

Animal Biotechnology: Applications and Implications in the Near East & North Africa (NENA) Countries

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Summary

The major biotechnologies that are used effectively in livestock production include conservation and utilization of animal genetic resources, reproductive biotechnologies, diagnosing disease, vaccine production and improving feed utilization. Successful implementations of such animal biotechnological practices in NENA countries were presented.

Major constraints for applying animal biotechnologies, in NENA countries were summarized as: negligible investment in modern animal biotechnology, high cost of technological inputs, lack of trained scientists and other manpower resources, failure to address issues of biosafety and to conduct risk analyses and absence of an accurate database on livestock and holders.

Research to enhance animal productivity and the sustainability of production systems should focus on applications of animal biotechnologies and their objectives. Molecular genetics tools can be used in combination with reproductive technology for accelerating rate of genetic improvement and its dissemination. Modifying rumen ecosystem and expanding the use of GM feeds will improve feed utilization. While developing DNA-based vaccine and diagnostics will result a significant improvement of animal health care.

Economic benefits of animal biotechnology cannot be realized without a conscious, sustained, multi-stakeholder participatory approach. It is necessary to assure development of human and institutional capacity continuously so that, as biotechnology advances, the procedures required for its safe use can be constantly evaluated, upgraded and applied. There is a need to identify the role of the state and the private sector in its service delivery. Policy-makers and funding bodies must not lose sight of the substantial benefits that can be gained in the longer term by investing in strategic research on animal biotechnology. Adoption of animal biotechnology will result in distinct benefits in prosperity, food security, rural development, animal improvement and economic returns to resource-poor farmers.

Keywords: Animal; Biotechnology; NENA; Genetics conservation; Diagnosis; Vaccines; Reproduction; Nutrition.

Introduction

Animal biotechnology is the result of a multistage process, involving research, development, testing and registration, production and marketing. The goal is to develop a technology, process or product that has clear commercial potential and can be commercialized after due testing and regulatory approval. Developing countries, as most of the NENA, find it difficult to develop biotechnology as the facilities or resources needed to complete all the stages in the process are often lacking (Hobbelink, 1987).

There are a number of animal biotechnologies that have been developed or adapted in both developed and developing countries. However, the major technologies that are used effectively in livestock production include conservation and utilization of animal genetic resources; reproductive biotechnologies, diagnosing disease and vaccine production; and improving feed utilization. Table (1) presents utilization for some animal biotechnologies by region and species.

1. Conservation and Utilization of Farm Animal Genetic Resources (FAnGR)

Seventy percent of the world's rural poor depend on FAnGR as a critical component of their livelihoods. Under intensive livestock systems, genes for productivity are highly valued and cross-breeding with more-productive animals are favored to provide rapid productivity gains. Given rising demand for livestock products, there are market incentives

to improve productivity and efficiency of production.

In more marginal systems, e.g., arid areas, disease resistance, drought tolerance and other adaptive traits are of greater importance. Under these systems, livestock have diverse livelihood functions; as assets for savings and insurance; diversifying livelihood options for food security and meeting the socio-cultural roles of their owners. Livestock have also evolved with environment over millennia, in retention of adaptive attributes and to increase resilience to environmental and disease risks are critical.

The relative importance of different genetic traits varies between the two systems at the extreme.

1.1. Characteristics of FAnGR in NENA Countries:

The livestock in NENA countries, which are an integral part of the existing ecosystem, is a rich source of animal biodiversity. Buffaloes, sheep, goats, camels, etc have adapted to their regional environments over thousands of years and have provided an important source of nutrition for the population of the region. Livestock production in the developing world have number of advantages over developed countries (Madan, 2003), for instance:

- Low-input production system.
- Considerable genetic biodiversity.
- Resistance/tolerance to local (a) biotic stresses.
- Adaptation of rumen ecosystem for high-roughage contents and poor feeds.
- Potentiality for biopharmaceutical developments e.g. camel and goat milk.
- Potentiality for expanding the microbial food e.g. fermented milk, gee and other by-products-based industries.

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- Integrated agro-production system tailored to the local ecology.
- Potentiality for integrating inherited knowledge and industry.

Several genes and desirable traits have been identified in the livestock of NENA countries (FAO, 2004). Examples of FAnGR from the NENA countries that are particularly important on a global level are:

- Buffaloes that produce milk with a high fat content or with the protein quality required to produce specific high-value-milk products (e.g. mozzarella cheese).
- Camels, sheep and goats that are adapted to arid/desert environment and can tolerate poor roughages.
- Many FAnGR species that resist /tolerate various (a) biotic stresses. (Madan, 2003).

that will meet the goals of breeding programs in NENA countries.

