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Review on Status of Animal Biotechnology and Options for Improving Animal Production in Developing Countries

Andualem Tonamo
Department of Animal and Range sciences, Madawalabu University, Ethiopia

Biotechnologies have contributed immensely to increasing livestock productivity, particularly in developed countries, and can help to alleviate poverty and hunger, reduce the threats of diseases and ensure environmental sustainability in developing countries. A wide range of biotechnologies are available and have already been used in developing countries in the main animal science disciplines, i.e. animal reproduction, genetics and breeding; animal nutrition and production; and animal health. In animal reproduction, genetics and breeding, artificial insemination (AI) has perhaps been the most widely applied animal biotechnology, particularly in combination with cryopreservation, allowing significant genetic improvement for productivity as well as the global dissemination of selected male germplasm. Complementary technologies such as semen sexing can improve the efficiency of AI. Embryo transfer provides the same opportunities for females, albeit on a much smaller scale and at a much greater price. Molecular DNA markers can also be used for genetic improvement through marker-assisted selection (MAS) as well as to characterize and conserve animal genetic resources. Biotechnologies for animal nutrition and production are often based on the use of micro-organisms including those produced through recombinant DNA technology. Fermentation technologies are used to produce nutrients such as particular essential amino acids or complete proteins or to improve the digestibility of animal feeds. Microbial cultures are used to increase the quality of silage or to improve digestion, when fed as probiotics. Biotechnologies in animal health are used to increase the precision of disease diagnosis as well as for disease control and treatment. Specific options that should assist developing countries make informed decisions regarding the adoption of appropriate biotechnologies in the livestock sector in the future.
Keywords: Animal Biotechnology, Developing Country, Production

INTRODUCTION

Livestock contribute directly to livelihoods worldwide, providing not only food, but also non-food products, draught power and financial security (John and Andrea, 2011). It has been reported that the livestock production currently accounts for about 43 % (Jutzi, 2003) of the gross value of agricultural production and this proportion is expected to increase. Livestock production is one of the fastest growing agricultural sectors in developing countries, where it accounts for more than a third of agricultural GDP (FAO, 2006a). Many developing and transition countries have realized high economic growth in recent years. This, coupled with an increasing population, an expanding urban population and growth in personal incomes, is altering the lifestyle and purchasing patterns with respect to food products. It is projected that the demand for animal products will nearly double by 2030 and that a large proportion of this increase will be in developing countries (FAO, 2002).

However, increasing land degradation, global warming, erosion of animal and plant genetic resources, livestock-mediated environmental pollution, severe water shortages and the threat of emerging infectious diseases pose several new challenges to sustainable animal production, particularly in developing countries (FAO, 2006a; World Bank, 2009). Currently, this fast population growth and the associated increase in the demand for livestock products present many development opportunities and also growing challenges. The key challenge is determining how to intensify livestock productivity in a sustainable manner to meet the increasing demand under the constraints of limited land, water and other natural resources. Current advancements in science and technology will have an important role to play in promoting the livestock sector (Enyew, 2011).

Biotechnology has the potential to improve the productivity of animals via increase in growth, carcass quality and reproduction, improved nutrition and feed utilization, improved quality and safety of food, improved health and welfare of animals and reduced waste through more efficient utilization of resources. Therefore, 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 (Madan, 2005).

However, developing world is grossly unprepared for the new technological and economic opportunities, challenges and risks that lie on the horizon. Although it is hoped that biotechnology will improve the life of every person in the world and allow more sustainable living, crucial decisions may be dictated by commercial considerations and the socioeconomic goals that society considers to be the most important (Macer, 1996). The application of biotechnology in production of animal is a need and must to meet the worldwide demand as well as for the genetic improvement in the animal diversity (Ramli- Bin *et al.,* 2011). Therefore, the objectives of this paper were to review the current status of application of animal biotechnologies in improving animal production in developing countries and to address biotechnological options for developing countries to make decisions on the use of appropriate biotechnologies to improve animal production.

