Research Journal of Agriculture
Volume 15, Number 9; September-2024;
ISSN: 2836-6050 | Impact Factor: 6.58
https://zapjournals.com/Journals/index.php/rja/index
Published By: Zendo Academic Publishing

100. BIOTECHNOLOGICAL METHODS FOR IMPROVING THE NUTRITIVE VALUE OF RUMINANT FEEDS: A REVIEW

[1]Mahgoub Gaafar El Hag

Article Info

Keywords: Biotechnology, fibrous feeds, recombinant-DNA, productivity, ruminants, developing countries, quality

DOI
10.5281/zenodo.13870994

Abstract

Biotechnology is an important and broad science or group of sciences that has been successfully applied in many fields for the betterment of human life, including cell biology, environmental sciences, animal science, food science, medicine, and pharmacy. Modern Biotechnology has been successfully used in developed countries to enhance animal production and productivity and has resulted in increasing the quantity and quality of animal products. Biotechnology provides cutting-edge experiences that depend on the best scientific practices, innovative research, and applied technology. An increase in the world population and demand for animal products necessitates that developing countries must implement and adopt more modern biotechnological means in addition to effective traditional methods to improve the quality of available fibrous livestock feeds and the nutritional status and productivity of ruminants. Currently, the use of biotechnology in developing countries is limited to animal breeding, health care, and the conservation of animal feeds and products. Increased use of biotechnological methods via manipulations of rumen fermentation, recombinant DNA, removal of toxic compounds in feeds, use of exogenous enzymes etc. coupled with use of appropriate traditional methods will improve the quality of fibrous-animal feeds and the productivity of ruminants in developing countries.

Introduction:

It is well documented in the literature that animal-source foods are more important for normal human growth, pregnancy, and lactation than plant-based foods. Animal-source foods provide more energy, fat, protein, and micronutrients than plant-based foods (Allen 2017). Ruminant animals provide many benefits beyond the provision of food. They provide a source of cash income and livelihood for farmers, traction in developing countries, organic manure, a source of important by-products (skins, hides, bones and blood), and other offals

[1] Department of Animal Production, Faculty of Agriculture, Alzaem Alazhari University, Khartoum -Sudan

that are used in many industries like leather, poultry feed, etc. Ruminants also provide a source of recreation like camel-race in Arab countries. The productivity of ruminants in developing countries is rather poor and lagging compared with that in developed countries, mainly due to their poor genetic makeup and harsh environmental conditions (nutrition, climate, housing, health, and husbandry management practices), (El Hag et al 2023).

For improving the genetic makeup of native cattle in developing countries, artificial insemination (A.I.) was the most successful and used tool for introducing new superior genes by crossing local cows with imported semen from reputable bulls of dairy or meat breeds as targeted. However, in addition to A.I., many important biotechnological and conventional methods can be used to improve the production performance of ruminants in developing countries.

Biotechnology is a broad field that can be defined as the science or biological systems using cells, microorganisms, or tissues of multicellular plants or animals after genetic engineering. The applications of biotechnology in many fields, such as cell biology, environmental sciences, animal sciences, agriculture, medicine, and pharmacy, have resulted in improving the quality of human life (Awulachew 2022). Biotechnology is an old field of knowledge that dates back to the early dawns of history, since 4000 B.C. man used it to produce bread and wine.

An increase in the world population and increase in demand for animal-source foods stresses the need for increased productivity per animal as well as increases in the number of livestock. It was estimated that the world population will increase from 6 to about 8.3 billion by the year 2030 ,at an average growth rate of 1.1% per year , and it is appropriate to be prepared to increase adequate food for the increased population based on locally available feed resources , particularly in developing countries (Wanapat et al 2013). Traditional means will not be capable of enhancing animal products to meet the increased demand for livestock products (Tona 2018). Biotechnological and related applications can be used to boost livestock production in developing countries. In addition to improvements in genetic potential and reproductive efficiency, improvements in animal production performance are greatly affected by nutrient supply and efficiency of nutrient use by ruminants.

2. Biotechnological methods for improving ruminant nutrient supply and efficiency of use by ruminants:

Ruminants are less competitive with humans and other monogastric animals for feed because of their compound stomach and presence of microorganisms (bacteria, protozoa and fungi) in their reticulo-rumen. These unique characteristics enable ruminants to use fibrous feeds that cannot be used by monogastric animals. Fibrous feeds, particularly cellulose, are the most abundant organic compounds in the universe. However, the utilization of cellulose, which constitutes the majority of feed resources available for ruminants feeding in developing countries, is hampered by the presence of lignin, which affects the digestibility and intake of cellulosic feed materials (Schwartz 1992). Reliance on fibrous feed alone will result in slow rumen fermentation and low productivity. Increasing the productivity of ruminants in developed countries can be achieved by feeding concentrate feeds, however this cannot be achieved on a large scale in developing countries, as cereal grains are consumed largely by humans and poultry. Improving the productivity of ruminants in developing countries will mainly depend on the improvement of the utilization of fibrous feeds (Schwartz 1992). Efficient use of fibrous feeds by ruminants requires suitable rumen manipulation methods, including genetic and feeding methods (Malmuthuge and Guan 2017, Chharang et al. 2019).

2.1 Manipulation of rumen fermentation:

Generally, rumen manipulation techniques can be divided into two categories, i.e. genetic and nongenetic. In genetic manipulation, rumen microorganisms are genetically engineered using gene transfer techniques to boost animal productivity, whereas nongenetic manipulation can be performed via dietary manipulation (Chharang et al. 2019).

The reticulo-rumen hosts a highly specialized anaerobic group of microorganisms responsible for fiber digestion, which is influenced by the biochemical and microbial characteristics of the rumen environment. The rumen environment is greatly influenced by rumen pH, which has a great impact on rumen function, rate and type of fermentation, and ultimately ruminant health and production. Very low acid rumen pH may result in acidosis and impair animal health and production. The important factors affecting rumen pH include species and type of rumen microbes, type of feed, buffering agents, rate of feed passage, fiber particle size, and animal factors. To manipulate rumen fermentation to promote fiber digestion and utilization, efforts were directed toward microorganisms, probiotics, and probiotics.