Molecular markers have been widely used in the identification of genotypes and the 'genetic fingerprinting' of organisms (Elbeltagy *et al.*, 2006). Genotype verification is used intensively to determine the parentage of domestic animals and to trace livestock products in the food chain back to the farm and animal of origin.

1.3. Threats to FAnGR Diversity:

There is a lack of information on losses of FAnGR in NENA countries. For the most part, the genetic characterization of most livestock populations in developing countries has not been adequately characterized. It is estimated that approximately 16% of breeds were lost over the last century (Blench, 2005). A further 22% of mammalian breeds and

48% of avian breeds are at risk of becoming extinct in the near future, and the rate of extinction is accelerating. Of the livestock breeds known to exist today, 70% are in developing countries. In rapidly intensifying livestock systems, the pace of genetic change is great and the potential for loss of gene diversity greatest. Understanding such system, genetic diversity dynamics will be a critical component of identifying hot spots of loss of genetic diversity and priority for livestock conservation. Such understanding will inform the development of

strategies that can be applied to facilitate the co-evolution of FAnGR with production systems in ways that respond to human livelihood needs while minimizing loss of genuine diversity. According to FAO 2007, 49.4%, in the Near East region are classified as "not at risk"; 46% are classified as at "unknown risk status"; only 2.3% are "at risk" and 2.3% has already extinct, (Table 2).

Table 1. Utilization of biotechnology by species in different regions

| Region | Artificial Insemination | | | Embryo Transfer | | | Molecular genetic technology | | |
|-------------------------------|--|-----------------------------|---------------|--|-----------------------------|---------------|--|-----------------------------|---------------|
| | CRs with ⁽¹⁾ information op Species | Reporting use of technology | | CRs with ⁽¹⁾ information op Species | Reporting use of technology | | CRs with ⁽¹⁾ information op Species | Reporting use of technology | |
| | | Cattle | Other species | | Cattle | Other species | | Cattle | Other species |
| Europe & the Caucasus | 38 | 100% | 66% | 11 | 100% | 36% | 18 | 89% | 100% |
| Africa | 31 | 100% | 10% | 4 | 100% | 0% | 3 | 100% | 33% |
| Asia | 18 | 94% | 56% | 6 | 100% | 50% | 7 | 86% | 100% |
| Latin America & the Caribbean | 21 | 100% | 71% | 12 | 100% | 33% | 9 | 78% | 89% |
| Southwest Pacific | 5 | 100% | 80% | 2 | 100% | 0% | 0 | - | - |
| North America | 2 | 100% | 50% | 0 | - | - | 1 | 100% | 100% |
| Near & Middle East | 6 | 100% | 33% | 1 | 0% | 100% | 2 | 0% | 100% |

Source: FAO, 2006.

(1) Either for research or in practice.

1.2. Characterizing Genetic Diversity:

There is considerable genetic diversity in the livestock of NENA countries, much of which controls traits that influence adaptability to harsh environments, productivity and susceptibility to disease and parasitism. However, little if any data on these genetic resources are available.

The primary challenge facing animal conservation is to identify sound reasons why society should preserve animals that livestock keepers have abandoned (Mendelsohn, 2003). On the one hand, conservation cannot be achieved through a conventional breeding program as the animals carrying the most advantageous traits cannot be easily identified; on the other hand, necessary technologies are either unavailable or expensive. In livestock populations with a high degree of genetic variation, molecular markers are being increasingly used to study the distribution and patterns of genetic diversity. Here, biotechnology is used as a tool for animal breeding aiming to preserve animals in NENA countries.

Global surveys indicate that 40% of domestic livestock breeds are at risk of extinction. Most of these breeds are found only in developing countries, and often little is known about them or their potential. Rapid progress is being made in the preparation of dense microsatellite linkage maps to assist in the search for genetic traits of economic importance. These linkage maps can be used to develop strategies for marker assisted selection and marker assisted introgression

Table 2. Risk status of mammalian breeds (numbers) in the NE region recorded up to December 2005

| Status | Near East | | World | |
|-----------------------|-----------|-------|-------|-------|
| | No. | % | No. | % |
| Total | 259 | | 6455 | |
| Critical | 0 | 0.00 | 264 | 4.09 |
| Critical-maintained | 0 | 0.00 | 59 | 0.91 |
| Endangered | 6 | 2.32 | 440 | 6.82 |
| Endangered-maintained | 0 | 0.00 | 160 | 2.48 |
| Extinct | 6 | 2.32 | 644 | 9.98 |
| Not at risk | 128 | 49.42 | 2861 | 44.32 |
| At unknown risk | 119 | 45.95 | 2027 | 31.40 |

Source: FAO, 2007.