Current status of application of animal biotechnology in developing countries

Animal biotechnology: Definitions and historical perspective

Ramli-Bin *et al.* (2011) defined the term "Animal biotechnology" as the application of scientific and engineering principles to the processing or production of materials by animals or aquatic species to provide goods and services for the wellbeing of human population. Biotechnology has been practiced since the beginning of animal husbandry (FAO, 2011). The evaluation and selection of different breeds started with the domestication of animal species around 12000 years ago which was led by the wish to obtain traits dictated by social, nutritional and environmental needs with no understanding of the molecular processes involved (FAO, 2011).

Biotechnologies in animal reproduction, genetics and breeding

Reproductive biotechnologies

The main objectives of using reproductive biotechnologies in livestock are to increase production, reproductive efficiency and rates of genetic improvement. Over the years, many options have become available for managing the reproduction of the major large and small ruminants. Artificial insemination (AI) and preservation of semen are the main technologies that are used extensively. Reproductive technologies can also be used to control reproductive diseases if procedures and protocols are accurately followed (Madan, 2002).

Artificial insemination (AI)

Among this set of biotechnologies, AI is the most widely used both in developing and in developed countries. A large number of AIs are performed globally each year, more than 100 million cattle, 40 million pigs, 3.3 million sheep and 0.5 million goats (FAO, 2006b). Artificial insemination is recognized as the best biotechnological technique for increasing reproductive capacity and it has received widespread application in large farm animals. It is widely used in most African countries and the demand is growing. However, owing to a number of technical, financial, infrastructural and managerial problems its applicability in Africa has not yet matched that of its success in the developed countries (Van, 2011).The conception rate in field AI programmes in developing countries is very low, and therefore the desired effect in terms of animal improvement has not been achieved. Most semen banks still evaluate semen on the basis of sperm motility, even though significant advances have been made in techniques for semen evaluation. Although detailed guidelines are available regarding the processing, storage and thawing of cattle semen (Vishwanath & Shannon, 2000), the processing and handling procedures in laboratories processing semen are often inadequate.

Embryo transfer

One of the major reproductive technologies that can facilitate genetic improvement in cattle is ET. Embryo transfer is a hormonal manipulation of the reproductive cycle of the cow, inducing multiple ovulations, coupled with AI, embryo collection, and embryo transfer to obtain multiple offspring from genetically superior females, by transferring their embryos into recipients of lesser genetic merit. The high genetic merit embryos can be frozen for later transfer or sale. Most dairy farmers who use embryo transfer simply want more heifer calves from their best cows. The effect of this use of embryo transfer is to increase the selection intensity of dams to produce female herd replacements (Kahi & Rewe, 2008).

In smaller animals, such as sheep and goat, this requires surgery, in larger animals non-surgical procedures may be adequate. Multiple ovulations and embryo transfer takes AI one-step further, in term of both the possible genetic gains and the level of technical expertise and organization required (Madan, 2005). The main potential advantage of MOET for developing countries is that the elite females of local breeds can be identified, and bulls can be produced from them for use in a field programme of breed improvement (Barros & Nogueira, 2001). However, over the last 10 to 15 years, the number of transferable embryos produced by zebu donors has increased from 2.4 to 5.8 embryos per flush in the late 1980s to 5.6 to 9.9 embryos per flush in 2000 (Barros & Nogueira, 2001). The use of ET has been less successful than envisaged for several reasons. The low reproductive efficiency (Singh, Nanda & Adams, 2000), poor superovulatory responses (Madan, Das & Palta, 1996), very low primordial follicle population and high incidence of atresia (Madan, 2003) all contribute to low embryo production.

Semen and Embryo sexing

Although these biotechnologies do not dramatically increase the rate of genetic gain, they can increase production efficiency. They are being developed and refined in a number of research institutions in developing countries. The involvement of private companies providing these services is likely to increase their accessibility in developing countries where AI is already established. With few exceptions, they are not widely used by breeders or farmers in developing countries (FAO, 2007a). Sexed sperm is commercially available in several developing countries, including Argentina, Brazil and China (Rath, 2008).

In vitro fertilization (IVF)

Unfertilized eggs (oocytes) from ovaries of live donor animals are gathered by a technique referred to as "ovum pickup". The oocytes are matured in an incubator then fertilized with sperm. The resulting zygotes are incubated in the laboratory to the blastocyst stage. The fertilized embryos can be transferred fresh or can be frozen. Sexed semen can be used to obtain embryos of the desired sex, which is more efficient and less complicated than the Y-chromosome probe-based approach. However, the practical use of IVEP is limited by high production costs and the low overall efficiency under field conditions (Madan, 2005).