Table1: Summary of important responses due to the use of biotechnological and traditional methods for different types of ruminants (Summarized results from studies reviewed)

Livestock Type	Biotechnological and Conventional methods: Responses regarding some performance parameters and digestibility							
Dairy cattle	Ionophores	Probiotics	Enzymes	By-pass proteins	Defaunation	Nano-particles	NH_3-from Urea	UMMB.
	-	Control of GIT-associated diseases Improved cell wall digestibility	Improved: DMI, Milk production	Improved Milk yield	Improved protein supply and decreased energy loss	Increase biogas prod. from cattle manure	Increased CP, energy DMI*, Milk yield*, Profits	Improved Milk yield
Reference	-	Alugongo et al. 2017, Bimrew Asmare, 2014, Chahal et al. 2008	Mohmed et al. (2013)	Garag and Sherasia 2010b; Rufino et al. 2016	Nguyen et al. 2020, Nguyen et al. 2018	Abdelsalem et al... (2016)	(Walli 2010)	Garag et al. 2007, EL Hag et al. 2002
Beef cattle	Improved: ADG and FCR Decreased methane and favorable Propionate production	Improved ADG*	Improved: Hot carcass yield	. -	. -	administration of nutrients, probiotic, enzymes, diagnosis + disease treatment	Increased CP, energy DMI*, ADG* Profits	. -

Reference	(McDonald et al. 2010). (Gupta et al. 2019)	Mansilla et al. 2024	Vargas et al. 2013			Fesseha et al. 2020, Marra pan et al. 2017	(Walli 2010)	
Buffalo	-	-	Improved: DMI*, ADG* Fiber-digestibility*	Improved Milk yield	. -	. -	. -	. -
Reference			Thakur et al... (2010)	Garag and Sherasia 2010b				
Sheep	-	-	Improved: ADG* Digestibility*	-	Decrease CH_4 prod.	. -		Improved: ADG
Reference			Arce-Cervantes et al... (2013)		Nguyen et al... (2016)			EL Hag et al. 2002

2.2 Biotechnology products as feed additives:

Feed additives (Table2) can be defined as materials that are given to animals to boost the effectiveness of nutrients and exert their effects in the gut (Fuller 1989). These include antibiotics, enzymes, probiotics, and prebiotics (McDonald et al. 2010).

***Table2:** Categories, types, uses of Feed Additives, and Most researched Types

Categories	*Feed Additives and uses*	Most researched types
Technological additives: any substance added to the feed for a technological purpose.	Preservatives, Antioxidants, Emulsifiers, Stabilizers, Thickeners, Gelling agents, Binders, Substances for controlling radionuclide contamination, Anticaking agents, Acidity regulators, Silage additives, Denaturants, and Substances for reducing the contamination of feed by mycotoxins.	Buffers and silage- additives.
Sensory additives: Any substance, and the addition of which to feed improves or changes the organoleptic properties of the feed or the visual characteristics of the food derived from animals.	Colorants and Flavoring compounds.	Both Colorants and Flavoring compounds are mainly researched in the area of animal feed-industry (Pelleted feeds).

Nutritional additives	Vitamins, provitamins, and chemically well-defined substances having similar effect. Compounds of trace elements. Amino acids, their salts and analogs. Urea and its derivatives, molasses.	Vitamins, pro-vitamins, trace minerals, urea, and molasses are heavily researched in the area of strategic supplementation for poor-quality ruminant feeds. Nanoparticles.
Zootechnical additives: Any additive that favorably affects the performance of animals in good health or that favorably affects the environment.	Digestibility enhancers: substances that increase the digestibility of the diet when fed to animals through action on target feed materials. Gut flora stabilizers: microorganisms or other chemically defined substances that, when fed to animals, positively affect the gut flora. Substances that favorably affect the environment. Other zoo technical additives.	Exogenous enzymes, antibiotics, probiotics, probiotics, genetically modified plants and feeds, recombinant DNA, bypass proteins, defaunation This effect affects the environment by decreasing methane production by ruminants.
Coccidiostats and histomonostats.	Substances in which one or more of the functional groups intended to kill or inhibit protozoa. Ionophore antibiotics.	Monensin sodium.

*__Source:__ (Tomar et al. 2022) with some modifications.

2.2.1 Antibiotics and enzymes:

Antibiotics are produced by fungi, and small doses can prevent bacterial growth. They are used as therapeutic agents via injection, food, or water to treat bacterial diseases. In addition, subtherapeutic antibiotics are added to promote animal growth. Many types of antibiotics are used for health promotion in animals in addition to ionophore antibiotics, which interfere with the electrolyte balance of the bacterial cell, eventually leading to the rupturing of the cell. Monensin Sodium is an example of this type of antibiotic (McDonald et al. 2010). Antibiotic growth inhibitors have been used primarily in poultry and swine feeds, typically at levels of 20-40mg/Kg, resulting in noticeable improvements in growth rates and feed conversion efficiency. Young-suckling ruminants can use the addition of antibiotics to promote good health and growth, unlike mature ruminants. In mature ruminants monensin sodium has been used successfully at levels of 20-30mg/Kg of feed to promote growth and the efficiency of feed conversion by altering rumen fermentation in favor of propionate production in carbohydrate -rich diets (McDonald et al 2010). (Gupta et al 2019) reported that supplementation with monensin (about 0.6 mg/Kg body weight) in growing heifers reduced enteric methane production. The intensive use of antibiotics for growth promotion in animal feeds has recently received growing criticism in Europe and the USA (Centner 2016) due to the buildup of immunity by certain bacteria and the fear of residual effects in treated animal products. Antibiotic resistance has been identified as a security risk in the USA (George 2018). The haphazard use of antibiotics (Lazzaro et al. 2020) triggered scientists to launch monitoring programs to find alternatives to antibiotics, with attention directed toward probiotics.