The main problem in NENA countries is lack of breed population data needed to adequately monitor the risk status of such breeds. However, countries that have a high popula-

tion data index e.g. Kuwait for mammalian species and Oman for avian species have very small numbers of respective breeds which are easy to track. Other countries have a population data index of only about 30% for mammalian species and 20% for avian species. Examples of extinct breeds are the Totom sheep of Bahrain and the Giza White and Egypt Baladi White rabbits of Egypt.

Animal biotechnology could play an important role for characterization and assisting programs of animal conservation. States of NENA region that have endangered species need to adopt the needed biotechnology in their conservation plans.

1.4. Exploring Gene:

In the last few years, the impact of the public availability of genome sequences and resources for farm animals and other species is beginning to bear fruition, e.g. the chicken genome sequence in 2004 and the bovine genome in 2006. However, it is clear that the interpretation and exploitation of the vast amounts of data being generated requires considerable input and novel approaches to harness all of the potential benefits from functional genomics. Data generated will elucidate networks of interacting molecules, and will aid to the identification of hub control points e.g. key transcription factors controlling intracellular signaling pathways. It is becoming clear that many pathways and processes, that were previously considered as entirely separate, may well have interlocking components.

Functional genomics will have the power to identify new and novel targets for modulating physiological processes such as enhancing disease resistance whilst maintaining other desirable phenotypes such as efficient growth and reproduction. The following presents the major 7 themes in this concern:

- **Genetics and QTLs:** eQTL are being identified in mouse models, and have the potential to greatly accelerate livestock research.
- **Bioinformatics and Data Mining:** The challenge with the great exponential rise in data is interpretation, and new user friendly approaches are needed.
- **Animal Health:** New insights have the potential to identify new pathways and targets to improve the health and welfare of animals world-wide through breeding and improvements in current vaccines.
- **Functional Genomics for Physiology:** Including growth, reproduction and metabolism.
- **Proteomics:** One of the challenges for applying proteomics to animal research is the low level of annotation for animal proteins and the lack of suitable antibodies. This theme will highlight the latest discoveries being made in this area with relevance to livestock e.g. designer milk.
- **Animal Genomics in Industry:** Breeding for many livestock traits is underway, but identifying locations and genes more precisely has the opportunity to target breeding and strategies more efficiently.
- **Systems Biology:** The new discipline of systems biology essentially aims to bring together and understand all

the information encoded in a genome and its downstream elements which should lead to the emergence of completely new concepts and insights.

Fadiel *et al.* (2005) presents some bioinformatics and their electronic addresses for gene expression of various genes for human, mouse, rat, ovine, bovine and equine species (Table 3).

Table 3. General gene expression (genomics and proteomics) databases for genetic resources of human, mouse, rat, ovine, bovine and equine species

| DB name | URL address | Major contents |
|---|---|--|
| General utility databases | | |
| GenBank | http://www.ncbi.nlm.nih.gov/Genbank/ | DNA/protein |
| PDB | http://www.rcsb.org/pdb/index.html | Experimentally determined 3D structure of proteins |
| EMBL | http://www.ebi.ac.uk/embl/ | Nucleotide sequences of loci |
| Codon usage DB | http://www.kazusa.or.jp/codon/ | Codon usage in animals and other organisms |
| OMIA | http://www.angis.org.au/Databases/BIRX/omia/ | Mendelian inheritance in animals |
| Entrez_gene | http://www.ncbi.nih.gov/entrez/query.fcgi?db=gene | Loci sequences |
| GOBASE | http://megasun.bch.umontreal.ca/gobase/gobase.html | Mitochondrial genes |
| IMGT | http://imgt.cines.fr:8104/home.html | Genes evolving in immunology |
| Swiss-Prot | http://us.expasy.org/sprot | Annotated sequences of proteins |
| Special genomic region databases | | |
| ISIS | http://isis.bit.uq.edu.au/front.html | Introns of genes |
| Loci-specific databases | | |
| Deerbase | http://www.thearkdb.org/browser?species=deer | Loci homologies with deer |
| Goatmap | http://locus.jouy.inra.fr/cgi-bin/lgbc/mapping/common/intro2.pl?Base=goat | Loci homologies with goat |
| MGD | http://www.informatics.jax.org/ | Loci homologies with the mouse |
| Ratmap | http://ratmap.gen.gu.se/ | Loci homologies with rat |
| Comparative genomic databases | | |
| Homology form | http://www.informatics.jax.org/searches/homology_form.shtml | Comparative maps |
| HomoloGene | http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?db=homologene | Gene homology |

Source: Fadiel *et al.*, 2005.

