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Opportunities, Constraints and Future Implication of Biotechnology in Animlal Feed Improvement

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Abstract

The major cause of poor livestock productivity in tropical regions of the world is inadequate nutrition. The shortage of feed in most developing countries and the increasing cost of feed constituents entail that there is a call for to improvement feed utilization strategies in developing countries. Animal feeds and feeding practices can be enhanced by biotechnology to develop better animal nutrition packages in smallholder and commercial production systems as well as to reduce environmental waste. Roughages are the major diets of farm animals, particularly ruminants in the tropics; hence, improving the nutritive value of such kind of feed is very important for best utilization. Among application of biotechnology, roughage improvement using a non-toxic fungus has been practiced in many countries. The white rot fungi have been used especially because of their ability to delignify the plant material. The other application of biotechnology is to produce genetically modified fodder crops of vast benefits to consumers as well as environment like that of food crops. Another area of nutritional biotechnology is the successful attempt in the use of genetically modified micro organisms to enhance rumen fermentation and thereby increase nutrient availability to the host animal. The ultimate goal of using biotechnology in animal feeds and feeding systems is then to improve the plane of nutrition through the use of enzymes to improve the availability of from feed and to reduce the wastage of the feed. Though application of biotechnology has various opportunities, it is not easily expanded due to prevailing environmental and social constraints of developing countries in the tropics.

Keywords

Biotechnology, Roughage, Lignin, White Rot Fungi

Subject Areas: **Agricultural Science, Biotechnology, Genomics, Molecular Biology**

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1. Introduction

In developing countries, livestock production is increasing rapidly as a result of growth in population and incomes and changes in lifestyles and dietary habits [1]. Demand for livestock products in the developing countries is increasing because of the increasing human population, growth in income and urbanization [2]. Most food of animal origin consumed in developing countries is currently supplied by small-scale, often mixed crop-livestock family farms or by pastoral livestock keepers [3]. The productivity of animal agriculture in developing countries will need to be substantially increased in order to satisfy increasing consumer demand, to more efficiently utilize scarce resources and to generate income for a growing agricultural population.

Conventional methods of livestock improvement and agricultural research and development have in the past served the purpose of increasing livestock productivity. However, these options can no longer sustain production; hence new intensive techniques including biotechnology are now required to augment livestock productivity. The United Nations Convention of Biological Diversity [4] defines biotechnology as any technological application that uses biological systems, living organism, or derivatives thereof, to make or modify products or processes for specific use. The proponents of biotechnology perceive biotechnology as the universal remedy to food insecurity in developing countries and improvement of environmental management [5].

Biotechnology provides possible solutions to many economic, social, and environmental problems that developing world is facing. Agricultural biotechnology is one area of application of biotechnology involving applications to agriculture [6] and the application has long been a source of innovation in production and processing, extremely impacting the sector [7]. Agricultural biotechnology has been practiced for a long time, as people have sought to improve agriculturally important organisms by selection and breeding. This includes plant breeding to raise and stabilize yields; to improve resistance to pests, diseases and abiotic stresses such as drought and cold; and to enhance the nutritional content of foods. Biotechnology is being used to develop low-cost disease-free planting materials for crops such as cassava, banana and potato and is creating new tools for the diagnosis and treatment of plant and animal diseases and for the measurement and conservation of genetic resources.

2. Opportunities of Biotechnology in Animal Feed Improvement

Contemporary biotechnology has the potential to provide new opportunities for achieving enhanced livestock productivity in a way that alleviates poverty, improves food security and nutrition and promotes sustainable use of natural resources [8]. The major cause of poor livestock productivity in tropical regions of the world is inadequate nutrition [9]. Low-quality forages are a major component of ruminant diets in the tropics. The lack of quality of ruminant feeds is caused by a high content of lignified crop residues and mature grasses, usually associated with a low content of nitrogen, phosphorus and sulphur. The shortage of feed in most developing countries and the increasing cost of feed ingredients mean that there is a need to improve feed utilization [6]. Animal feeds and feeding practices are being changed by biotechnology to improve animal nutrition and to reduce environmental waste. The ultimate goal of using biotechnology in animal nutrition is to improve the plane of nutrition through the use of enzymes to improve the availability of nutrients [10] from feed and to reduce the wastage of the feed.