2.2.2 Use of exogenous enzymes:

Enzymes are proteins in nature and are considered very important for the maintenance and production of livestock and poultry. Enzymes are considered important products of biotechnology for increasing the effectiveness of nutrients from available feed and reducing the wastage of feed (Yamagushi 2017, Awulachew 2022). Exogenous enzymes are used as feed additives mainly to improve the digestion of feed or to remove or breakdown harmful materials that interfere with the digestion, absorption, or use of nutrients (McDonald et al. 2010). Exogenous enzymes that improve the availability of plant storage poly saccharides (e.g. starch), proteins, and oils (that are protected from digestive enzymes by the impermeable cell wall structures) are the most commonly used enzymes for improving the digestion of feed and the availability of nutrients (Chharang et al. 2019). Fibrolytic enzymes are the most researched types among the different groups (Mohamed et al 2013) because of the rather low digestibility of fiber by ruminants, being about 65-70% even under ideal conditions (Sujani and Sersinhe 2015). Fibrolytic enzymes are further subdivided into three sub categories :1-cellulases which hydrolyze the fiber of plant cell wall to glucose ,cellobiose or cellooligisacccharides .2 -Xylanase that catalyzes the hydrolysis of the xylosidic-linkages in xylans that are constituents of hemicellulose , which is found in plant cell wall together with cellulose.3-A variety of debranching enzymes including : -L-arabino-furanosidases ; -glucuronidases and acetyl esterases (Kamble and Jadhav 2012) .The development of biotechnology ,recently has allowed the use of cellulase enzyme produced by non-toxic fungi ,like White rot fungi and anaerobic bacteria for improvement of feeding value of fibrous feeds like straw ,crop residues and agro-industrial by-products . Some fungal strains have been evaluated for ligno-cellulose hydrolysis, such as *Aspergillus niger*, *Aspergillus terreus*, *Chaetomium cellulolytic* and *Fusarium sp* (Akinfemi and Doherty2009). Increasing fiber digestion has also been approached indirectly through the use of silage inoculants produced commercially by microorganisms (e.g. amylase, hemicellulase and cellulase enzymes). The production of such enzymes by genetically modified silage bacteria was reported to result in improved ensiling, which consequently led to improved digestibility (Chharang et al. 2019). In different review articles (Sujani and Sersinhe 2015, Anil et al 2022) concluded that a lot of research work was conducted with respect to supplementation of ruminant diets with exogenous enzymes (using cattle, both beef and dairy, goat, sheep and less with buffalo). Although the results seem to be inconsistent, positive results on feed intake, nutrient digestibility, growth performance, and other production parameters have been reported (Thakur et al 2010, Arce-Cervantes et al 2013, Bhasker et al 2013, Mohmed et al 2013, Vargas et al 2013 and Hussain et al 2014). In a few studies, some researchers reported either a negative or lack of response (Tewoldebrhan et al. 2017, Hassan and Almaamory 2019). The inconsistent results regarding the use of enzymes in ruminant diets were ascribed to factors such as enzymatic handling, dosage, diet constituents, time, and method of application (Anil et al. 2022).

2.2.3 Probiotics and Prebiotics:

Probiotics were defined by (Fuller 1989) as live microbial feed supplements that have a beneficial effect on the host animal by improving its intestinal microbial balance. Probiotics are available in powder, paste, liquid form, or as a direct feed additive. Microorganisms used as probiotics include *Lactobacillus acidophilus, Lactobacillus fermentum, Lactobacillus lactis, Aspergillus oryzae, streptococcus faecium, Bacillus spp, saccharomyces cerevisiae* etc. Probiotics are part of the normal gut flora, but when these microorganisms are given in high doses, they improve antibiotic susceptibility and improve production. Of the many commercially available probiotics, Bacillus probiotics are regarded as among the best (Rashid et al. 2023). Bacillus probiotics were found to be effective against salmonellosis (Tazehabadi et al. 2021). The word ‘probiotic’ came from a phenomenon discovered among co-cultured organisms in which some microbes produced growth-promoting chemicals that consequently enhanced the growth of the host (Jeni et al. 2021).

An ideal probiotic should be non-toxic or pathogenic to the host, have a positive effect on the host ,have a high survival and multiplication rate in the digestive system with a good form and faster adhesive characteristics to microorganisms, easy and safe to be fed to host animals, and economically feasible (Chahal et al 2008).In ruminants, probiotics are more effective in controlling the disease of GIT in young suckling animals due to lack of complications of presence of rumen microbes (Asmare 2014 , Alugongo et al 2017).However, in adult ruminants, positive effects were reported for yeast culture in improving rumen environment as well as microbial activities (Fuller 1989). Improved plant cell wall digestibility was also reported with the use of yeast probiotics (Chahal et al. 2008). Significant improvements in daily gain and body weight were reported when probiotics with high-energy diets were fed to feedlot cattle (Mansilla et al. 2024).

Prebiotics are defined as non-digestible feed ingredients that have beneficial effects on the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon, resulting in improved host health. Galato-Oligosaccharides (GOS), Fructo-Oligosaccharides (FOS), and lactose derivatives are classified as probiotics (Chahal et al 2008). (GOS), (FOS), and lactose derivatives are used in poultry and other monogastric animals.

3. Genetically modified plants and feeds:

For removal of harmful materials that impair utilization of nutrients like tannins, cyanogens in legumes, glucosinolate, protease inhibitors, etc., conventional plant-breeding has been used to decrease or even in some cases eliminate such anti-nutritive factors from the feed. One example was the introduction of oilseed rape cultivars that are free or low in erucic acid and glucosinolate. The combination of conventional plant breeding and genetic engineering should lead to or result in marked reductions or removals of major anti-nutritive factors in plant species of importance as animal feeds (Adeymo and Onilude 2013). Rumen microbes can be genetically modified to increase their ability to perform defined functions or to add new functions (Chang 1996). Genetically modified microorganisms are either able to delignify fibrous components or degrade toxic substances, reduce ruminal methane production, synthesize essential amino acids, and tolerate acids (Forsberg et al. 1993).

