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Biotechnological Interventions In Livestock Sector To Increase Productivity And To Combat Diseases

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Biotechnology can be defined as any technique that uses living organisms or substances from such organisms to make or modify a product, to improve plants or animals or to develop microorganisms for specific purposes. It is one of the frontier areas of scientific development in the world today. Advances in the field of biotechnology catered to a wide area of science viz., Agriculture, Animal Sciences, Environmental Science, Food Science, Medicine etc. This sphere of science is increasingly becoming sustainable means of improving livestock production by influencing animal health, nutrition, reproduction and animal products.

The major challenge faced by animal production is to provide society with food products that meet their evolving nutritional requirements, within specific economic and environmental constraints. According to FAO, 70% of world population will be in hunger in around 50 years from now (2060). It has been reported that the world human consumption for the animal protein is 29 g per capita daily (or 10 kg per capita consumption). However, the trend toward increased per capita demand for foods of animal origin is occurring primarily in developing countries (80% of world population).

Livestock production is expected to grow tremendously in line with the projected demand for production by influencing animal health, nutrition and animal products. Therefore, the methods of livestock production must be changed to allow for efficiency and improvement in productivity. Biotechnological research is important in order to respond to the pressure of producing more food from animals to cater the food requirement of the ever-growing human population. Biotechnology has the potential to improve the productivity of animals by increasing growth, carcass quality and reproduction, improving nutrition and feed utilisation, improving quality and safety of food, improving health and welfare of animals and reducing waste through more efficient utilisation of resources. The biotechnology of livestock production is growing faster than any other sectors and by 2020 livestock is predicted to become the most important agricultural sector in terms of value-added commodity.

Biotechnology in animal physiology and nutrition

Animal nutrition has provided one of the greatest challenges to animal production with limitations arising from both quality and quantity. A large proportion of animal feeds are fibrous with varying levels of digestibility and nutritive values. Animal nutritionists have developed technology to improve nutritive value for feeds, enhance digestibility and acceptability, and removal of anti-nutritive factors from feeds especially for ruminant animals. Apart from the technology targeted on feeds, the manipulation of rumen microbial population through alkali

treatment, microbial balancing and genetic manipulations are probably the most reliable means of enhancing degradation of low quality feeds.

Lignin has been identified as the main cause of difficult digestion of fibrous material. A potent lignase enzyme produced by the soft-rot fungus (Phanerochaete chrysosporium) that causes a high degree of depolymerisation of lignin is now available. Although the lignase levels produced by the fungi cannot meet the requirements for commercial treatments of straw, recombinant DNA technology has been claimed to have the potential to modify lignase genes and proteins to increase efficiency and stability considering that the lignin gene has already been cloned and sequenced from P. chrysosporium.

Manipulation of digestive tract environments which includes mainly the rumen in ruminants and intestinal tract in monogastrics using prebiotics and probiotics has been reported to be beneficial and effective in increasing the availability of nutrients to the animals. The main focus in the rumen is the manipulation of microbial flora population and type. Attempts have been made to introduce transgenic bacteria in the rumen environments to increase efficiency of rumen fermentation. Inactivation as well as detoxification of anti-nutritive factors in plants such as protease inhibitors, tannins, phytohaemaglutinins and cynogens mainly in legumes can also be done using transgenic bacteria.

Bovine somatotropin (a growth hormone), also called BST, has been produced with the help of a bacteria through recombinant DNA technology. Injection of BST in cows every two weeks increases milk production by about 20 per cent. Even though scientists consider BST very safe and cost-effective, it has been banned in some European countries. This is partly because of current milk surpluses and partly because of the risks inherent in DNA recombinant technology.

Biotechnology in animal reproduction

Artificial insemination is by far the most widely used biotechnology in animal reproduction and has been reported to result in genetic progress that is four times better than natural mating. Artificial insemination (AI) and embryo transfer (ET) are probably the most popular methods that have been adopted in developed and developing livestock industries. Supporting technologies that have increased the efficiency of AI and ET include micromanipulation of gametes and embryos for splitting, sexing, cloning, gene transfer, cryo-preservation of embryos, in-vitro maturation, fertilisation and culture (IVFMC) as well as genome analysis. The recent advances in biotechnology in reproduction also include production of transgenic animals and cloning.