Cryopreservation

A large number of livestock breeds (>20 percent) are at risk of extinction (FAO, 2007a). Semen and embryo cryopreservation have been used for conserving rare livestock breeds (Long, 2008). An evaluation of country reports indicates that over one third of countries use *in vitro* conservation (FAO, 2007a). Cryopreservation of gametes, embryos, DNA or cells (for example skin fibroblasts) is a cost-effective approach for the conservation of endangered species, although using DNA or non-germ cells to regenerate an extinct breed is still problematic with available technologies. It has been suggested (Hodges, 2005) that cryo-preserved cells of each breed should be stored long-term in secure locations and accessed if and when the need arises in the future, either to sequence their DNA to understand genetic differences among breeds or to use the cells in cloning to regenerate extinct breeds.

Conservation of indigenous genetic resources is one of the top priorities of developing countries and several country reports noted the potential use of AI and ET for cryo-conservation purposes (FAO, 2007a). Due to changes induced by global warming, it is plausible that the need in developed countries for the indigenous genetic resources in developing countries will increase.

Cloning/Nuclear transfer

Cloning is a powerful technique and potentially opportunity to utilize the genetic contribution of both it could be used for multiplication of elite animals and minimize the genetic variation in experimental animals. It can be used for the conservation as well as propagation of endangered species. It may be used as a tool for the production of stem cells for therapeutic purposes, as therapeutic cloning. Cloning using somatic cells offers opportunities to select and multiply animals of specific merits (Das *et al.,* 2003).

Numerous types of somatic cells are used as donors in somatic cloning: foetal fibroblasts, adult fibroblasts, granulosa cells, hepatocytes, lymphocytes etc (Campbell *et al.,* 2007). First animal obtained by somatic cloning was a sheep, "Dolly" (Willmut *et al.,* 1997). Since then, SCNT was used successfully for cloning cattle (Cibelli *et al.,* 1998), pig (Polejaeva et al., 2000), goat (Baguisi *et al.,* 1999) and horse (Galli *et al.,* 2003). Cloning procedure using embryonic stem cells (ESCs) is called Nuclear Transfer-derived Embryonic Stem Cell (NTESC). However, although ESCs were derived for humans and some laboratory animals, derivation of farm animal embryonic stem cells (faESCs) is still unsuccessful (Beyhan *et al.,* 2007). The alternative to faESCs could be embryonic germ cells (EGCs) and spermatogonia stem cells (Brevini *et al.,* 2008).

Cloning holds the promise of bypassing conventional breeding procedures to allow creation of thousands of precise duplicates of genetically engineered animals. In remote areas, where sampling and storage of adequate samples of semen and embryos is not practical, one could use clone samples from diverse animals for conservation of the available genetic diversity. The local breeds may contain valuable genes that confer adaptation, especially to heat tolerance or disease resistance, and there is an urgent need to prevent their extinction, which can be achieved by cloning techniques. In the future, cloning may be used in xenotransplantation, as it would allow multiplication of humanized pigs, the organs of which could be transplanted to humans (Duszewska and Reklewski, 2007).

Biotechnology in animal genetics and breeding

Transgenesis

Since the initial demonstration in 1980s that a transgenic animal can be generated harboring a transgene from a different species, genetic engineering has revolutionized all aspects of fundamental biological and biomedical research. Since then much has been accomplished in the generation of various types of first transgenic animals like mouse (Gurdon and Ruddle, 1981) pig (Hammer *et al.,* 1985) sheep (Simon et al., 1998) goat (Ebert *et al.,* 1991) and cattle (Cibelli *et al.,* 1998). Several biotechnological techniques, such as pro-nuclear microinjection, cytoplasmic microinjection, and retrovirus based vectors, transferring DNA to embryos or embryonic stem cells via retroviral vectors, sperm mediated gene transfer of lentivectors and RNA interference, are presently being used to produce transgenic animals.

