International Journal of Interdisciplinary and Multidisciplinary Studies,2014,Vol 1,No.3,1-8.

Available online at httt://www.ijims.com

ISSN: 2348 – 0343

# Animal Biotechnology Options in Improving Livestock Production in the Horn of Africa

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## Abstract

The techniques of modern biology incorporates molecular cloning of genes, gene transfer, genetic manipulation of animal embryo transfer, genetic manipulation of rumen microbes, chemical and biological treatment of low quality animal feeds for improved nutritive value, genetically engineered immunodiagnostic and immunoprophylactic agents as well as veterinary vaccines, inter alia. Of course, these are a reality today and are finding their ways into research and development programs of developing countries. Biotechnology is offering unprecedented opportunities for increasing agricultural productivity and for protecting the environment through reduced use of agro-chemicals. The major thrust in biotechnology research is currently directed at solving immediate problems of industrialized countries, with major investments coming from transnational companies. However, many of the new discoveries and products will find their biggest markets in developing countries where the potential for improvement in agricultural productivity and health is greatest. The importance of biotechnology and its relevance is only slowly being accepted by policy makers in developing countries. In the presence of economic crisis, strong fiscal constraints, rapid social change and constant political instabilities, the difficulties associated with major policy changes in developing countries are enormous. In this review we discuss the potentials and limitations for biotechnological applications in animal breeding and animal health, food processing and forage improvement in the horn of Africa.

**Key words:** Livestock production, biotechnology, horn of Africa

**Introduction**

*"Responsible biotechnology is not our enemy; hunger and starvation are. Without adequate food supplies at affordable prices, we cannot expect world health, prosperity, and peace."*

………………Norman Borlaug and former U.S. President Jimmy Carter

Africa for the largest part is still regarded as part of the developing world and has a history of political instability, natural disasters, floods and droughts that all had an effect on the development of livestock production systems and the potential application of biotechnologies. It is expected that the human population in sub Saharan Africa will experience a growth of 1.2 % per year over the next 30 years. Hence there is pressure to increase sustainable productivity of livestock [1]. Human populations not only depend on domestic animals for production of meat, but also for milk, and other dairy products, eggs and fibers like wool or cashmere as well as other purposes such as transport, draft, and provision of fertilizers, especially in developing countries. Besides, in some parts of the Africa, farm animals particularly cattle are symbolic of an individual's wealth and status. As a result, demand for animal products is expected to grow tremendously.Livestock systems occupy about 30% of the planet's ice-free terrestrial surface area [2]. In developed countries, livestock accounts for more than half of agricultural production, while in developing countries the share is about one-third [3]. Livestock are important in supporting the livelihoods of poor farmers in sub Saharan Africa and the same is true throughout the developing world [4,5,6,7]. Furthermore, animal disease and veterinary public-health problems constitute a major constraint to livestock production and safe utilization of animal products worldwide [8,6]. Large sums of money have been invested by governments, non-governmental organizations (NGO's) and other donors into research and methods of control of livestock disease; however, there are still major gaps in our ability to control a large number of these diseases [9]. It is generally recognized that there is a lack of availability of and access to veterinary medicines and vaccines in many developing countries, largely because the US and European based animal health industries do not believethere is adequate potential for return on investment [10] and that this is often due to lack of supply chains at the local level [11].Biotechnology has the potential to improve the productivity of animals via increase 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 [12]. It is now established that biotechnology is increasingly becoming a sustainable means of improving livestock production by directly influencing animal health, nutrition, reproduction, breeding and genetics. 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 [3]. However, there are many who believe that Biotechnology has only a very limited potential to alleviate poverty in rural Africa, because it does not address the main reasons for poverty, such as weak infrastructure, bad governance and unfavourable terms of trade and most importantly African farmers still depends on their local knowledge for farming [13]. Looking at the main characteristics of the predominantly small-scale animal farming in Africa, the potentials and limitations for biotechnological applications in animal breeding and animal health, food processing and forage improvement in the horn of Africa are discussed.