Artificial insemination (AI): Especially since the development of efficient semen freezing methods, AI has become the most widespread biotechnology applied to livestock and especially cattle production. No other technology in agriculture except hybrid seed and fertilizer use has been so widely adopted at a global scale as AI. Progress in semen collection, dilution and cryopreservation now enables a single bull to be used simultaneously in several countries for up to1, 00,000 inseminations a year. By allowing for the widespread use of small numbers of elite sires, AI has had a dramatic impact on selection intensity. In addition, AI has allowed for the implementation of the progeny-testing scheme prevalent particularly in dairy cattle production, and which has had a major impact on the improvement of the herd by increasing the accuracy of selection despite the associated increase in generation interval.

Embryo transfer technology (ETT): Although presently not economically feasible for commercial use on small farms, embryo technology can greatly contribute to research and genetic improvement of local breeds. Advances in this area are mainly applicable in cattle. There are two procedures presently available for production of embryos from donor females. One consists of superovulation, followed by AI and then flushing of the uterus to gather the embryos. The other, called in vitro fertilization (IVF) consists of recovery of eggs from the ovaries of the female then maturing and fertilizing them outside the body until they are ready for implantation into foster females. The principal benefit of embryo transfer is the possibility to produce several progeny from the female, just as AI produces many offspring from one male animal.

Oocyte harvesting (OPU), in-vitro oocyte maturation (IVM), in vitro fertilisation (IVF): While the number of embryos that can be obtained from a cow / year using multiple ovulation and embryo transfer (MOET) is on an average limited to the order of 20 or less, the development of OPU in conjunction with IVM and IVF increases by at least 5-fold. Moreover, OPU can be applied to pregnant animals as well as prepubertal animals. The impact of these methodologies on genetic response operates through the same channels as MOET, i.e. increase of selection intensity on the female side and increase of selection accuracy on the male and female side.

Nuclear transfer or embryo cloning: The transfer of totipotent nuclei in enucleated oocytes theoretically allows for the production of large numbers of identical twins or “clones”. This opened the prospective to affect genetic response in a variety of ways including selection intensity, selection accuracy and generation interval. Initially, the sources of totipotent nuclei were blastomeres. Despite the potential use of first as well as higher order generation blastocysts as nuclei donors, the size of the clones has remained very small. The recent generation of totipotent embryonic stem “ES”-like cells might lead to a considerable increase in the efficiency of embryo cloning.

Sex selection: The use of sexed semen alters the sex ratio in favour of either sex. It is a great advantage for the dairy industry for producing replacement heifers. The availability of sexed semen in dairy cattle has been eagerly anticipated for many years, and recent developments in fluorescence-activated cell sorting have brought this technology to commercial application. Recent improvements in flow cytometric sorting now allows for the effective separation of viable X and Y-bearing sperms. While the numbers of cells recovered are incompatible with conventional AI practices, they are sufficient when combined with IVF techniques. This might become the method of choice to generate embryos of a desired sex. Embryo sexing can also be achieved by micro-biopsy and sex determination using polymerase chain reaction (PCR) amplified Y-specific sequences. This approach, however, is economically only justified in very exceptional circumstances.

Gamete and embryo cryopreservation: Most methods described are only effective when used in conjunction with gamete and embryo freezing methods. In addition cryopreservation plays a crucial role in conservation programmes aimed at maintaining genetic diversity.

Biotechnology and Animal Production:

Based on the central theory, “P = G + E”, that is, the Phenotype of an animal reflects its intrinsic genetic aptitude or Genotype as expressed in a given Environment, animal breeders have adopted a two-pronged approach towards improving the quality of their production. On the one hand, they have learned to master the environmental component by improving animal husbandry and nutrition practices, disease

prophylaxis and treatment. On the other hand, artificial selection has allowed to continuously improve the genetic make-up of domestic species. Biotechnology has been adopted in the battery of tools aimed at improving both the nurture (E) as well as nature (G) components of the equation. Applications of biotechnology to improve the environmental component include:

genetically engineered forage species, either to increase their productivity, or to improve their nutritional value,

genetically engineering microorganisms to produce food additives,

genetically engineering the gut micro flora,

production of therapeutic or prophylactic compounds – including vaccines – from genetically engineered microorganisms,

production of hormones or hormone analogues from genetically engineered microorganisms,

immunomodulation of physiological processes,

improved DNA-based diagnostic procedures.