3.1 Use of single cell proteins:

Fermentation by microorganisms such as bacteria, yeast, fungi, and algae can be used to produce proteins for feeding animals. Single-cell proteins (SCP), particularly those produced by yeasts and bacteria, have been reported to be technically feasible as animal feeds or feed components. The protein content of bacteria is higher than that of yeasts and contains higher concentrations of s-containing amino acids but lower contents of lysine. (SCP) usually contains higher levels of nucleic acids, ranging between 5-12% DM-basis in yeasts and 8-16% in bacteria. SCP is recommended to be used at approximately 80 kg/ton (Alkaline yeast) in calf milk substitutes and at 20-50Kg/ton for broilers and 100 kg/ton for layers (McDonald et al 2010).

3.2 Use of By-pass Proteins:

By-pass proteins are considered the most important feeding methods used for manipulating rumen fermentation. In the case of bypass or protected proteins, the idea is to treat feedstuffs that are highly degradable in the rumen through certain treatments to escape microbial degradation in the rumen and be digested in the lower intestinal tract (duodenum), avoiding rumen degradation losses, sparing good protein sources, and contributing to improved animal performance (Schwartz 1992, Garag and Sherasia 2010-b, Rufino et al 2016,). The technology of bypass protein was reported to be very effective in India and has resulted in increases in milk-yield of10-15percent and increased profits of dairy farmers by 10% in the case of cows. By-pass protein technology has also resulted in improved milk production by dairy cows in Bangladesh (Aasiwal et al. 2015, Tiwari et al. 2018).

3.3 Defaunated animals:

Protozoa in rumen account for as much as 50% of total ruminal microbial biomass and up to 50% of total fermentation products. It has been reported that removal of protozoa, unlike that of bacteria, is not vital for the development and survival of the ruminant host, although it may result in a less stable rumen environment (Fuller

1989). Defaunation was found to increase bacterial numbers due to a decrease in the predation of bacteria and to increase the efficiency of bacterial protein synthesis and the rate of nitrogen flow to the duodenum, particularly in protein-deficient feeds relative to energy content. Defaunation also results in decreased methane production (Nguyen et al. 2016) and may decrease carbohydrate digestion in plant cell walls. Improvements in protein supply and ruminant productivity coupled with reductions in methane production may exceed the reduction in digestibility of cell wall constituents observed with defaunation (Nguyen et al. 2018, Nguyen et al. 2020). Many researchers have reported the beneficial effects of defaunation on increasing protein outflow, which increases protein supply to the host for liveweight gain and wool growth. A small decrease in DM intake and DM digestibility was not associated with reduced animal growth (Newbold et al. 2015). The positive effects of defaunation on ruminants' growth were observed in poor quality roughage diets that were low in fermentable carbohydrates and rumen degradable nitrogen (Nguyen et al. 2015). Defaunation is carried out by many methods, including isolating newly born animals from their dams and other adult ruminants. The use of chemical methods like Coconut oils did not eliminate all rumen protozoa. It was also reported that defaunation was easier in ovines than bovines (Nguyen et al. 2020). The commercial application of defaunation is hindered by a lack of effective, safe, and practical defaunation methods for commercial enterprises.

3.4 Nanotechnology:

The term 'Nano ' originated from the Greek word 'Nanos' meaning dwarf, and was originally just a prefix substituting factor 10^{-9} for SI units (Grunwald 2017). Nanotechnology can be defined as the branch of science and engineering concerned with designing, producing, and using structures, devices, and systems by manipulating atoms and molecules at the nanoscale. A dimension generally ranging between 1 and 100 nm (10^{-9} – 10^{-7}m), (Morris 2014, Pundir 2015, Hill and Li 2017). Nanotechnology revolutionized many industrial sectors such as Electronics, Energy, Environment, Textile, Biomedicine, Food and Agriculture (Omietimi et al. 2023). In agriculture, the applications of nanotechnology were pronounced in the use of fertilizers, pesticides, plant pathology, storage, and processing of agricultural products. In animal nutrition, the use of nanoparticles encompasses two groups: organic (proteins, fat and sugar nano-molecules) and inorganic(nano-minerals). Accordingly, animal nutrition applications of nanotechnology include the administration of nutrients, probiotics, enzymes, and diagnosis and treatment of diseases (Marappan et al 2017, Fesseha et al 2020). The feeding of nanoparticles has reflected improvements in digestive efficiency, immunity, milk, meat, and egg quality (Fesseha et al 2020). Nano-minerals offer low-dose usage and improved bioavailability (Fesseha et al 2020, Gelaye 2023). The penetration of nanoparticles into cell membranes is the basis of interactions with biological systems, immune systems, uptake, absorption, distribution and metabolism is facilitated biologically (Abdelsalem et al. 2016).

4. Allied conventional methods in improving productivity of ruminants:

4.1 Strategic supplementation for high fiber-based diets:

Animal feeds can be categorized into two main categories: roughage and concentrate. Roughages are feed items that contain more than 18% crude fiber (CF) and less than 60% total digestible nutrients (TDN). They are bulky in nature and a poor source of readily available carbohydrates and can be subdivided according to their moisture content as dry (hays, straws, stover, hulls, crop residues etc.) or succulent (pasture/range, forage crops, haylages and silages). Concentrate feedstuffs contain less than 18% CF and more than 60% TDN. Concentrates are usually more digestible and nutritive compared to roughages (concentrates include energy sources such as cereal grains, molasses and brans; protein sources such as soyabean, groundnut seed cake, sunflower cake, sesame oil seed cake ,animal proteins such as fish ,meat meal ,milk by-products and non-protein nitrogen such as urea and biuret) ; and minor supplements such as common salt, limestone, bone meal and commercial supplements like dicalcium phosphate and trace-mineralized salts etc. in addition to vitamin supplements (Tomar et al 2022). Low-quality roughages are characterized by large quantities of lignocellulose material, deficient in protein, energy, minerals, and vitamins, and poor to moderate in digestibility (Preston 1995). The best strategy to improve the low nutritive value of fibrous feeds in developing countries is to use conventional supplementation methods to provide the most deficient nutrients, particularly energy and protein through:

a. Direct supplementation with readily fermentable sources of energy such as cereal grains or molasses together with conventional plant proteins usually gives good results with respect to improving the nutritive value of high-fiber diets, but the problem is the high cost and the problems of competition between monogastric and ruminants for such high-quality energy and protein concentrates. In urea-supplemented diets, urea should not provide more than 33% of the total nitrogen in the ration. In pelleted total mixed rations (TMR), molasses should be used at a level of 5-10 percent. Molasses not only improves palatability and feeding value of the ration but also acts as a binding agent for pelleting (Chahal et al. 2008). In a feedlot study using 3 different nitrogen sources (plant protein, urea and yeast single cell protein) for growing calves fed high-fiber diets, supplementation with 8.5% molasses +1.5% urea resulted in growth performance comparable to that of the conventional plant protein with a decrease in feeding cost by 4.6% (Mohamed et al 2020).