Transgenic farm animals can be used in both breeding and biomedicine (Wells, 2010). In breeding, transgenic individuals produced are equipped with disease resistance and improved quantitative and qualitative traits. For

example transgenic cows producing milk of increased caseine content, pigs with high body weight gain or fat to muscle tissue, expressing human growth hormone and human haemoglobin (Niemann *et al.,* 2005), sheep with integrated keratin-IGF-I gene and higher production of wool (Kues and Niemann, 2004), sheep and goat with antitrombin III and á antitripsin in milk (Kues and Niemann, 2004). An important achievement was production of transgenic cows resistant to *mastitis* (Wall *et al.,* 2005). There is a high interest in using transgenic farm animals as bioreactors producing human recombinant proteins in mammary gland (Kues and Niemann, 2004; Redwan, 2009). Transgenic domestic pigs are used in studies on xenotransplants, *i.e.* transplantation of animal body parts into humans (Niemann *et al.,* 2005).

Molecular markers

According to FAO (2007a), four countries in Africa (Cameroon, Chad, Nigeria, and Togo) reported using molecular markers to characterize genetic resources. Molecular marker information has not yet been widely integrated into breeding programmes in developing countries. Marker assisted selection can accelerate the rate of genetic progress by enhancing the accuracy of selection and by reducing the time to gather the data needed for selection. The benefit is greatest for traits with low heritability and which are unavailable before sexual maturity or without sacrificing the animal. However, in the low-input systems existing in many developing countries it may be more difficult to realize the full value of marker information because the phenotypic and pedigree information necessary to determine associations between traits and markers is often not available.

ILRI's programmes focus on the characterization of local poultry in Cambodia, Laos, Vietnam, Egypt, Ethiopia, Kenya and Uganda and on small ruminants from seven countries. At ILRI, work is also underway on marker identification for trypanotolerance. The identification and subsequent use of markers for trypanotolerance and helminth resistance would enhance future prospects of breeding for such traits in developing countries. The International Bovine Hap Map project (Gibbs *et al.,* 2009) included two African breeds considered to be resistant to trypanosomosis. Opportunities to increase disease resistance seem particularly promising but uptake in developing countries is likely to be achieved only in the medium to long term rather than in the near future. Marker/gene-assisted selection has been applied in the Awassi and Assaf dairy breeds for the introgression of the Booroola gene for enhancing prolificacy (Gootwine *et al.,* 2003). In developing countries, genotype information is expected to be initially more useful in marker/gene-assisted introgression rather than in selection within breeds (Perera and Makkar, 2005).

Biotechnologies in animal nutrition and production

In animal nutrition, the biotechnology can improve the plane of nutrition through protection of protein, amino acids (Yadav and Chaudhary, 2010) and fat (Shelke *et al.,* 2011), use of enzymes to improve the availability of nutrients from feed and to reduce the wastage of the feed and fodder, prebiotics and probiotics or immune supplements to inhibit enteric pathogenic bacteria, use of plant biotechnology to produce feed and fodder with good nutritive values can be done with ease, addition of vaccines or antibodies in feeds can be used to protect the animals from the disease, genetic manipulation of rumen microbes to improve animal health.

Amino acids

The amino acids in feed, L-lysine, L-threonine, L-tryptophan and DL-methionine constitute the largest share of the total amino acid. Amino acids are mostly produced by microbial fermentation and in the world market for fermentation products, after ethanol and antibiotics, amino acids are the most important category and demand for them is increasing rapidly. Most grain-based livestock feeds are deficient in essential amino acids such as lysine, methionine and tryptophan and for high producing monogastric animals (pigs and poultry) these amino acids are added to diets to increase productivity. Balancing of diets using amino acids also decreases excretion of nitrogen from the animals into the environment (Leuchtenberger *et al.,* 2005).

Enzymes

The use of enzymes in animal nutrition has an important role in current farming systems (Choct, 2006). Feed enzymes can increase the digestibility of nutrients, leading to greater efficiency in feed utilization. In addition, they can degrade unacceptable components in feed, which are otherwise harmful or of little or no value. Currently, feed enzymes available commercially by catalytic types are: 3-phytase, 6-phytase, subtilisin, α-galactosidase, glucanase, xylanase, α-amylase and polygalacturonase, and most for the swine and poultry segment (Selle and Ravindran, 2007). The use of enzymes as feed additives is restricted in most countries by local regulatory authorities (Pariza and Cook, 2010).

