring in saliva, buffering capacity of ingested feed, and;added dietary buffers.

Acidifiers as promising feed additives for ruminants

Acidifier feed additives are considered to be important to promote rumen fermentation, and consequently improves animal health, performance and quality of the animal products. Acids used as feed additives are predominantly natural products with minimum level of toxicity [49]. Some of the important acidifying substances which are currently used by dairy farmers like dicarboxylic organic acids e.g. aspartate, malate, and fumarate have been evaluated as feed additives because they reduce methanogenesis byacting as 'Hydrogen sink 'during their conversion to propionate [50]. This theory has also been validated by [51]; Moss and Newbold (2002) [52]; Wallace *et al.* (2005) [53]. Organic acids could be beneficial due to their antimicrobial effect on rumen fermentation. They are sometimes found in their salts like sodium, potassium, or calcium salts, etc. The reduced concentration of rumen H_2 can also stimulate cellulolyticbacteria and thus increase cellulose digestion. By dropping the ruminal pH and reducing methanogenesis [54], these acids can stimulate ruminal growth of prominent bacteria and consequently change favorably ruminal fermentation, improving ruminant performance [55]. Organic acids stimulate the growth of *Selenomona ruminantium* and favorably alter the mixed ruminal microorganism fermentation, and improve the performance of feedlot steers [56, 57]. *S. ruminantium*bacteria use lactate as a source of energy [58]. Nisbet and Martin (1990) [59] observed significant effects of malate in inhibition of a reduced ruminal pH. Organic acids have been reported to act as an electron sink for *S. ruminantium* [60].

However, according to Sanson and Stallcup (1984) [61] and Martin *et al.* (1999) [57] the beneficial effects of these acids on animal performance have been found inconsistent. In spite of the fact that these organic acids have GRAS status, problems with palatability [52], decreased ruminal pH[62], inconsistent responses, and high costs [50], have limited their use in ruminants.

Ionophores

Ionophores are organic compounds mainly from *Streptomyces* spp. that facilitate selective transportation of ions across the outer cell membrane. Examples of commonly used ionophores include Monensin Sodium, LasalocidSodium, Salinomycin, and Laidlomycin Propionate Potassium. They are approved for preventing coccidiosis, and or improving feed efficiency or performance of different classes of livestock. Among these, monensin is mostly used ionophore in the dairy animals. It is recommended orally as monensin sodium [63, 64]. By reducing the fibre digesting gram positive bacterial and increasing the concentrate utilizing gram negative bacteria, the ionophores change the pattern of rumen fermentation towards higher propionate production and decreased methanogenesis.Gram-positive bacteria lack the complex cell wall of gram-negative bacteria and the associated lip polysaccharide layer with its protein channels (porins) that have a size exclusion limit (600 Da) that is impervious to ionophores (> 600Da) as suggested by McGuffey *et al.* (2001)[65]. Consequently, ionophores successfully infiltrate the outer cell membrane of gram-positive bacteria and rapidly and repeatedly cause efflux of intracellular K^+ from the cell and influx of extracellular protons (Na^+ and H^+). The resulting cytoplasmic acidity causes cell death of gram positive bacteria [66]. Application of ionophores in ruminant diet leads to increased propionate while decreased acetate ad methane production resulting in enhanced feed utilization efficiency of the dairy animals. Monensin has a benefit to cost ratio of 5 to 1 when added to dairy cow diets; it is recommended for increasing feed efficiency in lactating cows and reducing metabolic disorders in dry cows [67].Ionophores are also labeled as a coccidiostats in growing heifers leading to improved growth and health. These are recommended at dose rate of 300 to 350 milligrams per cow per day.

Conclusion

It can be concluded that feed additives can be used to manipulate rumen function, increase the level and efficiency of animal performance, and minimize adverse effects of diets on animal health and the environment. However, various products with contrasting effects are available. Hence, careful scrutiny of the literature is required to identify effective additives. Only research-proven additives that consistently produce an economically justifiable return should be added to ruminant diets.

Application of review: This review presents the currently used digestion enhancer feed additives which will help dairy farmers update themselves for gaining maximum possible economic return from their dairy animals.

Review Category: Animal nutrition.

Abbreviation used:

MOS- Mannanoligosaccharides
FOS- Fructooligosaccharides
XOS- Xylooligosaccharides
AXOS- Arabinoxylooligosachrides
SARA- Sab acute ruminal acidosis
SCFAs- Short chain fatty acids
VFA- Volatile fatty acids
DMI- Dry matter intake
IVDMD- In-vitro dry matter digestibility
IVOMD- In-vitro organic matter digestibility
IVNDFD- In-vitro neutral detergent fibre digestibility

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