b. Treatment with urea -solution (Ammonia from urea): Treatment with ammonia could be either gaseous ammonia or with urea-solution (4-5 percent) to release ammonia through the action of urease enzyme, which is naturally present in plant materials . For obtaining better results with urea treatment of fibrous feeds, a moisture-level of 35-40% of roughage is adequate for ureolysis, and the optimum temperature for urease activity in the soil was reported to be 30 0C and ammoniation is increased at higher temperatures. The optimal level of urea for better utilization and avoidance of urea toxicity was reported to be 4-5 percent(W/V) solution (Chahal et al. 2008). Walli (2010) reported that straw urea treatment was suitable and inexpensive for developing countries. He reported increased CP and energy contents of treated straw, increased intake by 10-15 percent, growth rate by 100-150 g in growing calves, and increased milk yield in dairy cows.

c.Use of urea-molasses multinutrient blocks (UMMB): Feeding (UMMB) is considered a strategic feed supplement, which provides fermentable nitrogen, energy, and minerals intermittently, which are needed for optimal growth of rumen microbes (Garg and Sherasia 2010-a). Supplementation with UMMB increased the digestibility of low-quality basal diets, resulting in improved milk production (Garg et al 2007). Many feed ingredients can be used in the manufacture of UMMB, according to availability and cost. (EL Hag et al 2002) used by-products of Dates in the manufacture of UMMB together with urea and reported improved growth performance with small ruminants as well as improved milk production with dairy cows (EL Hag et al 2002).

5. Conventional feeding strategies to improve productivity of ruminants:

Flushing and steaming up for pregnancy and lactation and the use of total mixed rations (TMR-feeding) can improve the poor productivity of ruminants in developing countries, particularly in cases of drought and poor feeding.

5.1 Flushing and steaming up during pregnancy and lactation:

Flushing (enhancement of the plane of nutrition for breeding animals through feeding of an energy or protein supplement or both for a period of 6-8 weeks during breeding season) for a period of about six weeks would be valuable in improving the reproductive performance of ruminants and decreasing fetal mortality (Robinson et al 2006). In Sudan (EL Hag 2001), a mixture of Sesame Cake (95 parts) with 5 parts of a salt-lick block was used at a rate of 450g/ewe every 3 days during watering time for flushing for six weeks during breeding time. The same mixture was used for steaming up pregnant ewes six weeks before parturition. Steaming up decreased the abortion rate and increased the weight of lambs. Combining both flushing and steaming up noticeably increased twinning rate.

5.2 Use of total mixed rations (TMR):

Poor nutrition in farm animals has been identified as a severe constraint in developing countries (Quansah and Makkar 2012). Grazing and pastoral systems are the major feeding practices in many developing countries in Africa and Asia. In efforts to address the issue of poor nutrition in developing countries, a shift from extensive grazing to stall feeding using (TMR) has been explored in Asia (Bodahewa et al 2014) and Africa (EL Hag et al 2023). Many of these efforts were directed at improving the productive and reproductive performance of lactating dairy cattle (Karunanayaka et al. 2022). The preparation of a nutritionally complete single ration composed of both roughage and concentrate components that meet the desired nutrient requirements of a particular dairy cow is known as a TMR (Coppock et al 1981, Beigh et al 2017). Animals are grouped according to production, age, and weight (Mohammad et al. 2017). Feeding TMR provides a good strategy to address shortages of forage without affecting milk production or quality compared with traditional separate feeding with concentrate and roughage diets (El Hag et al. 2023).

6.Conclusion:

Biotechnology provided good and appreciated experience for improving ruminants productivity in developed countries. However, its use in developing countries still lags because of technical and economic constraints. Some reasonable and easy to apply biotechnological methods can be selectively tried in developing countries (Tables 1 and 2), such as feed additives (enzymes, probiotics and prebiotics), bypass proteins, etc. In developing countries, not even all the promising conventional methods have been implemented because of the use of extensive animal production systems such as transhumance, poor extension services, pasture disputes, and a shortage of water points in grazing areas. Revision of the production systems of ruminants in developing countries and improvement of research and extension systems are needed before advocating modern biotechnological methods. Efforts to include biotechnology courses in the curricula of faculties of agriculture and animal sciences in developing countries are needed to recruit future scientists for biotechnology.

References:

Aasiwal, D. P., Meena, B. S., Mahesh, M. S., et al. (2015). Effect of formaldehyde-treated rapeseed and cottonseed cakes in milk yield and composition at various stages of lactation and parity in Jersey cows. Journal of Animal Research, 5(1), 15-20. https://www.semanticscholar.org/paper/Effect-of-Feeding-Formaldehyde-Treated-Rapes...