1.5. Potentiality of Animal Transgenesis:

Transgenic animals an organism (typically a mouse) that is engineered to carry a foreign gene as part of its genetic material these animal are very useful for delineating the function of newly discovered gene as well as for producing useful proteins in large animals. These proteins could be for medicinal purposes or make organs for transplant to human. However, the concern are: will they be harmful and could they replace or contaminate natural animals?

Although transgenic animals (mice, pigs, and goats) are used routinely in research (particularly in the medical field), no GM animals have yet been released on farms. The genetic modification of livestock has proceeded much more slowly than the genetic modification of crops for a variety of rea-

sons, including the high costs, the inefficiency of the gene transfer techniques and the low reproductive rates of animals. Recombinant DNA approaches have been used to promote the expression of desirable genes, to hinder the expression of undesirable genes, to alter specific genes and to inactivate genes so as to block specific pathways.

Transgenic animals enable scientists to understand the role of genes in specific diseases. By either introducing or inactivating particular genes, researchers can discover the root causes of diseases associated with gene defects. For example, scientists engineered the overexpression of the human mitochondrial transporter protein, "uncoupling protein-3" (UCP-3), in skeletal muscle in mice. In this model, the transgenic mice were found to eat more than wild-type littermates, yet remain leaner and lighter. The mice also exhibit lower glucose and insulin levels and an increased glucose clearance rate, leading to the hypothesis that compounds that regulate expression of UCP-3 might be of use in treating obesity.

Transgenic animals allow more effective treatments to be developed. Having found the genes implicated in a disease, scientists can then target these or design other therapies which act by influencing their expression.

Transgenic animals help test the safety of new medicines and vaccines. Transgenic models can highlight specific characteristics; certain mechanisms involved in the formation of tumors can demonstrate more clearly the possible side effects of new therapies. Their use in early toxicity trials may also serve to prevent the subsequent use of a larger number of animals in the development phase. Transgenic mouse model are currently used (as an alternative to non-human primates) for neurovirulence testing of Human Oral Polio Vaccine. Additionally, transgenic mice have been successfully bred to produce human CD4, a receptor found on the surface of white blood cells. Since successfully developing mice with this human receptor, some pharmaceutical companies, e.g. GSK have been able to eliminate the need to use "higher" animals for testing drugs that interact with the human CD4 receptor. This was particularly important as chimpanzees, an endangered and protected animal, are the only other animals, other than humans, that carry the CD4 receptor.

Transgenic animals can produce biological products. It is possible to use transgenic animals to produce more biological products for medical treatment. Research is underway to breed transgenic sheep which produce the protein in their milk. Transgenic animals are being developed by some companies to provide new organs for transplantation such as kidneys, livers and hearts. Transgenic pigs with human histocompatibility genes have been bred with the aim that their "humanized" organs will not be rejected by a patient's immune system.

Gene-based biomedical research offers one of the best hopes for curing the major diseases which still afflict mankind. The use of transgenic animals is central to realizing hope and offers the potential for the use of fewer animals in more targeted experiments. The appropriate use of transgenic animals is a positive development with potential for significant medical benefits. The challenge is for governments, in-

dustry and society to ensure that transgenic research continues to be carried out for proper medical ends in a suitably balanced regulatory environment.

2. Biotechnology in Reproduction

The main objectives of using biotechnology in reproduction are to increase reproductive efficiency and rates of genetic improvement in livestock. Artificial Insemination (AI) and preservation of semen were the first technology that is used extensively for reproductive improvement. Presently, they are no longer considered reproductive biotechnology practices, rather being breeding practices. Assessing the fertilization capacity of sperms, sexing sperms, synchronization and fixed-time insemination, super ovulation, Embryo Transfer (ET) and *In Vitro* Embryo Production (IVEP) are the current biotechnological reproductive techniques that used widely to improve reproductive efficiency. In NENA countries more efforts are needed to use these technologies widely. Reproductive technologies can also be used to control reproductive diseases if procedures and protocols are accurately followed.