The use of phytase in pig and poultry feeds in intensive production systems in developing countries is significant. Phytase addition can reduce phosphorus excretion by up to 50%, contributing significantly to environmental protection. It also increases profitability (phosphorus resources are limited and expensive) by decreasing the amount of phosphorus added to the diet and increasing productivity by improving the availability

of minerals, trace elements and nutrients for the animal. The animal feed enzyme sector grew at a rate of 4 percent per year between 2004 and 2009 and it is expected to grow annually by 6 percent from 2007 to 2012 (Thakore, 2008). Exogenous enzymes such as xylanases, glucanases, proteases and amylases and their mixtures are also added to the diets of monogastric animals in commercial farms in some developing countries. The use of cellulases and xylanases has the added advantages of increasing digestibility, thereby reducing the amount of manure and possibly methane emissions from ruminants. However, the response to the addition of enzymes in ruminants appears to be variable (Rode *et al.,* 2001).

Ionophores

The use of monensin is banned in the EU, although it is used in some industrialized countries. In China, monensin can only be used as anti-coccidian for chicken and as a growth promoting additive for beef cattle, whereas it is prohibited for use during lactation in dairy cows and laying chickens (MOA, 2001).

Single cell protein

From the 1970s to the 1990s extensive research was conducted on single cell proteins. With the exception of some algae, however, they are not being incorporated in livestock diets in either developing or developed countries. Algae such as azolla and lemna are used to a limited extent as feed for pigs by small-scale farmers.

Solid-state fermentation

The degradation of wheat and rice straws and other lignocellulosic materials using white rot fungi that degrade lignin was also extensively researched from the 1970s to the 1990s. In general, however, the nutrient availability from the treated material is decreased due to the consumption of carbohydrates present in the lignocellulosic materials by the fungi for their growth and metabolism. The nitrogen content of the treated material is higher but a large proportion of this nitrogen is contributed by nucleotides, which do not increase productivity. Probably for these reasons, this technology has never got off the ground but solid-state fermentation for producing enzymes, especially phytase for animal feeding is being employed commercially (Vats and Banerjee, 2004).

Probiotics and prebiotics

Probiotics are live microorganisms which, when administered in adequate amounts, confer a health benefit on the host (Pineiro and Stanton, 2007). They are used in animal nutrition in a number of developing countries, mostly in monogastrics. Prebiotics are non-viable food components that confer a health benefit on the host associated with modulation of the microbiota (FAO, 2007b). Although probiotic and prebiotic products have been claimed to elicit several beneficial effects in both monogastric and ruminant animals, the results have been variable (Krehbiel *et al.,* 2003; Patterson, 2005). Live microbes such as *Aspergillus oryzae* and *Saccharomyces cerevisiae* are being used increasingly in ruminant diets to improve rumen efficiency, especially in intensive production systems. A success story in the use of live microbes for ruminants is the introduction of a bacterium *Synergistes jonesii* into the rumen. It prevents mimosine toxicity and enables the safe use of *Leucaena leucocephala* as a protein-rich feed in many developing countries.

Silage additives

The use of bacteria such as *Lactobacillus plantarum*, *L. buchneri, L. acidophilus, Streptococcus bovis*, *Pediococcus pentosaceus*, *P. acidilacti*, and *Enterococcus faecium* and yeasts such as *Saccharomyces cerevisiae* alone or their mixtures, and the use of enzymes (cellulases, hemicellulase, amylase etc.) alone or as a mix with microbial inoculants in silage production is restricted to few intensively managed commercial dairy and beef production farms in developing countries. However, the extent of their use in developed countries is higher.

Recombinant metabolic modifiers

The beneficial effects of recombinant somatotropin in most farm animals are well established. Recombinant bovine somatotropin (rBST) increases feed conversion efficiency and milk yield. The increase in milk yield has been reported to be about 10-15%, both in developed and developing countries (Chauvet and Ochoa, 1996; Forge, 1999). Administration of rBST to lactating Holstein cows also improved milk yield during heat stress without compromising fertility (Jousan *et al.,* 2007). However, before adopting this technology, an economic analysis of the production unit should be available. Regular administration of recombinant somatotropin could also become a constraint under some production conditions. The risks of increasing mastitis or other pathogenic infections (the elimination of xenobiotics is slower in animals receiving rBST) and the negative effects of rBST on fecundity and fertility when administered before breeding must also be taken into consideration before introducing this technology (Chilliard *et al.,* 2001).