Abdelsalam, E., Samer, M., Attia, Y. A., et al. (2016). Comparison of nanoparticle effects on gas and methane production from anaerobic digestion of cattle dung slurry. Renewable Energy, 87, 592-598. https://doi.org/10.1016/j.renene.2015.10.053

Adeymo, S. M., & Onilude, A. A. (2013). Enzymatic reduction of anti-nutritional factors in soyabean fermentation by Lactobacillus plantarum isolates fermenting cereals. Nigerian Food Journal, 31(2), 84-90. https://doi.org/10.1016/S0189-7241(15)30080-1

Akinfemi, A., Adu, O. A., & Doherty, F. (2009). Assessment of the nutritive value of fungi-treated maize cob using in vitro gas production. Livestock Research for Rural Development, 21(11). https://lrrd.cipav.org.co/lrrd21/11/akin21188.htm

Alugongo, G. M., Xiao, J., Wu, Z., et al. (2017). Review: Use of yeast of Saccharomyces cerevisiae origin in artificially raised calves. Journal of Animal Science and Biotechnology, 8(34). https://doi.org/10.1186/s40104-017-0165-5

Allen, I. H. (2017, March). Impact of animal-source food consumption on availability of critical nutrients in breast milk for newborn infants. In Nurturing Development: Improving Human Nutrition Using Animal-Source Foods. Symposium conducted at the University of Florida, Gainesville, FL.

Anil, Y., Yadav, S., Anand, V. M., Chouraddi, R., et al. (2022). A review on the role of exogenous fibrolytic enzymes in ruminant nutrition. Current Journal of Applied Science and Technology, 41(36). https://journalcjast.com/index.php/cjast/article/view/3966

Arce-Servantes, O., Mendoza, G. D., Hernandez, P. A., et al. (2013). The effects of a lignocellulolytic extract of Fomes sp. EUMI on the intake, digestibility, feed efficiency, and growth of lambs. Animal Nutrition and Feed Technology, 13, 363-372. https://www.indianjournals.com/ijor.aspx?target=ijor:anft&volume=13&issue=3&article=003

Asmare, B. (2014). Biotechnological advances for animal nutrition and feeding improvements. World Journal of Agricultural Research, 2(3), 115-118. https://pubs.sciepub.com/wjar/2/3/5/

Awulachew, M. T. (2022). Application of biotechnology in human food processing and animal feed. International Journal of Food Science, Nutrition and Dietetics, 11, 575-580. https://scidoc.org/IJFS.php

Beigh, Y. A., Ganai, A. M., & Ahmad, H. A. (2017). Prospects of a complete feed system in ruminant feeding: A review. Veterinary World, 10, 424-437. https://doi.org/10.14202/vetworld.2017.424-437

Bhasker, T. V., Nagalakshmi, D., & Rao, D. S. (2013). Development of appropriate fibrolytic enzyme combination for maize stover and its effect on rumen fermentation in sheep. Asian-Australasian Journal of Animal Science, 26, 945-951. https://doi.org/10.5713/ajas.2012.12590

Bodahewa, A. P., Weerasinghe, W. M. P. B., & Palliyeguru, M. W. C. A. (2014). Effects of feeding total mixed ration (TMR) on the production performance of dairy cows. Sri Lanka Veterinary Journal, 11(Supplement).

Chahal, U. S., Niranjan, P. S., & Kumar, S. (2008). Handbook of general animal nutrition (1st ed.). International Book Distributing Co.

Chang, H. (1996). Genetic engineering to enhance microbial interference and related therapeutic applications. Nature Biotechnology, 14, 423-431. https://www.nature.com/articles/nbt0496-444

Centner, T. J. (2016). Recent government regulations in the United States seek to ensure the effectiveness of antibiotics by limiting their agricultural use. Environmental International, 94, 1-7. https://doi.org/10.1016/j.envint.2016.04.018

Coppock, C. E., Woelfel, C. G., & Belyea, R. L. (1981). Forage and feed testing programs, problems, and opportunities. Journal of Dairy Science, 64, 1625-1633. https://doi.org/10.3168/jds.S0022-0302(81)82736-1

Chharang, D., Saini, V. P., Chopra, D., et al. (2019). Current and future perspectives regarding biotechnological applications in livestock nutrition: A review. International Journal of Current Microbiology and Applied Sciences, 8(6), 973-982. https://doi.org/10.20546/ijcmas.2019.806.118

Hag, E. L. (2001). Some options for improving desert sheep productivity under range conditions in North Kordofan, Sudan. (Unpublished PhD thesis). University of Khartoum, Sudan.

El Hag, M. G., Al-Merza, M. A., & Al Salti, B. (2002). Growth in the Sultanate of Oman of small ruminants given date byproducts-urea multinutrient blocks. Asian-Australasian Journal of Animal Science, 15(5), 671-674. https://doi.org/10.5713/ajas.2002.671

El Hag, M. G., El Khangeri, H. H., & Al-Merza, M. A. (2002). Milk production in the UAE Sultanate of Oman from dairy cows given date byproducts (urea) multinutrient blocks. Asian-Australasian Journal of Animal Science, 15, 371-376. https://www.cabidigitallibrary.org/doi/full/10.5555/20023042057

Hag, E. G., Mohammed, B. A., Sayed, M. A., et al. (2023). Effect of total mixed rations versus traditional feeding of concentrate and roughage rations on dairy cattle performance in Sudan. Arab Universities Journal of Agricultural Sciences, 31, 223-230. https://doi.org/10.21608/AJS.2023.226641.1531

El Jeni, R., Dittoe, D. K., Olson, E. G., et al. (2021). Probiotics and potential applications in poultry production systems. Poultry Science, 100, 101156. https://doi.org/10.1016/j.psj.2021.101156

Fesseha, H., Degu, T., & Getachew, Y. (2020). Nanotechnology and its application in animal production: A review. Veterinary Medicine – Open Journal, 5, 43–50. https://doi.org/10.17140/VMOJ-5-148

Forsberg, C. W., Cheng, K. J., Krell, P. J., et al. (1993). Establishment of rumen microbial gene pools and their manipulation to benefit digestion by domestic animals. In Proceedings of the Seventh World Conference on Animal Production (Vol. 1, pp. 281–316). Edmonton, Alberta. https://www.cabidigitallibrary.org/doi/full/10.5555/19931467219

Fuller, R. (1989). Probiotics in man and animals. Journal of Applied Bacteriology, 66, 365-378. https://europepmc.org/article/med/2666378

Garg, M. R., & Sherasia, P. L. (2010a). Production of urea-molasses mineral blocks in a process developed by the Dairy Board of India. In H. P. S. Makkar (Ed.), Success and failures with animal nutrition interventions (pp. 131–141). Springer. https://doi.org/10.1007/978-94-007-0786-4_10

Garg, M. R., & Sherasia, P. L. (2010). Rumen by-pass protein enhancing productivity in dairy animals. In H. P. S. Makkar (Ed.), Success and failures with animal nutrition practices and technologies in developing countries (pp. 29–35). FAO Animal Production and Health Proceedings No. 11. FAO.

