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Agricultural biotechnologies in developing countries: Options and opportunities in crops, forestry, livestock, fisheries and agro-industry to face the challenges of food insecurity and climate change (ABDC-10)

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Synthesis: Current status and options for livestock biotechnologies in developing countries

Introduction

Livestock contribute directly to people's livelihoods worldwide, providing not only food, but also non-food products, draught power and financial security. Livestock production already accounts for more than one third of the global agricultural GDP in developing countries, and this proportion is expected to increase. The rapidly increasing demand for livestock products, known as the "Livestock Revolution", has created opportunities for improving the welfare of at least some of the nearly one billion poor people who depend on livestock for their livelihoods. However, land degradation, environmental pollution, global warming, the erosion of animal genetic resources, water shortages and emerging diseases are all expected to present challenges to the growing global livestock sector. Conventional technologies and biotechnologies in livestock have contributed immensely to increasing 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.

This document synthesizes the key elements of the document ABDC-10/2010/5.1 that evaluates the use of livestock biotechnologies in developing countries, and considers the extent of their current use, the reasons for their success or failure in the past, emerging challenges and future options both for developing countries and for the international community (FAO, UN organizations, NGOs, donors and development agencies).

Stock Taking - Learning from the Past

A wide range of biotechnologies are available and have already been used in developing countries in each of the three main sectors of animal sciences, which can be categorized as 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 the monitoring of reproductive hormones, oestrus synchronization and semen sexing can improve the efficiency of AI. Embryo transfer (ET) 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 using markers located beside genes of interest, as well as to characterize and conserve animal genetic resources. Use of most molecular marker systems depends on the polymerase chain reaction (PCR), which is an important technique for amplifying specific DNA sequences.

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. Recombinant bacteria have been developed to produce specific enzymes and hormones that improve nutrient utilization, which can increase productivity (e.g. somatotropin) and/or decrease environmental impact (e.g. phytase).

Biotechnologies are used in animal health to increase the precision of disease diagnosis as well as for disease control and treatment. Monoclonal antibodies are used in immunology-based diagnostic methods, including enzyme-linked immunosorbent assays and radioimmunoassays. These methods may not allow the distinguishing of vaccinated from infected animals, so molecular biology approaches that detect specific DNA sequences are now preferred. Vaccination is also an indispensable method for maintaining animal health, and recombinant vaccines offer potential advantages over traditional vaccines in specificity, stability and safety. In addition, the sterile insect technique (SIT) is used to improve livestock health within a certain geographical area by controlling insects that cause or transmit specific livestock diseases.

Reliable quantitative information on the use of livestock biotechnologies in developing countries is generally lacking, except in relation to the use of some assisted reproductive biotechnologies such as AI and ET. Among these biotechnologies, AI is the most widely used, being practiced at some level in a majority of countries. Its use is primarily in dairy cattle and peri-urban areas where complementary services including milk marketing are available. The high cost of liquid nitrogen for the cryopreservation of semen often restricts AI use far from cities. AI is usually used for crossbreeding with imported germplasm rather than for superior local genetics, due to the paucity of animal identification, recording and evaluation programmes. This lack of a system for the identification of superior animals precludes (along with lack of technical capacity) the use of more advanced technologies, such as ET or marker-assisted selection. Molecular biotechnologies in the area of animal reproduction, genetics and breeding have generally been limited to genetic characterization studies, usually through international cooperation.

Although data are scarce, amino acids and enzymes appear to be the most prominent and widespread nutrition-related biotechnology products used in developing countries. India and China have developed local industries to produce them. Various factors have limited the use of many other biotechnologies. For example, silage production is not common, thus precluding the use of microbial cultures. The uptake of recombinant somatotropin has been affected by low public acceptance, the lack of adequate and good quality feed and the low genetic potential of animals in developing countries. Fermentation of lignocellulosic materials to improve the quality of crop residues and forages has not been very effective.

In animal health, molecular-based serological techniques are widely used in developing countries. PCR-based diagnostics are increasingly used to allow early diagnosis of diseases, but their use is mainly restricted to the laboratories of research institutions and larger governmental diagnostic laboratories. Vaccination has been widely used as a cost-effective measure to control infectious diseases, as exemplified by the soon-to-be-confirmed eradication of rinderpest. However, few recombinant vaccines are being produced commercially, and their use in developing countries is

negligible. SIT has played a vital role in the eradication of the tsetse fly population in Zanzibar and in the control of screwworms in several countries.