**Horn of Africa:** Horn of Africa denotes the region containing the countries of Eritrea, Djibouti, Ethiopia & Somalia and is inhabited by roughly 100 million people. Large parts of the Greater Horn of Africa Region, and particularly pastoral and agropastoral areas in northern, eastern, and southeastern Kenya, southeastern and northeastern Ethiopia, southern Somalia and most of Djibouti have suffered multiple shocks between late 2005 and 2007. These shocks include droughts, flooding, conflict and civil insecurity, Rift Valley Fever (RVF), border closures and market disruptions, and have affected the different groups to varying degrees. Continued drought had devastating effect for the last several months, though, significant improvement is now note. However, it is still estimated that 8.1 million people are still in need of assistance. The Food and Agriculture Organization (FAO) thus extends a continued appeal to the international community for $50 million to be able to continue efforts to improve the conditions in these areas [14]. Famine is not a new development in the horn of Africa [15]; the question is how are African governments going to respond individually and collectively? When will the African Cornucopia stop being a figment of global imagination and return to reality?

**Animal biotechnology:** Biotechnology has been practiced since the beginning of animal husbandry. Animal biotechnology encompasses a broad range of techniques for the genetic improvement of domesticated animal species, although the term is increasingly associated with the more controversial technologies of cloning and genetic engineering [16]. Genetic modification of animals was first achieved with mice in 1980 and of cattle, sheep and pigs by about 1985 [17]. Animal biotechnology includes artificial genetic modification of all animals: livestock, poultry, fish, insects, companion animals and laboratory animals [18]. In the developing countries, application of animal biotechnology is essential to improve animal production and to conserve the indigenous animal genetic resources. Specifically, animal reproductive biotechnologies will be useful in augmenting reproduction, implementing embryo transfer and related technologies, diagnosing diseases and controlling and improving nutrient availability. Applications developed through research have led to the emergence of three scientific agricultural animal biotechnology sectors: animal genomics, animal cloning and genetic engineering of animals.Despite potential outcome from animal biotechnology, there are a number of controversies regarding several areas of the application of animal biotechnology. Some people hold that it is ethically questionable to transfer genes from one species to another [19]. This attitude is sometimes grounded in a religious belief that humankind should not violate boundaries set by God, and so this line of reasoning is usually referred to as the 'playing-God argument' [20, 21]. If we concentrate only on the benefits of human beings in terms of the consequences, possibly we will not find any problem in it. However, there are also dark side of biotechnology (as well as of animal biotechnology), which cannot flight away our insight. A number of ethical experts have realized the adverse effect of this technology.

**Overview of available biotechnologies:** Livestock production is multifaceted requiring that animals be nursed, fed and bred in a sustainable manner to enable consistency in food production [22]. In pre-industrialization agriculture, production depended entirely on natural soil fertility and climatic conditions. Nonetheless, it is still widely believed that the major market for biotechnologies lies in developing countries where food security is an urgent priority [23, 24, 25]. It is rather difficult to rank the most urgent area of focus with respect to animal production in developing countries. However, animal health, nutrition and breeding have been cited as key areas that if improved will result in large scale economic impact.

**Animal Health:** Animal disease is a major social and economic problem across the globe [26]. Diseases can lead to animal suffering and distress, reduced performance, and possibly even death. Conventional means of controlling major livestock disease include chemotherapy, vector control, vaccination, slaughter of infected stock and other managemental practices [27]. Successful control of a disease requires diagnosis. This has been greatly improved in recent years through development in biotechnology Improving animal health requires better control of animal diseases and biotechnology has been helpful in this respect as it has led to the development of quality reagents such as monoclonal antibodies and recombinant antigens [28]. The biotechnologies in animal health have been developed in a number of areas that include transgenesis, disease prevention, diagnosis, treatment and control [29, 30]. Disease prevention is probably the most active faculty in animal heath technologies that has resulted in the development of vaccines. Immunization remains one of the most economical means of preventing specific disease. Although other methods of disease prevention and control such as vector control and quarantine are widely applied, vaccination still remains comparatively a sustainable means of providing health, since the cost implication of vector control and quarantine is a limiting factor. Table 1 summarizes some vaccines developed by recombinant DNA Technology.

To control disease in many parts of Africa, however, the problem is not how to develop new, more effective diagnostic methods, vaccines or drugs. Rather, it is their availability of local level.