Genetic markers and marker assisted selection

A genetic marker for a trait is a DNA segment which is associated with, and hence segregates in a predictable pattern as, the trait. Genetic markers facilitate the "tagging" of individual genes or small chromosome segments containing genes which influence the trait of interest. A genetic marker need not have an effect on performance. Its value is simply that it 'marks' chromosome segments containing genes affecting performance. Markers have already been identified for some traits controlled by single genes. Availability of large numbers of such markers has enhanced the likelihood of detection of major genes influencing quantitative traits. The process of selection for a particular trait using genetic markers is called marker assisted selection (MAS). MAS can accelerate the rate of genetic progress by increasing accuracy of selection and by reducing the generation interval. Marker identification and use in domestic livestock should enhance future prospects for breeding for such traits as tolerance or resistance to environmental stresses, including diseases. Research is currently underway to identify genetic markers for tolerance or resistance to various economically important diseases in livestock and poultry. Marker technology may provide in the near future an opportunity for selecting animals for resistance or tolerance to the important parasites and infectious diseases.

Production of good quality and high yielding animals

Transgenic animals

A transgenic animal is an animal whose hereditary DNA has been augmented by addition of DNA, through recombinant DNA techniques, from a source other than parental germplasm. Transgenesis is the technique that permits the manipulation of genes of one organism which can subsequently be introduced into genome of another organism of same or other species in such a way that the genes are not only expressed but also gets transmitted to its progeny. Transgenic animals thus produced will have enhanced growth rate and improved food quality. Successful production of transgenic animals has so far been reported in pigs, sheep, rabbits and cattle. For example, transgenic cows are developed to produce milk containing specific human proteins that helps in the efficiency of treatment of human emphysema or hemophilia. Cloned transgenic cattle produced increased amount of beta and kappa casein in milk fat and increased level of human lactoferrin. So also, such cows have been known to produce more milk or milk with less lactose or cholesterol, pigs and cattle that have more meat on them, and sheep that yield more

wool. Pigs with human insulin-like growth factor-1 (IGF 1) had 30 per cent more loin mass, 10 per cent more carcass lean tissue and 20 per cent less total carcass fat. Transgenic pigs carrying plant gene had increased amount of unsaturated fatty acids in their muscle to produce a meat called "Healthy Pork". The ability to insert new genes for such economically important characteristics as fecundity, resistance or tolerance to other environmental stresses would represent a major advance in the breeding of commercially superior livestock and poultry.

Improvement in quality of livestock products

Major genes for meat quality offer excellent opportunities for increasing level of meat quality and decreasing variability. Identification, isolation and modification of useful genes are some of the important aspects of biotechnology research and development. The quality of carcass can be improved by manipulating the lipoprotein receptor and leptin genes thereby the cholesterol and fat content of meat can be altered.

Functional and designer livestock products

In order to improve the products, attempts can be made to develop strains of starter cultures capable of enhanced anticholestermic attributes, enhanced anticarcinogenic attributes, and enhanced antagonistic influence on enteropathogenic microorganism. Genetically engineered strains can play a vital role in manufacture of tailor-made high quality products. Cloning of genes from lactic acid bacteria could be carried out in strains of *E. coli* for which vectors and transformation systems are available.

Animal health and survival

Disease prevention is a vital tool in animal survival as healthy animals can be used longer in various production systems. The biggest risk to developing countries in the use of vaccines, drugs and pesticides is product dumping from manufacturing nations. Product dumping is unfortunately easy due to the lack of a strict monitoring mechanism and corruption. The livestock industries are still developing and are without organised structures to effect vaccine, drug and pesticide production and control as well as for controlling product delivery (viz. maintenance of cold-chain) to organized livestock keepers. The prospects for using sub-unit vaccines developed by recombinant DNA technology, pathogen attenuation by gene deletion (knock-out) and vectored vaccines depends on the level of technological development and even more importantly, the packaging of the technology which directly influences its affordability. The hope of utilisation of diagnostic tools based on basic DNA detection techniques and PCR methodology is clearly evident now. The use of monoclonal antibodies is increasing efficiency of disease diagnosis and has yielded encouraging results exemplified by the development of diagnostic tool for trypanosomosis. Treatment using passive immunization of farm animals using monoclonal antibodies is limited by cost implications whereas cytokine therapy is still a work-in-progress even in developed countries.