2.1. Embryo Transfer and its Accelerating Rate of Genetic Improvement:

One of the major reproductive technologies that facilitate genetic improvement in cattle is ET. Multiple Ovulation and Embryo Transfer (MOET) takes AI one step further, in terms of both the possible genetic gains and the level of technical expertise and organization required. 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 program of breed improvement.

Zebu cattle and buffaloes exhibit less consistent follicular dynamics with super ovulation than *Bos Taurus* in the developed world (Barros and 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 and Nogueira, 2001). The use of ET in buffalo has been less successful than envisaged for several reasons; low reproductive efficiency (Singh *et al.*, 2000), poor super-ovulation responses, very low primordial follicle population and high incidence of atresia (Madan *et al.*, 1996) all contribute to low embryo production. Table (4) shows the overall activity of *in vivo* derived bovine embryos in various continents in 2002.

Table 4. Overall activity of *in vivo* derived bovine embryos (number and percentages)

| Continent | Numbers | % |
|---------------|--------------|-------|
| Africa | 13.3 | 2.57 |
| Asia | 92.4 | 17.78 |
| Europe | 90.4 | 17.39 |
| North America | 189.1 | 36.39 |
| Oceania | 15.3 | 2.95 |
| South America | 119.1 | 22.92 |
| Total | 519.7 | |

Source: Thibier, 2005.

2.2. In vitro Embryo Production:

The practical use of IVEP is limited by high production costs and the low overall efficiency under field conditions. High rates of maturation (70% to 90%), fertilization (60% to 70%) and cleavage (40% to 50%), and moderate to low rates of blastocyst formation (15% to 30%) and calf production (10.5%) have been reported in the literature (Nandi *et al.*, 2002). The efficiency of blastocyst production in buffaloes is much poorer than that reported for cattle (Farin *et al.*, 2001). Embryos produced *in vitro* have led successfully to pregnancy and calf birth in buffalo (Chauhan *et al.*, 1997 and Madan *et al.*, 1994), but the success rate is low. IVEP must be improved before it can be widely used in cattle and buffaloes in NENA countries.

3. Nutrition and Improving Feed Utilization

The shortage of feed in most NENA countries and the increasing cost of feed ingredients mean that there is need to improve feed utilization. Additives to animal nutrition, such as enzymes, probiotics, single-cell proteins and antibiotics in feed, are already widely used in intensive production systems worldwide to improve the nutrient availability of feeds and the productivity of livestock. Gene-based technologies are being increasingly used to improve animal nutrition, through conservation of feed stuff in a form that keep or even improve its nutrients e.g. silage, biological treatment with microorganisms or through modifying the digestive and metabolic systems of the animals, i.e. modifying rumen ecosystem, to enable them to make better use of the available feeds (Gordon & Phillips, 1998 and Bedford, 2000). Table (5) presents some common inoculants for silage making and their main product or effect.

Table 5. Inoculants for silage and their main product/effects

| Organisms | Conditions required | Major products/effects |
|----------------------------|---|--|
| Lactic acid bacteria (LAB) | Anaerobic; wilting of crop is desirable; crop should be chopped for rapid establishment of LAB. | Homofermentative pathway: lactic acid and some acetic acid. Heterofermentative pathway: lactic acid, ethanol, mannitol, acetic acid and CO ₂ . |
| Clostridia | Anaerobic; wet forage. | Saccharolytic species: butyric acid, CO ₂ and H ₂ . Proteolytic species: butyric acid, acetic acid, amines, CO ₂ and NH ₃ . |
| Enterobacteria | Anaerobic; optimum pH 7.0; active in early stages of fermentation. | Acetic acid, ethanol, CO ₂ H ₂ and NH ₃ . |
| Listeria | Aerobic; pH above 5.5; growth possible at low temperatures and in high-dry matter silages | Listeriosis, especially in sheep. |
| Fungi | Aerobic; active on surface layers of silage. | Spores and mycotoxins. |

Source: Gado, 2007.

Feeds derived from GM plants (a quarter of which are now grown in developing countries), such as grain, have contributed to increases in growth rates and milk yield. Genetically modified crops with improved amino acid profiles can

be used to decrease nitrogen excretion in ruminants and poultry. Increasing the levels of amino acids in grain means that the essential amino acid requirements can be met by diets that are lower in protein. Table (6) presents some expressed traits and associated genes in GM crops used as animal feeds (Abate, 2007).