Molecular gut microbiology and rumen microbe genomics

Although at the research stage, these approaches have high potential for increasing livestock productivity by providing a better insight into the digestive physiology of livestock. The understanding about the role of strict anaerobic rumen microorganisms in the digestion of feed, the microbiological transformations that occur in the rumen, and the physiological importance of the products released from feed because of microbial digestion has increased (FAO, 2011). Stahl et al. (1988) described the use of 16S rRNA gene sequences to classify and identify rumen microbes based on DNA sequence. This study and the development of PCR revolutionized the study of diversity and complexity of ruminal microbial communities without the need to culture them. So far, the direct benefit of these advances to developing countries has been by providing a means to track the establishment of a bacterium, *Synergestis jonesii* (which degrades mimosine, a toxic component) in the rumen by using a PCR-based technique, enabling better utilization of *Leucaena luecocephala* leaves as livestock feed (FAO, 2011).

Biotechnologies in animal health

Diagnostics and epidemiology

Advanced diagnostic tests that use biotechnology enable the agents causing disease to be identified and the impact of disease control programmes to be monitored more precisely than was previously possible. Molecular epidemiology characterizes pathogens (viruses, bacteria, parasites and fungi) by nucleotide sequencing, enabling their origins to be traced. This is particularly important for epidemic diseases, in which pinpointing the source of the infection can significantly improve disease control. Enzyme-linked immunosorbent assays have become the standard means of diagnosing and monitoring many animal and fish diseases worldwide, and the PCR technique is especially useful in diagnosing livestock disease. Molecular diagnostic technologies that are either already in use or being tested in low-income regions include polymerase chain reaction (PCR), monoclonal antibodies and recombinant antigens. These technologies can be modified to facilitate their application in the developing world (Daar *et al.,* 2002).

PCR-based diagnostics are increasingly used in developing countries for the early diagnosis of disease. Molecular epidemiology is one of the most powerful applications of gene-based technologies in animal health. PCR-based techniques are used in molecular epidemiology in some developing countries to compare sequence data on PCR products to determine the genetic relationship of the disease causing agents, thereby facilitating the determination of their source, monitoring their spread, and providing new information about their biology and pathogenicity. The information obtained from such investigations helps develop appropriate strategies for the diagnosis and control of diseases and to monitor the impact of disease control programmes. Molecular genetic analysis studies of rinderpest viruses have contributed substantially to the Global Rinderpest Eradication Programme (GREP). Similar studies on virus serotypes associated with FMD were useful for vaccination and control programmes in Asia (Madan, 2005).

Increased use of molecular-based diagnostics in developing countries has been possible due to the availability of reliable and affordable laboratory equipment and the increased support of international organizations such as FAO, IAEA and OIE, in providing training and post-training support services, regular proficiency testing, and giving increased emphasis on validation, standardization and quality control of diagnostic techniques. WHO and FAO have also trained developing country scientists in molecular diagnostics in zoonotic and transboundary animal diseases. International staffs providing training on PCR-based methodologies are of the opinion that only 30 to 50 percent of laboratories in developing countries are using the techniques properly (J. Crowther and G.J. Viljoen; personal communication). Work to make PCR-based assays robust, to develop isothermal amplification methods (which do not require thermal cycling and result in a colour change that can be seen without the need for equipment), and on-site assays (e.g. pen-side tests, biosensors) (Belak, 2007), is ongoing.

Efforts to enhance human capacities in developing countries and countries in transition to use modern diagnostic methods will improve the capability of surveillance systems and disease control in these countries. International organizations are encouraged therefore to develop mechanisms and provide resources to train scientists to have the necessary skills to perform good research. Such capabilities will equip the scientific community to develop and adapt biotechnologies that meet local conditions and provide solutions to emerging and future problems.

Improving health through developing vaccines

Two main approaches are being used to develop vaccines using recombinant DNA technology. The first involves deleting genes that determine the virulence of the pathogen, thus producing attenuated organisms (non-pathogens) that can be used as live vaccines. Currently, this strategy is more effective against viral and bacterial diseases than against parasites. Attenuated live vaccines have been developed against the herpes viruses that cause pseudorabies in pigs and infectious bovine rhinotracheitis in cattle. A number of candidate *Salmonella* vaccines have also been produced. The second approach is to identify protein subunits of pathogens that can stimulate immunity (Madan, 2005). Vaccination is one of the most effective and sustainable methods of controlling disease (Jutzi, 2003; Kurstak, 1999).