Molecular Diagnostic Techniques

Recent revolutionary progress in human genomics is reshaping our approach to therapy and diagnosis. Nucleic acid–based testing is becoming a crucial diagnostic tool not only in the setting of inherited genetic disease but in a wide variety of neoplastic and infectious processes. Molecular diagnostic tests detect specific sequences in DNA or RNA that may or may not be associated with disease, including single nucleotide polymorphism (SNP), deletions, rearrangements, insertions and others. Clinical applications can be found in at least six general areas: infectious diseases, oncology, pharmacogenomics, genetic disease screening, human leukocyte antigen typing and coagulation. The advantages of using molecular diagnostic tools include its high sensitivity and specificity, speed and simplicity. They are particularly useful in case of non-culturable agents, fastidious slow-growing agents, highly infectious agents that are dangerous to culture, in-situ detection of infectious agents, agents present in low numbers, and for differentiation

of antigenically similar agents. A few important molecular techniques are –

- PCR (Nested, RT, Multiplex, Real time, etc.)
- Loop mediated amplification (LAMP) technique
- DNA sequencing
- Hybridization/ DNA probing (In-Situ, FISH)
- Random amplified polymorphic DNA (RAPD)
- Amplified fragment length polymorphism (AFLP)
- Restriction fragment length polymorphisms (RFLP)
- Southern and Northern Blot Analysis
- Ribotyping
- Single-locus sequence typing (SLST)
- Plasmid Profiling and Analysis
- Pulse Field Gel Electrophoresis (PFGE)
- Microarray techniques
- Recombinant DNA technology & Gene cloning

New Generation Vaccines:

The past two decades have seen an expanded scientific and commercial interest in the potential of new vaccines. Scientific advances have created new tools for developing vaccines for diseases for which no vaccines exist. The complete genomic sequence of a pathogen provides a catalogue of potential vaccine components. Improved techniques of protein purification and peptide synthesis facilitate the identification, isolation, and engineering of candidate vaccines. Novel adjuvants, formulations, and delivery systems to induce an optimal immune response have been developed. Recombinant-DNA techniques facilitate the construction of live vaccines, live vectors, or nucleic acid vaccines into which a gene coding for the vaccine antigen can be cloned.

New generation vaccines act upon the immune system in different ways depending on the type of vaccine. Subunit vaccines or vaccines based on synthetic proteins (inactivated proteins) act in a way similar to that of conventional inactivated vaccines, although usually more antigen is required to induce similar responses (because they are less antigenic). The most important advantage of these vaccines is the lack of the entire infectious agent. This makes it possible to differentiate between vaccinated and sick animals. This characteristic is even more important in deleted live vaccines or recombinant vaccines, which induce better immune responses than those of the inactivated proteins by expressing antigens with similar characteristics to those of conventional attenuated vaccines. It is also possible to differentiate them.

Major constraints on applying the technology in developing world

The constraints and limitation of biotechnology in animal production in developing countries are due to factors such as the poor conditions of the human population in such countries that include poverty, malnutrition, disease, poor hygiene and unemployment. In other words, the progress of biotechnology applications is hampered by several factors in the developing countries. The major constraints include:

- Lack of database on livestock and animal owners in most of the developing world
- Biodiversity within species and breeds
- Biotechnologies generated in developed countries not suitable for developing countries
- Uniqueness of animal breeds in developing world (each has its own developmental, production, disease resistance and nutrient utilisation characteristics)
- Lack of trained scientists, technicians and field-workers
- Absence of mechanism between industry, universities and institutions for technology transfer
- Expensive technology to be purchased from developed world

- High cost of technological inputs
- Poor bio-safety measures of biotechnology developed in developing countries
- Negligible investment in animal biotechnology
- Lack of clear policy and commitment from the government

Conclusion

Biotechnology has been applied in animal production in developing countries so far only in a very limited extent particularly in areas like conservation, animal improvement, healthcare (diagnosis and control of diseases) and augmentation of feed resources. Adopting biotechnology in a larger scale may greatly benefit the livestock sector ascertaining improved economic returns to the livestock entrepreneurs and small producers. However, developing countries have to address issues relating to policy making, development of trained manpower, infrastructure and enhancement of funding towards research & development in the frontier areas of biotechnology

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