2.1. Crop Residue Improvement

Fibrous feeds of low digestibility comprise the major proportion of feeds accessible to most ruminants under smallholder situations in developing countries [11]. It is well recognized that some micro-organisms, including cellulose enzymes from anaerobic bacteria and white rot fungi (*Pleurotus ostreatus*) can degrade lignin in the cell walls. The possibility of biological methods of roughage treatment has a great appeal as an alternative to the use of expensive chemicals [12] and pollution can also be minimized. Several fungal strains have been used for lignocellulosic hydrolysis such as *Asprigullus niger*, *A. terreus*, *Fusarium moniliforme* and *Chaetomium celluloyticum* [13]. However, among many species of fungi white rot fungi have been reported to be suitable for treatment of roughages so far. [14] found that, the white rot fungi have the capacity to attack lignin polymers, open aromatic rings and release low molecular weight fragments.

Significant results were reported by [15] for CP of maize cob treated with fungi species (*Pleurotus pulmonarius* and *Pleurotus sajor-caju*). It must be remembered, however, that whatever organism is grown on the roughage must obtain its energy from the roughage itself [16]. In general, the organisms that suit for this purpose must have a number of special properties. They must be capable to grow on a wide range of carbon sources, have high growth rates to minimize the size of the fermentation system and have a high efficiency in converting of substrate to biomass with high protein content.

Another indirect approach to the enhancement of fibre digestion in ruminants is through modification of silage inoculants. Silage preservation involves the growth of lactobacilli on soluble sugars present in the plants with the production of lactic acid. In silages containing low carbohydrate contents, inclusion of amylase, cellulase or hemicellulase enzymes has been shown to increase lactic acid production by releasing sugars for growth of lactobacilli [17]. Thus, inoculation of silage bacteria genetically modified to produce such enzymes has been proposed to obtain better ensiling and/or pre-digest the plant material in order to lead to better digestibility in the rumen. [18] reported that recombinant *Lactobacillus plantarum*, a species used as silage starter, were constructed to express alphaamylase, and cellulase or xylanase genes. The competitive growth and survival of such modified lactobacilli in silage has been reported by other workers [19], although the impact on silage digestibility has not been investigated. As to the supplements, live microbial cultures and their extracts, particularly of *Aspergillus oryzae* and *S. cerevisiae*, have been used as feed additives for many years. Their widespread use as manipulating agents for ruminal fermentation, so called direct-fed microbials, is more recent, as are most of the research papers [20].

2.2. Fodders Improvement and Management

Improving and utilization of food and forage crops through bioengineering technique has variety of potential benefits for production, the environment and human health, are at present being developed [21]. The modification of crops can be done by modifying recombinant DNA technology with the objective of introducing or enhancing a desirable characteristic in the plant or seed. These genetically engineered crops are aimed at offering a range of benefits to consumers, as well as developers and producers. Products to be consumed by humans, derived from animals fed on transgenic forage crops, are not themselves transgenic. Thus, food products derived from animals fed on transgenic forage crops offering human health benefits may receive different levels of support from the public than the currently obtainable set of transgenic food crops [22].