For this, more effective organizational structures of veterinary services are more important than further refinement of diagnostic methods or better vaccines. More effective services also include community-based animal health workers, who live in the livestock-keeping communities and provide the local animals with inexpensive “first aid” [13]. Disease resistance benefits not only livestock producers and their animals, but consumers also benefit as a result of safer animal products in the market place, and a reduction in the incidence of human-transmissible diseases such as influenza [31].

**Animal nutrition:** Animal nutrition has for a long time provided one of the greatest challenges to animal production with limitations arising from both quality and quantity. Animal nutritionists have developed biotechnologies to improve nutritive value for feeds, enhance digestibility and acceptability and removal of anti-nutritive factors from feeds especially for ruminant animals [32]. Low-quality forages are a major components of rumen diets in the tropics. Thus, much progress can be made by improving the forage component of the ration [27]. In animal nutrition, the biotechnology can improve the plane of nutrition through protection of protein, amino acids [33, 34] and fat [35], use of enzymes to improve the availability of nutrients from feed and to reduce the wastage of the feed and fodder, pre-biotics and pro-biotics or immune supplements to inhibit enteric **pathogenic bacteria**, use of plant biotechnology to produce feed and fodder with good **nutritive value**s 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 the animal health. Feed constitutes a major portion of the total animal production costs. Thus, efficient utilization of feed to produce meat, milk and eggs can therefore significantly reduce overall production costs. Certain nutritional areas that require attention in this part of Africa are as follows: 1.Increasing digestibility of low-quality forage 2.Improving nutritive value of cereals 3.Removing anti-nutritive factors from feeds 4.Improving nutritive value of conserved feed.

**Animal breeding and genetics:**Genetic improvement of livestock depends on access to genetic variation and effective methods for exploiting this variation. Genetic diversity constitutes a buffer against changes in the environment and is a key in selection and breeding for adaptability and production on a range of environments [27]. In developed countries, breeding programmes are based upon performance recording and this has led to substantial improvements in animal production. In horn of Africa the distinct disadvantages for setting up successful breeding programmes are: infrastructure needed for performance testing is normally lacking because herd sizes are normally small and variability between farms, farming systems and seasons are large; reproductive efficiency is low, due mainly to poor nutrition, especially in cattle; and communal grazing precludes implementation of systematic breeding and animal health programmes. Reproductive biotechnology provides means whereby reproductive performance may be modified at a number of points [36]. The main objectives of using reproductive biotechnologies in livestock are to increase production, reproductive efficiency and rates of genetic improvement [3]. Various biotechnology methods are used in improving the breeding stock of animals. These include artificial insemination (AI), embryo transfer (ET), and associated technologies. Reproductive technologies can also be used to control reproductive diseases if procedures and protocols are accurately followed [37].

**Artificial Insemination:** One of the earliest perfected technologies is artificial insemination (AI) where new breeds of animals are produced through the introduction of the male sperm from one superior male to the female reproductive tract without mating. AI reduces transmission of venereal disease, lessens the need of farms to maintain breeding males, facilitates more accurate recording of pedigrees, and minimizes the cost of introducing improved genetics [38, 39]. Progress in semen collection, dilution and cryopreservation now enables a single bull to be used simultaneously in several countries for up to 100, 000 inseminations a year [40].Though AI is widely available in developing countries it is used far less, particularly in Africa, than in developed countries. Its use has been limited largely to "exploratory" purposes mainly by research institutions. A few countries including Botswana, Ethiopia, Ghana, Malawi, Mali, Nigeria, Senegal and Sudan have taken the technology to the field, mostly for programmes of "upgrading" indigenous stock and as a service to a limited number of commercial farmers keeping exotic dairy cattle breeds. A few others have used the technology more widely. Kenya and Zimbabwe, for example, have elaborate AI systems which include national insemination services incorporating progeny testing schemes [27].In Ethiopia, genetic improvement through crossbreeding has been introduced through development and research projects during the last four decades. The distribution of crossbred heifers, the provision of artificial insemination service and setting up of bull service stations were major components of the development projects. As indicated by [41] through the effort of these projects, Ethiopia has built up a herd of more than 120 thousand cattle with exotic inheritance. However, since cattle breeding are mostly uncontrolled in Ethiopia, appropriate bull selection criteria have not been established applied and controlled which makes genetic improvement difficult [42]. On the other hand, artificial insemination (AI), the most commonly used and valuable biotechnology [43] has been in operation in Ethiopia for over 30 years. Nevertheless, the efficiency and impact of the AI operation has not been well-documented [44].