A recent approach has been to use vaccines based on DNA (Madan, 2005). The use of DNA in vaccines is based

on the discovery that injecting genes in the form of plasmid DNA can stimulate an immune response to the respective gene products. This immune response is a result of the genes being taken up and expressed by cells in the animal after injection. An exhaustive review of the information available on the use of DNA vaccines in farm animals, including cattle, pigs and poultry, has identified the areas that need specific attention before this technology can be used routinely (Madan, 2005). These areas include the delivery, safety and compatibility of plasmids in multivalent vaccines and the potential for using immune stimulants as part of a DNA vaccine.
In general, vaccines offer considerable benefits at a comparatively low cost, which is a primary consideration for developing countries. Molecular techniques can be used to produce a variety of different constructs of pathogenic agents and offer several advantages over more conventional vaccines such as: the deletion of the gene(s) responsible for causing disease and thus greater safety; increased stability (which is an advantage for their effective use in developing countries); the possibility of developing vaccines against protozoan and helminth parasites; and differentiating between infected and vaccinated animals through detecting antibodies either against the peculiar proteins elicited by the vaccine or failing to detect antibodies against the deleted gene/protein (Madan, 2005).
In addition to validated, robust, specific and sensitive diagnostic tools and safe and effective vaccines, control and eradication of animal diseases requires a complete package of good veterinary infrastructure, reporting systems, laboratories with skilled staff, epidemiological units able to execute surveys, and a carefully designed plan with clear objectives. Regional and intergovernmental cooperation is also vital since many of animal diseases are transboundary (FAO, 2011).

Sterile insect technique
The SIT depends on the integration of biological and engineering techniques to produce on an industrial scale and release, usually by air, adequate numbers of reproductively sterilized insects of the target pest in areas where it severely threatens the environment, agriculture or livestock production. Virgin female individuals in the target insect pest population that are mated and inseminated by released sterile male insects do not produce any offspring. Repeated inundative releases of mass-produced sterile insects can be integrated with suppression, eradication, containment or prevention strategies against key insect pests (FAO, 2011). The African Union's Pan-African Tsetse and Trypanosomiasis Eradication Campaign (AU-PATTEC) is coordinating various national programmes that aim to integrate the SIT for creating selected trypanosomosis- and tsetse-free zones in Ethiopia, Kenya, Senegal, Uganda, Tanzania and in a transboundary area in Mozambique, South Africa and Swaziland (Feldmann *et al.,* 2005).
The SIT was also used to suppress, locally eradicate or prevent the (re-)invasion of two other livestock pest insects, namely the New World screwworm (NWS) fly, *Cochliomyia hominivorax*, and the Old World screwworm (OWS) fly, *Chrysomya bezziana*, which cause (Vargas Teran, Hofmann and Tweddle, 2005) have described the various steps needed for making this continent free of NWS. In late 2007, an outbreak of OWS flies was observed in Yemen that is threatening the livelihoods of people, either directly or through their livestock. At present, there are many uncertainties surrounding the production and use of transgenic insects due to instability of the insertion and expression of the transgene. In addition, it requires addressing public concerns and putting in place a regulatory mechanism to properly conduct a risk assessment (Robinson, 2005).

Animal biotechnological options for developing countries
A number of specific options can be identified that should assist developing countries make informed decisions regarding the adoption of appropriate biotechnologies in the livestock sector in the future.

Biotechnologies should build upon existing conventional technologies
Solving new problems will require novel ideas and may involve new technologies. However, substantial impact of new biotechnologies can only be realized at the ground level in developing countries if the capabilities and infrastructure to effectively use conventional technologies are in place. For example, molecular diagnostics and recombinant vaccines will not improve the health or well-being of animals if an effective animal health infrastructure does not exist. Semen sexing and ET have no relevance in places where less advanced reproductive technologies such as AI are not well established and systems for the distribution of improved germplasm are not in place (FAO, 2011). Efficient animal identification systems, e.g. based on ear tags, animal passports and computer recording, are needed in order to take full advantage of molecular markers, DNA sequencing and other advanced biotechnologies for animal genetics, nutrition and health (FAO, 2007a; Shelke *et al.,* 2011 and Madan, 2005).