Table 6. Some expressed traits and associated genes in GM crops used as animal feeds

| Trait | Genetic element | Gene source |
|----------------------------------|---|---|
| Insect resistance | Cry1Ab, cry1Ac, cry9c, cry3A, cry1F | <i>Bacillus thuringiensis</i> <i>Streptomyces hygrosopicus</i> |
| Glufosinate herbicide tolerance | Phosphinothricin N acetyltransferase | or <i>S. viridochromogenes</i> |
| Glyphosate herbicide tolerance | 5-enolpyruvylshikimate 3-phosphate synthase | <i>Agrobacterium tumefaciens</i> strain CP4 |
| Modified seed fatty acid profile | (EPSPS) Delta-12 desaturase | <i>Glycine max</i> (soybean) |
| Virus resistance | Coat protein helicase/replicase | Potato virus Y Potato leafroll virus |

Source: Abate, 2007.

Metabolic modifiers hormones have also been used as gene transfer biotechnology to increase production efficiency (weight gain or milk yield per feed unit), improve carcass composition (meat-fat ratio), increase milk yield and decrease animal fat. The use of recombinant bovine somatotropin hormone (rBST) in dairy cows increases both milk yield and production efficiency and decreases animal fat. The use of rBST increases milk yield by 10% to 15%. Although trials conducted in developing countries have reported a similar percentage increase, the increase is not significant because of the low milk yields and the high cost-benefit ratio. However, rBST is being widely when the economic returns make its use worthwhile. A porcine somatotropin hormone has been developed that increases muscle growth and reduces body-fat deposition, resulting in pigs that are leaner and of higher market value.

4. Developing Vaccine Production

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. The live-vector and DNA vaccination systems could be manipulated further to enhance the immunity conferred by the gene products. Experimental studies have demonstrated that these vaccines can potentially induce appropriate and enduring immune responses. This technology is, in principle, one of the simplest and yet most versatile methods of inducing both humeral and cellular immune responses, as well as protecting against a variety of infectious agents. Although immune responses have been induced in a number of larger species, most of the information on the efficacy of DNA immunization comes from studies of mice. An exhaustive re-

view of the information available on the use of DNA vaccines in farm animals, has identified the areas that need specific attention before this technology can be used routinely. 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.

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. This strategy is more effective against viral and bacterial diseases. Live vaccines have been developed against infectious bovine rhinotracheitis and number of candidate Salmonella.

The second approach is to identify protein subunits of pathogens that can stimulate immunity. The International Livestock Research Institute (ILRI) used this approach to develop a vaccine against Theileria Parva, the parasite that causes East Coast fever in African cattle.

A novel strategy for developing vaccines against blood-sucking parasites involves using components of the gut wall of the parasite that are not usually exposed to the immune system of the host. When the parasite feeds, it ingests antibodies induced by the vaccine, which destroy the gut wall and consequently kill the parasite. This strategy has been used successfully to develop a vaccine against the one-host tick *Boophilus microplus* (Morrison, 1999). These technologies have to be developed in NENA countries. The research and practical implications are limited. Table (7) presents some diseases that DNA vaccination induced protective immune response.

Table 7. Diseases for which DNA vaccines have been shown to induce protective immune responses in animal models

| Pathogen | Symptoms |
|-----------|--|
| Virus | Avian influenza, bovine herpes, bovine viral diarrhoea virus, dengue fever, encephalitis, feline immunodeficiency virus, hepatitis B, hepatitis C, herpes, human cytomegalovirus, herpes simplex virus, human immunodeficiency virus, influenza, measles, papilloma, pseudorabies, rabies, respiratory syncytial virus, rotavirus, simian immunodeficiency virus, simian virus, ebola. |
| Bacteria | <i>Borrelia burgdorferi</i> (Lyme disease), cholera, Enterotoxigenic <i>E. coli</i> , <i>Moraxella bovis</i> , <i>Mycobacterium tuberculosis</i> , <i>Mycoplasma</i> , <i>Rickettsia</i> , <i>Salmonella</i> , tetanus toxin. |
| Parasites | <i>Cryptosporidium parvum</i> , <i>Leishmania</i> , <i>Plasmodium falciparum</i> (malaria), <i>Schistosoma</i> . |

5. Diagnostics and Epidemiology

Advanced diagnostic tests that use biotechnology enable the agents causing disease to be identified and the impact of disease control programs 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. For example, the molecular analysis of rinderpest viruses has been vital in determining the lineages circulating in the world and instrumental in aiding the Global Rinderpest Eradication Program. Enzyme-Linked Immunosorbent Assays (ELISA) 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.