High lignin content reduces the efficiency of feed utilization and thereby reduces animal growth. Conventionally bred forage varieties with reduced lignin are available, but they tend to have weaker stems and poor standability in the field. Researchers have developed engineered alfalfa with 20 percent less lignin and 10 percent more cellulose, a combination that makes it more digestible. The ability to modify specific components of fiber biosynthesis may allow scientists to develop reduced-lignin forage that is more digestible and still has the stem strength needed for good field performance. Protein content and feeding quality are being targeted for improvement in biotech crops [23]. Several fungal strains have been used for lignocellulosic hydrolysis such as *Asperigillus niger*, *A. terreus*, *Fusarium moniliforme* and *Chaetomium celluloyticum* [15]. However, among many species of fungi white rot fungi have been reported to be suitable for treatment of roughages so far. Zadrazil *et al.* [24] found that, the white rot fungi have the capacity to attack lignin polymers, open aromatic rings and release low molecular weight fragments.

It is known that forage legumes are comparatively low in sulphur-containing aminoacids and their availability to ruminants is further adversely affected during rumen digestion [25]. This leads to the reduction of the optimum for animal growth level of essential amino acids. Plant genetic modification with genes encoding for a sulphur amino acid-rich proteins, resistant to rapid rumen degradation can compensate this deficiency. Agronomic researchers around the globe are currently using recombinant DNA technology to create new and altered species of plants. High-oil corn reduces the amount of feed required for a livestock diet, and this in turn reduces the volume of manure [26]. Furthermore, conventional high-oil crops often have lower yield or protein content than their lower oil counterparts, whereas traits introduced via biotechnology can modify oil accumulation only at specific growth stages and in targeted tissues to minimize such deleterious effects. Biotech modification of the oil composition of feeds, such as raising the level of oleic acid, may also improve the quality of the resulting animal products for processing and human nutrition.

2.3. Post-Ingestion Feed Improvement through Biotechnology

Ruminants typically features a number of challenges on feeding, because plant matter is difficult to digest, relatively low in fat and protein, and the majority of nutrients are located within strong cell wall fraction [8]. As a result, considerable research efforts have focused on methods to modify ruminal fermentation. Rumen biotechnology has the potential to improve the nutritive value of ruminant feedstuffs that are fibrous, low in nitrogen and of limited nutritional value for other animal species. Manipulation of ruminal fermentation involves improving ruminant productivity by maximizing the efficiency of feed utilization performance [21]. One approach to achieve nutrient synchrony that has received considerable attention is the manipulation of dietary carbohydrate and protein sources [27]. The regulation of fermentation products made by the rumen microbial population would be another target area for use of genetically engineered micro-organisms. The use of genetically modified microorganisms is one area for manipulation of rumen fermentation to change the rumen digestion of specific dietary component.

Protozoa, unlike bacteria, are not vital for the development and survival of the ruminanthost, and their elimination (defaunation), although producing a less stable rumen environment, has been found to reduce gaseous carbon and nitrogen losses. It has been established that ruminants can survive with or without these organisms; however, manipulating their population may affect protein metabolism in the rumen [28]. The control of the rumen protozoal population by inhibition compounds would seem attractive because their eukaryotic cell nature would allow them to be susceptible to a number of compounds that would have little or no effect on the prokaryotic bacterial cells [6]. A study indicated [29], defaunation did not decrease total free amino acid concentrations in ruminal fluid, but it altered the profile of free amino acids. An important implication of this study is the possibility of developing a practical way to maintain a reduced number of protozoa in ruminants while at the same time being a source of nutrients.

3. Challenges in the Application of Biotechnology in the Developing World

Developing countries are faced with the challenge to rapidly increase agricultural productivity to help feed their growing populations without depleting the natural resource base. Biotechnology is regarded as a means to meet both objectives through addressing the production constraints of small-scale or resource-poor farmers who contribute more than 70% of the food produced in developing countries [11]. Among agricultural and allied fields, animal production and health have probably benefitted the most from biotechnology. Animal production in most developing countries could be increased many fold by finding ways and means of applying already established concepts. The constraints and limitation of biotechnology in animal production in developing countries are due to the facts that livestock production in these areas are practiced under extensive system requiring to change the production system first before biotechnological interventions are made. In addition, the majority (>80%) of biotechnological research activities in biotechnology are conducted by large private companies for commercial exploitation to meet the requirements of developed markets and large-scale commercial producers. They are thus unlikely to be very suitable for the conditions of small-scale farmers in tropical regions and this may lead to increasing inequality of income and wealth within countries.