Biotechnologies should be integrated with other relevant components in any livestock development programmes
Not all biotechnologies can be applied successfully in all situations at all times. Each biotechnology has

relevance to a specific situation and in most cases; it has to complement conventional technologies and other components of the livestock production and marketing system to elicit the desired impact for the farmer. An example is the integrated programme involving farmer organizations, extension workers, researchers and policy-makers that reversed the decline of a locally adapted dairy sheep breed in Tunisia (Djemali *et al.,* 2009).
The increasing importance of environmental issues also means that these should also be considered in any livestock development programme. For example, plans for the application of biotechnologies for nutrition (e.g. prebiotics and probiotics, enzymes and silage additives) should consider both the effects on animal productivity and the potential impacts (positive or negative) of the technology on the production system and the environment (FAO, 2011a).

Application of biotechnologies should be supported within the framework of a national livestock development programme

Developing countries must ensure that animal biotechnologies are deployed within the framework of national development programmes for the benefit of producers and consumers and not as stand-alone programmes. The models of biotechnology interventions in developing countries differ distinctly from those in developed countries. The biotechnologies that are simple and cost-effective are more likely to be successful in developing countries. To ensure the successful application of a biotechnology in the complex and diverse animal agriculture scenarios present in developing countries, not only does the mitigation of technical challenges need to be addressed but also, and probably more importantly, issues like management, logistics, technology transfer, human capacity, regulation and intellectual property (FAO, 2011). Policy-makers in developing countries should be aware that there would be practical, financial and legal obstacles that will preclude the full-scale adoption of many livestock biotechnologies (Madan, 2005). Therefore, strong scientific drive, vision and entrepreneurial skills are needed for contributing to progress in animal biotechnologies in developing countries.

Access to biotechnological products by end users should be ensured

An appropriate model for scaling up and packaging the technology should be integrated into the development and application of biotechnologies and biotechnological products, particularly for vaccines, diagnostics, probiotics, prebiotics and enzymes so that the products are not cost-prohibitive. It has to be borne in mind that the target end users of these biotechnologies in developing countries are normally resource-poor farmers with limited purchasing power. Without this scaled-up business approach/model, even good science and quality biotechnological products might not deliver desired impacts at the field level (FAO, 2011). In the business model, it is also imperative to consider the intellectual property issues, which impinge on several aspects of biotechnology. For example, for manufacturing a recombinant vaccine, developing countries might find that the use of antigens, delivery mechanisms, adjuvants and the process are already patented and subject to intellectual property conditions (Willadsen, 2005).

CONCLUSIONS

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 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, healthcare (diagnosis and control of diseases) and augmentation of feed resources. Adopting biotechnology has benefitted by in animal improvement and economic returns to the livestock entrepreneurs and small producers. However, developing countries has to address issues relating to political commitment, trained manpower, and infrastructure and funding in research development as well as industries. Concisely, investing in animal production and biotechnologies is necessary because it can bring social sustainability, economic prosperity, food security and safety, rural wealth creation and health improvements especially to poor populations in the developing countries. Therefore, the following points are recommended to strengthen the animal biotechnology capacity in the developing countries and realize its benefits. Effective biotechnology policy directives and biosafety system as well as regulatory and monitoring mechanisms need to be in place, in particular, for the introduction, research and release of genetically modified organisms; Applications such as microbial products development, vaccine production and diagnostics should be expanded; The wise utilization of the animal biodiversity by *in vitro* conservation, molecular characterization and introduction of marker assisted breeding and isolation of potentially useful genes should be promoted; Establishing and sustaining institutional linkage within the country as well as strengthening collaboration among Developing and Developed countries should be improved; Policies and incentive mechanisms should be developed to encourage private sector investment and their participation in Animal biotechnology research & development; Universities offering biotechnology courses should upgrade their laboratory in terms of manpower and facilities to acquaint the students with practical skills and produce competent manpower; Finally, an active and honest interaction between scientists and other society members including the public and decision makers

should be encouraged.

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