**Embryo Transfer:** After AI and estrus synchronization, embryo transfer (ET) is the third-most commonly used biotechnology [45]. Embryo transfer from one mother to a surrogate mother makes it possible to produce several livestock progenies from a superior female. Selected females are induced to super-ovulate hormonally and inseminated at an appropriate time relative to ovulation depending on the species and breed. Embryo transfer increases reproductive rate of selected females, reduces disease transfer, and facilitates the development of rare and economically important genetic stocks as well as the production of several closely related and genetically similar individuals that are important in livestock breeding research. The International Embryo Transfer Society (IETS) estimated that a total of approximately 550,000 in vivo derived bovine embryos, 68,000 sheep embryos, 1,000 goat embryos were transferred worldwide in 2004 [46].However, embryo transfer is still not widely used despite its potential benefits. In developing countries this is mainly due to absence of the necessary facilities and infrastructure. An evaluation of country reports [47] shows that only five of the African countries providing information (Cote d'Ivoire, Kenya, Madagascar, Zambia and Zimbabwe) use ET technology, all on a very limited scale. The use of ET has also been independently reported in South Africa [48]. Even in developed countries, cost considerations still limit the use of commercial embryo transfer in specialized niches or for a small proportion of best cows in the best herds.

**In-vitro Fertilization:** In case other artificial reproductive techniques fail due to difficulties such as blocked reproductive systems, non-responsive ovaries in the females, marginal semen quality and quantity in the male, and presence of disease, in vitro fertilization (IVF) is used. The fertilization of the sperm and the egg is conducted in vitro (outside the animal's body) at specific environmental and biochemical conditions. With in vitro fertilization (IVF), a technician removes unfertilized eggs (oocytes) from the donor cow's ovaries, usually recovering 6-8 useable oocytes. The oocytes mature in an incubator and are fertilized with sperm. The resulting zygotes incubate and develop in the laboratory before being placed into the recipient cow [45]. IVF facilitates recovery of a large number of embryos from a single female at a reduced cost thus making ET techniques economically feasible on a larger scale.

**Semen and embryo sexing:** Although these biotechnologies do not dramatically increase the rate of genetic gain, they can increase production efficiency. At a research level, they are being developed and refined in a number of research institutions in developing countries. However, with few exceptions, they are not widely used by breeders or farmers in developing countries [47] Sexed sperm is commercially available in several developing countries, including Argentina, Brazil and China [49, 50].

**Animal cloning:** Cloning technology is already being used commercially in some parts of the world for the replication of elite breeding animals, mostly cattle and also pigs, which are used to produce animals farmed for food production [51]. The birth of Dolly in 1996, the first animal cloned from an adult cell, was not universally celebrated. Critics of biotechnology worried that genetically modified livestock would fill the supermarket with identical copies of someone's idea of unnatural perfection. Up to 2004, about 1500 calves had been produced through somatic cell nuclear transfer (SCNT), mainly in Europe, North America, Japan and New Zealand, but also in South America and Asia [52]. China produced the first cloned buffalo in 2004 and India followed suit in February 2009. At present the production of cloned animals is at the experimental stage in most developing countries.

**Sustainable management of animal genetic resources:**The genetic diversity of livestock is in a state of decline globally. Genetic erosion of domestic animal diversity has placed 30% of the world's breeds at risk of extinction [52] and the risk status of a further 36 percent cannot be determined owing to the absence of information [47]. Of particular concern are the high rates of loss of indigenous breeds in developing countries, which, coupled with inadequate programmes for the use and management of the genetic resources, is negatively impacting on livelihood options for the poor [54]. Therefore, effective management of farm animal genetic resources requires comprehensive knowledge of the breeds‘characteristics, including data on population size and structure, geographical distribution, the production environment, and within- and between-breed genetic diversity [55]. In much of the literature on conservation of farm animal genetic resources, conservation methods are broadly grouped into in situ, and ex situ. Ex situ conservation approach includes: maintenance of small populations in domestic animal zoos; cryopreservation (deep freezing) of genetic material (semen, oocytes, embryos, DNA). Cryopreservation of gametes, embryos or DNA segments can be quite an effective and safe approach for breeds or strains whose populations are too small to be conserved by any other means. In in situ conservation method the animals are kept in the original production environment. This can also be done in two ways: on farm or community based.