Many diagnostic techniques currently used in NENA countries are cumbersome and unsuitable for low-resource settings. Molecular diagnostic technologies that are either already in use or being tested in developing countries; PCR, monoclonal antibodies and recombinant antigens. These technologies can be modified to facilitate their application in the NENA countries. Simple hand-held devices that rely on the binding specificity of monoclonal antibodies or recombinant antigens to diagnose infection may be easily adapted.

Molecular characterization of the virus serotypes causing Foot and Mouth Disease has helped in the vaccination and control programs in Asia. DNA testing is being used to check for the gene that causes leucocyte adhesion deficiency in Holstein cattle. Cattle with this condition suffer from gum disease, tooth loss and stunted growth. They usually die before they are one year old. By using DNA testing, carriers can be identified and eliminated. Another DNA test identifies the gene that leads to anaemia and retarded growth in Japanese Black cattle.

6. Constraints and Prospective of Applying Animal Biotechnology in NENA

The major constraints on applying animal biotechnologies, in developing countries, which applied also to NENA, have been reported (Madan, 2003):

- Negligible investment in animal biotechnology.
- High cost of technological inputs such as materials, consumables, and equipment.
- Lack of trained scientists, technicians and fieldworkers to develop and apply the technologies, both in the government and in the private sectors.
- Absence of an interface between industry, universities and institutions, which is necessary to translate technologies into products.
- Inability to access technologies from the developed world at an affordable price in order to make a right-ful, positive and sustainable contribution to livestock production and the economic welfare of farmers.
- Failure to address issues of biosafety and to conduct risk analyses of new biological, gene products, trans-genesis and modified feed items.
- Absence of an accurate and complete database on live-stock and animal owners so that programs can be im-plemented.
- Genetic biodiversity present within species and breeds in the agro-ecological systems.

- Models of biotechnological intervention differ distinctly between developed and developing economies.
- Many animal species and breeds are unique to the developing world; having its own distinct developmental, disease resistance and feed utilization characteristics.
- Lack of cooperation among NENA countries.
- Lack of clear plan in most of NENA countries.
- Lack of priority list of technologies that have direct impact on productivity in farm animals.
- International funds could not suit the need of the national programs and their priorities.

The potential production capacity of livestock to the economy are still not achieved in most NENA countries as the transfer, adaptation and adoption of biotechnology is hampered by the lack of a clear policy for livestock development that is conducive to the introduction of new proven technology and by the lack of information flow from and to decision makers.

Research that aims to utilizing biotechnology to enhance animal productivity and sustainability in developing countries including NINA countries should focus on applications of molecular genetics in animal breeding, utilization of reproductive technology in accelerating rate of genetic improvement, nutrition and improving feed utilization, developing vaccine production and diagnostics for improving animal health, managing natural resources relating to livestock sector, assessing the impact of technological interventions, and strengthening national capacity.

Owing to the constraints outlined above, the economic benefits of animal biotechnology cannot be realized without a conscious, sustained, holistic, multi-stakeholder, participatory approach. There is a great need to ensure that capacity is not just created but also is retained and enhanced. Capacity-building must be carried out at all levels; awareness of policy and decision makers must be raised, the necessary legal and regulatory frameworks must be initiated, the technical and regulatory capacities must be enhanced and institutions may need to be overhauled. More importantly, it is necessary to assess and deploy competent operators and institutional capacity continuously so that, as biotechnology advances, the procedures required for its safe use can be constantly evaluated, upgraded and applied. There is a need to identify new roles for the state and private sector in service delivery.

The global trends in funding for research and development do not address the concerns, needs and opportunities of the developing world. Developing countries find it increasingly expensive to access and use new biotechnologies. There is limited private- and public-sector investment in animal production and health, particularly in relation to modern biotechnologies that are 'resource deficiency'. Although several discoveries have been made in laboratories in the developing world, in most cases these have not been converted into useful technologies or products. The key potential users, resource-poor farmer, often illiterate farmers with a limited knowledge base, do not feel that applying these technologies is worth the effort, cost and risk involved. There is no agency or industry that can scale up and package the technology. Economic incentive to market biotechnological services and

products is lacking in the NENA countries because of the limited purchasing power of resource-poor stakeholders. For understandable reasons, current funding policies in developing countries focus on areas that will yield practical benefit in the short term. In determining future policy, policy-makers and funding bodies must not lose sight of the substantial benefits that can be gained in the longer term by investing in strategic research into animal biotechnology.