Future Prospect and Implication of Biotechnology

Developing countries are faced with the challenge to rapidly increase agricultural productivity to help feed their growing populations without depleting the natural resource base. Biotechnology is regarded as a means to meet both objectives through addressing the production constraints of small-scale or resource-poor farmers who contribute more than 70% of the food produced in developing countries [8]. Among agricultural and allied fields, animal production and health have probably benefitted the most from biotechnology. But successful application of biotechnology has generally been limited to developed countries. Specifically, there are hardly any success stories of the application of biotechnology in the improvement of livestock production in Africa.

Animal production in most developing countries could be increased many fold by finding ways and means of applying already established concepts [30]. Poor nutrition is one of the major production constraints in smallholder systems, particularly in Africa. Thorough the help of biotechnology, there are many potential novel feeds from various sources to provide alternative sources of protein and energy, such as plantation crops and various industrial (including ethanol) by-produts which can be efficiently utilized. Among the technologies include applying the newer concepts of supplementation of ruminants that emphasizes the use of local resources balanced with critical nutrients. Advances in genomics, transcriptomics, proteomics and metabolomics will continue to contribute to the field of animal nutrition and predictions relating to growth and development [31]. Another area of high priority for additional exploration, which could potentially have broad implications for tropical ruminant nutrition, is microbial genomics of the rumen, building on current research into the breaking down of lignocellulose for biofuels [32]. Addressing the nutritional constraints faced by pastoralists in extensive rangeland systems in the developing world is extremely difficult. While there is potential to improve livestock productivity in semi-arid and arid areas, probably the most feasible solutions require integrated application of what is already known, rather than new technology. This could involve dissemination of information from early warning systems and drought prediction, for example, so that herders can better manage the complex interactions between herd size, feed availability and rainfall [30].

Considerable work is under way to address some of the issues associated with various antinutritional factors. These include methods to reduce the tannin content of tree and shrub material, the addition of essential oils that may be beneficial in ruminant nutrition and the use of other additives such as enzymes that can lead to beneficial effects on livestock performance. Enzymes are widely added to feeds for pigs and poultry, and these have contributed (with breeding) to the substantial gains in feed conversion efficiency that have been achieved. What are the prospects for the future? For the mixed crop-livestock smallholder systems in developing countries, there may be places where these will intensify using the inputs and tools of high-input systems in the developed world. In the places where intensification of this nature will not be possible, there are many ways in which nutritional constraints could be addressed, based on what is locally acceptable and available. One area of high priority for additional exploration, which could potentially have broad implications for tropical ruminant nutrition, is microbial genomics of the rumen, building on current research into the breaking down of lignocellulose for biofuels [31].

Another key driver that will affect livestock nutrition is the need to mitigate greenhouse gas emissions. Future international agricultural trade flows will be influenced by two sets of biotechnology-related factors. First, current and new government regulations, and bilateral and multilateral trade agreements; and, second, the behavior of private actors: private traders, farmers, and consumer demands and preferences [32]. Future international agricultural trade flows will be influenced by two sets of biotechnology-related factors. First, current and new government regulations, and bilateral and multilateral trade agreements; and, second, the behavior of private actors: private traders, farmers, and consumer demands and preferences [29].

4. Conclusion

Biotechnology is a support for various fields of agricultural production and processing and offers a range of tools to advance our understanding, management and use of crop and livestock resources for different social and economic benefits of man. Up to now, biotechnology in animal production in developing countries has been applied only in a few areas such as conservation, animal improvement and healthcare in developing countries. Fibrous feeds, including crop residues, of low digestibility constitute the major proportion of feeds available to most ruminants under smallholder situations in developing countries. Hence, improving these kinds of feeds pre-ingestion will help in increasing nutrient availability and reducing waste of resources. The use of biotechnology to improve post-ingestion quality of fibrous forages is on the verge of delivering practical benefits to ruminant production system in the tropics. In general, adopting biotechnology has benefits in animal feed improvement and economic returns to the livestock entrepreneurs and small producers.