Garag, M. R., Sanyal, P. K., & Bhanderi, B. M. (2007). Urea-molasses mineral block supplementation in the ration of dairy animals—Indian experiences. In H. P. S. Makkar, M. Sanchez, & W. M. Speedy (Eds.), Feed supplementation blocks: Urea-molasses multi-nutrient blocks: Simple and effective feed supplement technology for ruminant agriculture (pp. 35–37). FAO Animal Production and Health Paper No. 164. FAO.

Gelaye, Y. (2023). Application of nanotechnology in animal nutrition: A bibliographic review. Animal Husbandry and Veterinary Science. Cogent Food and Agriculture. https://doi.org/10.1080/23311932.2023.2290308

George, A. (2018). Antimicrobial resistance, trade, food safety, and security. One Health, 5, 6–8. https://doi.org/10.1016/j.onehlt.2017.11.004

Grunwald, P. (2017). Biocatalysis and nanotechnology. CRC Press. https://www.routledge.com/Biocatalysis-and-Nanotechnology/Grunwald/p/book/9789814613699

Gupta, S., Mohini, M., Malla, B. A., et al. (2019). Effects of monensin feeding on performance, nutrient utilization, and enteric methane production in growing buffalo heifers. Tropical Animal Health and Production, 51(5), 859–866. https://doi.org/10.1007/s11250-018-1766-5

Hassan, S. A., & Almaamory, Y. A. (2019). Effect of enzyme treatments for some roughages on average gain performance, feed conversion ratio, and nutrient digestibility of Awassi lambs. Plant Archives, 19(1), 993–1002. http://plantarchives.org/PDF%2019-1/993-1002%20(4746).pdf

Hill, E. K., & Li, J. (2017). Current and future prospects for nanotechnology in animal production. Journal of Animal Science and Biotechnology, 8, 1–13. https://doi.org/10.1186/s40104-017-0157-5

Hussain, H. N., Khanum, S. A., Hussain, M., et al. (2014). Effect of fibrolytic enzymes produced from improved mutant of Chaetomium thermophile DG-76 on the performance of Beetal-dwarf crossbred goats. Pakistan Veterinary Journal, 34(4), 394–398.

Kamble, R. D., & Jadhav, A. R. (2012). Isolation, identification, and screening of potential cellulase-free xylanase producing fungi and its production. African Journal of Biotechnology, 11(56), 14175–14181. https://doi.org/10.5897/AJB11.2356

Karunanayaka, R. H. W. M., Liyanage, R. T. P., Nayananjalie, W. A. D., et al. (2022). Feeding total mixed ration (TMR) on production and reproductive performance of lactating dairy cows: A review. Agricultural Reviews, 43(1), 29–37. https://doi.org/10.18805/ag.R-208

Lazzaro, B. P., Zasloff, M., & Rolff, J. (2020). Antimicrobial peptides: Application informed by evolution. Science, 368(6490), eaau5480. https://doi.org/10.1126/science.aau5480

Malmuthuge, N., & Guan, L. L. (2017). Understanding host-microbial interactions in the rumen: Searching the best opportunity for microbiota manipulation. Journal of Animal Science and Biotechnology, 8(8). https://doi.org/10.1186/s40104-016-0135-3

Mansilla, F. I., Miranda, M. H., Ficoseco, C. A., Obregozo, M., Villar, M. D., Nader-Macias, M. E. F., & Vignolo, G. M. (2024). Use of probiotic lactobacilli as an alternative to monensin in beef feedlot cattle. Academia Environmental Sciences and Sustainability. https://doi.org/10.20935/AcadEnvSci6162

Marappan, G., Beulah, P., Kumar, R. D., et al. (2017). Role of nanoparticles in animal and poultry nutrition: Modes of action and applications in formulating feed additives and food processing. International Journal of Pharmacology, 13(7), 724–731. https://doi.org/10.3923/ijp.2017.724.731

McDonald, P., Edwards, R. A., Greenhalgh, J. F. D., Morgan, C. A., Sinclair, L. A., & Wilkinson, R. G. (2010). Animal Nutrition. Pearson Books. https://www.pearson.com/en-gb/subject-catalog/p/animal-nutrition/P200000007549/9781292251677

Mohammad, D. E. A., Borhami, B. E., El-Shazly, K. A., et al. (2013). Effect of dietary supplementation with fibrolytic enzymes on the productive performance of early lactating dairy cows. Journal of Agricultural Sciences, 5(1), 146–155. https://www.ccsenet.org/journal/index.php/jas/article/view/26140

Mohamed, H. I., El Hag, M. G., & Abdalla, H. I. (2020). Evaluation of feedlot performance and carcass characteristics of growing calves using high fiber diets supplemented with different nitrogen sources. Sudanese Journal of Agricultural Sciences, 6, 1–17. https://www.researchgate.net/publication/349304635-Evaluation-of-feedlot-performance-and-carcass-characteristics-of-growing-calves-using-high-fiber-diets-supplemented-with-different-nitrogen-sources-1-Evaluation-of-feedlot-performance

Mohammad, M. E. M. A., Gorgulu, M., & Goncu, S. (2017). The effects of total mixed and separate feeding on lactational performance of dairy cows. Asian Research Journal of Agriculture, 5(1), 1–7. https://doi.org/10.9734/ARJA/2017/33663

Morris, V. J. (2014). Foods, materials, technologies, and risks. In Encyclopedia of Food Safety. https://www.sciencedirect.com/science/article/pii/B9780123786122000798

Newbold, C. J., de la Fuente, G., Belanche, A., et al. (2015). The role of ciliate protozoa in the rumen. Frontiers in Microbiology, 6, 1–14. https://doi.org/10.3389/fmicb.2015.01313