**Future challenges:** Currently, more than enough food is produced to feed the world's population of over 7 billion inhabitants. However, still about one in six people in developing countries suffers from chronic hunger [56]. 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 [57]. In other words, the progress of biotechnology applications is hampered by physico-edu-medico-socio-economic situations of the developing countries especially, in the African world. According the same source, the major constraints of animal biotechnology includes:1. Insufficient access to land and other productive resources 2. Unfavorable terms of trade for food products, especially for animal products 3. Lack of database on livestock and animal owners in most of the developing world 4. Uniqueness of animal breeds in developing world 5. Lack of trained scientists, technicians and field-workers 6. Absence of coordination between industry, universities and institutions for technology transfer 7. Expensive technology to be purchased from developed world 8. High cost of technological inputs 9. Poor bio-safety measures of biotechnology developed in developing countries 10 . Negligible investment in animal biotechnology in Africa 11. Lack of clear policy and commitment from the government 12. Disregards for indigenous knowledge and local agricultural resources management.

Based on these identified problems facing biotechnology, the following supportive actions were suggested by the International Office of Epizootics member countries: 1). Organization of campaigns to inform the general public about the nature of biotechnology 2). Assistance with education in biotechnology of the future working force by fostering conferences and exchange programs between countries.

**Perspectives :** In all circumstances, biotechnologies development and use requires the involvement of stakeholders in a systematic design to enhance research and development as well as transfer of the biotechnologies to target groups. Government and National Agricultural Research Systems (NARS) are responsible for a majority of the processes required to successfully develop and transfer relevant biotechnologies. To deliver biotechnologies for use by target groups, there is need for cooperation between Government, NARS and agro-chemical companies. In context of Africa, use of biotechnology can be greatly enhanced through strategic partnerships with developed economies where such technologies are well established. However, biotechnology development and adoption requires a high level of commitment to research and development. Therefore, there is need to develop scientific capacity through local universities and research institutions for development of own technologies and dealing with technologies offered by the developed countries. Recently some authors have remarked that explorations / researches at molecular level may also be useful in maintainance of genetic diversity [58].

Livestock production is expected to grow tremendously in line with the projected demand for animal products. Therefore, the methods of livestock production must change to allow for efficiency and improvement in productivity. Biotechnology is important if the world is to respond to the pressure to produce more food from animals for the ever-growing human population. In a nutshell, investing in animal production and biotechnologies is a must 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. In general, biotechnology in livestock production can be categorized as the biological, chemical and physical techniques that influence animal health (survival), nutrition, breeding and reproduction. These techniques have been applied mostly in developed countries but their application in Africa is minimal due to reasons related to economic growth such as poor infrastructure, technical and educational capacity. However, Africa can still benefit from tailor-made technologies that simplify complex techniques into applicable form through strategic packaging. Public concerns on food safety, environment and ethics are issues that cannot be ignored.

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**Table 1: Example of some novel animal vaccines**

| Species | Disease | Producer |
|---|---|---|
| Avian | Coccidiosis, | Genex and A.H. Robins |
| | Newcastle virus | Codon and Salsbury labs |
| Bovine | Papilloma virus | Molecular genetics |
| | Viral diarrhoea | California Biotechnology |
| | Brucellosis | Ribi ImmunoChem |
| | Rinderpest | USDA and University of California, Davis |
| Swine | Parvovirus | Applied Biotechnology |
| | Dysentery | Codon |
| Equine | Influenza, Herpes | California Biotechnology |
| | | Applied Biotechnology |
| Companion | Canine parvovirus | Applied Biotechnology |

Source [27]