References

[1] Food and Agriculture Organization (FAO) (2003) World Agriculture: Towards 2015/2030. An FAO Perspective.

[2] Hsu, J.T., Fahey Jr., G.C., Merchen, N.R. and Mackie, R.I. (1991) Effects of Defaunation and Various Nitrogen Supplementation Regimens on Microbial Numbers and Activity in the Rumen of Sheep. *Journal of Animal Science*, **69**, 1279-1289.

[3] Ruane, J. and Zimmermann, M. (2001) Report of the First Six E-Mail Conferences of the FAO Electronic Forum on Biotechnology in Food and Agriculture.

[4] UN (United Nations Food and Agriculture Organization) (1992) Convention on Biological Diversity, 30.

[5] NRC (National Research Council) (2001) Emerging Technologies to Benefit Farmers in Sub-Saharan Africa and South Asia. National Academies Press, Washington DC.

[6] MacMillan, S. (1996) Improving the Nutritional Status of Tropical Ruminants. *Biotechnology and Development Monitor*, **27**, 8-9.

[7] Zadrazil, F., Puniya, A.K. and Singh, K. (1995) Biological Upgrading of Feed Components. In: Wallae, R.J., Chesson, A. and Weinheim, V.C.H. (Eds.), *Biotechnology in Animal Feeding*, 55-69.

[8] Leng, R.A. (1991) Application of Biotechnology to Nutrition of Animals in Developing Countries. Animal Production and Health Paper 90, FAO, Rome.

[9] McDonald, P., Edwards, R.A., Greenhalgh, J.F.D., Morgan, C.A., Sinclair, L.A. and Wilkinson, R.G. (2010) Animal Nutrition. Pearson Books.

[10] Sharp, R., O'Donnell, A.G., Gilbert, H.J. and Hazlewood, G.P. (1992) Growth and Survival of Genetically Manipulated Lactobacillus Plantarum in Silage. *Applied and Environmental Microbiology*, **58**, 2517-2522.

[11] Lebbie, S.H.B. and Kagwini, E. (1996) Small Ruminant Research and Development in Africa. *Proceedings of the* 3*rd Biennial Conference of the African Small Ruminant Research Network*, *UICC*, Kampala, 5-9 December 1994, 326 p.

[12] Food and Agriculture Organization of the United Nations Rome (1978) Treating Straw for Animal Feeding. Rome.

[13] Wallace, R.J. and Newbold, C.J. (1992) Probiotics for Ruminants. In: Fuller, R., Ed., *Probiotics*, *the Scientific Basis*, Chapman and Hall, London, 317-353.

[14] Kim, J.H., Hosobuchi, M., Kishimoto, M., Seki, T., Yoshida, T., Taguchi, H. and Ryu, D.D.Y. (1985) Cellulose Production by Solid State Fermentation System. *Biotechnology and Bioengineering*, **27**, 1450-1454.

[15] Akinfemi, A., Adu, O.A. and Doherty, F. (2009) Assessment of the Nutritive Value of Fungi Treated Maize Cob Using *in Vitro* Gas Production Technique. *Livestock Research for Rural Development*, **21**.