Nguyen, S. H., Barnett, M. C., & Hegarty, R. S. (2015). Use of dietary nitrate to increase productivity and to reduce methane production of defaunated and faunated lambs consuming protein deficient chaff. Animal Production Science, 56(2), 290–297. https://doi.org/10.1071/AN15525

Nguyen, S. H., Bremner, G., Cameron, M., et al. (2016). Methane emissions, ruminal characteristics, and nitrogen utilization changes after refaunation of protozoa-free sheep. Small Ruminant Research, 144, 48–55. https://doi.org/10.1016/j.smallrumres.2016.08.002

Nguyen, S. H., Nguyen, H. D. T., & Hegarty, R. S. (2020). Defaunation and its impact on ruminal fermentation, enteric methane production, and animal productivity. Livestock for Rural Development, 32(4), 1–9. https://www.Irrd.org/Irrd32/4/nghson32060.html

Nguyen, S. H., Nguyen, H. D. T., Bremner, G., et al. (2018). Methane emissions and productivity of defaunated and refaunated sheep while grazing. Small Ruminant Research, 161, 28–33. https://doi.org/10.1016/j.smallrumres.2018.02.004

Omietimi, H. B., Siyanbola, T. T., & Usman, T. J. (2022). Nutritional strategies to reduce enteric methane emissions in ruminants: A review. Journal of Agriculture and Environment for International Development, 116(2), 335–346. https://doi.org/10.12895/jaeid.2022.3329

Preston, T. R. (1995). Tropical animal feeding: A manual for research workers (FAO Animal Production and Health Paper No. 126). FAO.

Pundir, C. S. (2015). Enzyme nanoparticles: Preparation, characterization, and applications. Micro and Nano Technologies series. Elsevier. https://www.sciencedirect.com/book/9780323389136/enzyme-nanoparticles

Quansah, E. S., & Makkar, H. P. S. (2012). Use of lesser-known plants and plant parts as animal feed resources in tropical regions (Animal Production and Health Working Paper No. 8). FAO. https://www.feedipedia.org/content/fao-2012-emmanuel-s-quansah-harinder-ps-makkar-animal-production-and-health-working-paper-no

Rashid, S., Tahir, S., Akhtar, T., et al. (2023). Bacillus-based probiotics: An alternative for the treatment of salmonellosis in poultry. Pakistan Veterinary Journal, 43(2), 167–173. http://pvj.com.pk/pdf-files/22-430.pdf

Robinson, J. J., Ashworth, C. J., Rooke, J. A., et al. (2006). Nutrition and fertility in ruminant livestock. Animal Feed Science and Technology, 126(3-4), 259–276. https://pure.sruc.ac.uk/en/publications/nutrition-and-fertility-in-ruminant-livestock

Rufino, L. M. D. A., Detmann, E., Gomes, D. I., et al. (2016). Intake, digestibility and nitrogen utilization in cattle fed tropical forage and supplemented with protein in the rumen, abomasum, or both. Journal of Animal Science and Biotechnology, 7, 1–10. https://link.springer.com/article/10.1186/s40104-016-0069-9

Schwartz, H. J. (1992). Animal nutrition in relation to application of biotechnological procedures. Discussion paper presented at the symposium on: Potential and limitations of biotechnology for livestock breeding and reproduction in developing countries, Mariense, Germany, 14th to 16th May 1992.

Sujani, S., & Sersinhe, R. T. (2015). Exogenous enzymes in ruminant nutrition: A review. Asian Journal of Animal Sciences, 9(2), 85–99. https://doi.org/10.3923/ajas.2015.85.99

Tazehabadi, M. H., Algburi, A., Popov, I. V., et al. (2021). Probiotic bacilli inhibit salmonella biofilm formation without killing planktonic cells. Frontiers in Microbiology, 12, 615328. https://doi.org/10.3389/fmicb.2021.615328

Thakur, S. S., Verma, M. P., Ali, B., et al. (2010). Effect of exogenous fibrolytic enzymes supplementation on growth and nutrient utilization in Murrah buffalo calves. Indian Journal of Animal Sciences, 80(11), 1217–1219.

Tewoldebrhan, T. A., Appuhamy, J. A. R. N., Lee, J. J., et al. (2017). Exogenous β-mannanase improves feed conversion efficiency and reduces somatic cell count in dairy cattle. Journal of Dairy Science, 100(1), 244–252. https://doi.org/10.3168/jds.2016-11017

Tiwari, M. R., Jha, P. K., Pant, S. R., et al. (2018). Effect of bypass protein supplement on milk production in Jersey cows. Bangladesh Journal of Animal Science, 47(2), 98–104.

Tomar, K., Tiwari, S., Singh, D., et al. (2022). Feeding management of ruminant livestock. In Feeding management of ruminant livestock (Chapter 7). https://www.researchgate.net/publication/363847193-Feeding-Management-of-Ruminant-Livestock

Tona, G. O. (2018). Current and future improvements in livestock nutrition and feed resources. IntechOpen. https://www.intechopen.com/chapters/58928

Vargas, J. M., Mendoza, G. D., Rubio-Lozano, M. L. R. S., et al. (2013). Effect of exogenous fibrolytic enzymes on the carcass characteristics and performance of grain-finished steers. Animal Nutrition and Feed Technology, 13, 435–439.

Walli, T. K. (2010). Urea treatment of straws. In H. P. S. Makkar (Ed.), Success and failures with animal nutrition practices and technologies in developing countries (pp. 21–24). FAO Animal Production and Health Proceedings No. 11. FAO. https://www.fao.org/4/i2270e/i2270e00.pdf

Wanapat, M., Kang, S., & Polyorach, S. (2013). Development of feeding systems and strategies of supplementation to enhance rumen fermentation and ruminant production in the tropics. Journal of Animal Science and Biotechnology, 4, 1–11. http://pubs.scipub.com/wjar/2/3/5

Yamaguchi, S. (2017). The quest for industrial enzymes from microorganisms. Bioscience, Biotechnology, and Biochemistry, 81(1), 54–58. https://doi.org/10.1080/09168451.2016.124837