Adequate multi-institutional support, possibly through an international donor consortium, is needed to develop cost-effective, cheap and easily adaptable animal biotechnological products. The amount spent by international agencies on animal biotechnology in developing countries is currently very low and constitutes only a small percentage of the total spending on agriculture. Stakeholders, e.g. WB, FAO, UNDP and other multilateral, regional and bilateral organizations have to designate funds to the livestock sector and application of modern biotechnologies. It has been convincingly shown that investing in livestock has a dramatic and far-reaching impact on human development. There are strong arguments in favor of investing heavily in animal production, disease control, development of feed resources, and health biotechnologies. Adopting animal biotechnology will result in distinct benefits in prosperity, food security, rural development, animal improvement and economic returns to resource-poor farmer populations.

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التقانة الحيوية في مجال الإنتاج الحيواني: تطبيقاتها وآثارها في دول منطقة الشرق الأدنى وشمال أفريقيا

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الخلاصة

تشمل التقانات الحيوية الرئيسية التي تُستخدم بشكل فعّال في مجال الثروة الحيوانية وحفظ واستخدام الموارد الوراثية الحيوانية والتقانات ذات العلاقة بالتناسل وتقانات تشخيص الأمراض وإنتاج اللقاحات، بالإضافة إلى التقانات المُستخدمة في تحسين الاستفادة من الأعلاف. ولقد تمّ استعراض عدد من التطبيقات الناجحة في هذا المجال في دول منطقة الشرق الأدنى وشمال أفريقيا.

يمكن إجمال المُعوّقات الرئيسية لتطبيق التقانات الحيوية الحيوانية في بلدان الشرق الأدنى وشمال أفريقيا في: الإحجام عن الاستثمار في مجال التقانة الحيوية الحيوانية وعدم القدرة على الحصول على تلك التقانات من العالم المُتقدّم بأسعارٍ يمكن تحمّلها والافتقار إلى تدريب العلماء والفنيين وغيرهم من القوى العاملة والإخفاق في مُعالجة قضايا السلامة الأحيائية وإجراء تحليلات المخاطر وعدم وجود قاعدة بيانات دقيقة عن الموارد الحيوانية وحائزها.

ويوصى بأن تُركّز بحوث التقانة الحيوية الحيوانية بالمنطقة على تحسين الإنتاجية الحيوانية ونظم الإنتاج المُستدام. فالجمع بين علم الوراثة الجزيئي وتقانات التكاثر يُسرّع من مُعدّلات التحسين الوراثي ونشره على نطاق واسع. كما أنّ تعديل النظام الميكروبيولوجي للكرش في المجترات وتحسين وتوسيع نطاق استخدام المكونات العلفية المُعدّلة وراثياً هي مما يُوصى به من تطبيقات لتحسين الاستفادة من المواد الغذائية. في حين أنّ تطوير اللقاحات والمشخصات المعتمدة على اختبارات الحمض النووي يحقق تحسناً كبيراً واقتصادياً فيما يتعلّق بالصحة الحيوانية. وإنّ تعزيز القدرات الوطنية وتقييم أثر هذه التدخلات التقنية على مستوى المربي ينبغي أن يكون له الأولوية في هذا المجال.

ولا يمكن أن تتحقّق الفوائد الاقتصادية للتقانة الحيوية الحيوانية بدون اتباع نهج استثماري وتشاركي من أصحاب المصلحة. ومن الضروري ضمان تعزيز القدرات البشرية والمؤسسية بحيث أنه مع تقدم استخدامات التقانة الحيوية فإنه يمكن استمرار تقييم وتطوير الاستخدام المأمون لها. وثمة حاجة إلى تحديد جيد للأدوار الخاصة بالدولة والقطاع الخاص في تقديم تلك الخدمات. ويجب ألا يغيب عن صانعي السياسات وهياكل التمويل مقدار الفوائد الجمة التي يمكن الحصول عليها على المدى الطويل من الاستثمار في الأبحاث الاستراتيجية للتقانة الحيوية الحيوانية. وعلى ذلك فإنّ تبني ممارسات التقانة الحيوية الحيوانية سوف يسفر عن فوائد جمة في الإزدهار الاقتصادي والأمن الغذائي والتنمية الريفية والعائد الاقتصادي للمزارعين محدودي الموارد.

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