[16] Henk, L.L. and Linden, J.C. (1992) Simultaneous Ensiling and Enzymatic Hydrolysis of Structural Polysaccharides. *Enzyme and Microbial Technology*, **14**, 923-930. http://dx.doi.org/10.1016/0141-0229(92)90057-U

[17] Parawira, W. and Khosa, E.M. (2008) Biotechnology Research, Development, Applications and Management in Zimbabwe: Review. *Scientific Research and Essay*, **4**, 825-841. Http://Www.Academicjournals.Org/SRE

[18] Scheirlinck, T., De Meutter, J., Arnaut, G., Joos, H., Claeyssens, M. and Michiels, F. (1990) Cloning and Expression of Cellulase and Xylanase Genes in *Lactobacillus plantarum*. *Applied Microbiology and Biotechnology*, **33**, 534-541. http://dx.doi.org/10.1007/BF00172547

[19] Shelke, S.K., Thakur, S.S. and Amrutkar, S.A. (2011) Effect of Pre Partum Supplementation of Rumen Protected Fat and Protein on the Performance of Murrah Buffaloes. *Indian Journal of Animal Sciences*, **81**, 946-950.

[20] Thornton, P.K. (2010) Review Livestock Production: Recent Trends, Future Prospects. *Philosophical Transactions of the Royal Society B*: *Biological Sciences*, **365**, 2853-2867. http://dx.doi.org/10.1098/rstb.2010.0134

[21] Edwards, H.M., Douglas, M.W., Parsons, C.M. and Baker, D.H. (2000) Protein and Energy Evaluation of Soybean Meals Processed from Genetically Modified High-Protein Soybeans. *Poultry Science*, **79**, 525-527. http://dx.doi.org/10.1093/ps/79.4.525

[22] Dschaak, C.M. (2012) Use of Rumen Modifiers to Manipulate Ruminal Fermentation and Improve Nutrient Utilization and Lactational Performance of Dairy Cows. http://digitalcommons.usu.edu/etd/1238

[23] Etherton, T.D., Bauman, D.E., Beattie, C.W., Bremel, C.W., Cromwell, G.L., Kapur, V., Varner, G., Wheeler, M.B., Wiedmann, M., *et al*. (2003) Biotechnology in Animal Agriculture: An Overview. The Council for Agricultural Science and Technology.

[24] Fahmy, W.G., Bahaa, A.O., Murphy, M.R., Nombekela, S.W., Corley III, R.N. and Zhu, J.S. (1998) Effect of Defaunation and Amino Acid Supplementation on Growth and Amino Acid Balance in Sheep. University of Illinois Extension. http://www.livestocktrail.illinois.edu/dairynet/paperDisplay.cfm?ContentID=238

[25] Croissant, G., Meton, B., Miller, D. and Kellog, W. (1976) Biotechnology Journal. New Mexico State University Agricultural Experiment Station, Las Cruces.

[26] European Commission (2000) The Europeans and Biotechnology (Eurobarometer 52.1). European Commission, Brussels.

[27] Madan, M.L. (2005) Animal Biotechnology: Applications and Economic Implications in Developing Countries. *Revue Scientifique et Technique* (*International Office of Epizootics*), **24**, 127-139.

[28] Spangenberg, G., Kalla, R., Lidgett, A., Sawbridge, T., Ong, E.K. and John, U. (2001) Transgenesis and Genomics in Molecular Breeding of Forage Plants. http://www.regional.org.au/au/asa/2001/plenery/6/spangenberg.htm

[29] Wieczorek, A. (2003) Use of Biotechnology in Agriculture—Benefits and Risks. http://www.ctahr.hawaii.edu/oc/freepubs/pdf/BIO-3.pdf

[30] Dumas, A., Dijkstra, J. and France, J. (2008) Mathematical Modeling in Animal Nutrition: A Centenary Review. *Journal of Agricultural Science*, **146**, 123-142. http://dx.doi.org/10.1017/S0021859608007703

[31] NRC (National Research Council) (2009) Emerging Technologies to Benefit Farmers in Sub-Saharan Africa and South Asia. National Academies Press, Washington, DC.

[32] Pinstrup-Andersen, P. (1999) Agricultural Biotechnology, Trade, and the Developing Countries. *AgBioForum*, **2**, 215-217. http://www.agbioforum.org