The success or failure of a given livestock biotechnology has often depended on the presence of complementary factors, rather than on the effectiveness of the biotechnology *per se*. This observation is demonstrated by various case studies. The successful case study from India regarding use of DNA markers to select for prolific sheep carrying the $FecB^B$ gene allele was made possible by providing complementary veterinary services and training in flock management. Rinderpest has been essentially eradicated worldwide, thanks to the use of vaccines and biotechnology-based diagnosis, but the programme was supported by a global system of cooperation among governmental and intergovernmental agencies. The impact of an AI project for buffaloes in India was enhanced when combined with oestrus synchronization and through training and extension activities by the government and NGOs. AI has also contributed to increasing the productivity of dairy cattle and the income of farmers in some regions of Bangladesh, but only with complementary veterinary services and the establishment of organized milk markets. Similarly, the success of reproductive technologies for cattle in Brazil depended on the proper selection of genetic resources coupled with infrastructure development and improvements in animal nutrition and health.

Looking Forward - Preparing for the Future

The examples above show that biotechnologies, if used properly, can contribute to increased animal productivity and better disease management and thus improve farmers' livelihoods. In addition, looking to the future, one can identify unsolved problems in the livestock sector where biotechnologies could be a fundamental part of the solution. Livestock diseases are certain to present an ongoing challenge in the future. The spread of vector-borne diseases such as African swine fever to new areas, a phenomenon that is linked to global warming, is an increasing threat worldwide. The international trade in live animals, animal products and feeds and increasing animal-human interactions are also contributing to new high-risk situations. Molecular biotechnologies will play an ever-greater role in diagnostics, epidemiology, and vaccine development. In addition, "post-genomics" will provide new insight into host-pathogen interactions and, it is to be hoped, lead to novel approaches for disease control.

Climate change and environmental degradation are currently issues of critical importance and livestock production has been implicated as a substantial contributor. Biotechnologies can play a role in alleviating the environmental impact of livestock. Microbial genomics will increase the understanding of fibre degradation in the rumen, which may yield strategies to achieve sustainable decreases in methane emissions. Similarly, livestock genomics can assist in identifying animals that are naturally low emitters of various environmental pollutants. The application of biotechnologies to produce improved feeds can also contribute by increasing livestock productivity and reducing the excretion of environmental pollutants from animal agriculture.

The genetic diversity of livestock is in a state of decline globally. Demand for increased production has led many countries to import germplasm, endangering their local genetic resources. Molecular technologies may be useful in determining the genetic basis for adaptation of local breeds to their environment, including their ability to resist endemic diseases and to better utilize locally available feeds. Molecular genetics, in concert with conventional breeding approaches, can be used in genetic improvement programmes for indigenous breeds, making them more competitive and helping to ensure their *in situ* conservation. New approaches for the preservation of germplasm and cloning may improve the efficiency of cryoconservation.

Based on the preceding analysis, a number of specific options can be identified for developing countries to help them make informed decisions regarding adoption of biotechnologies in the future. First, if biotechnologies are to be adopted they should build upon existing conventional technologies. Most biotechnologies cannot be fully exploited in livestock unless a basic level of technical capacity and infrastructure is already present. Second, biotechnologies should be integrated with other relevant components of livestock production. As demonstrated in the case studies, the application of biotechnologies should complement other components of the livestock

production and marketing system to elicit the desired result. Third, the application of biotechnologies should be supported within the framework of a national livestock development programme. Potential use of biotechnologies in livestock development should be driven by the goal of tackling problems such as food insecurity and rural poverty, rather than on the desire to impose a biotechnological solution for its own sake. Fourth, it should be borne in mind that the target end users of these biotechnologies are normally resource-poor farmers with limited purchasing power, so appropriate models are needed to ensure that the eventual biotechnology products are accessible to them.

The international community can play a key role in supporting developing countries by providing a framework for international cooperation and funding support for the generation, adaptation and adoption of appropriate biotechnologies.

Support by the international community to public-private partnerships can increase the uptake of appropriate biotechnologies in areas such as livestock production, reproduction, breeding and nutrition. Assistance provided in applying biotechnologies to increase livestock productivity should be complemented by the creation and maintenance of markets for the end products. International support should be provided to developing countries in management of animal genetic resources, including policy development.

The early and accurate detection and efficient monitoring and control of transboundary animal diseases, particularly zoonoses, are of great international interest. International and national bodies should collaborate to support training in diagnostics, including the validation of diagnostic methods. The proper establishment of livestock disease reference laboratories that comply with international standards should be supported by international organizations through training, advice and political negotiations to secure sustainable funding.

The international community should help developing countries to integrate animal biotechnologies within the context of national livestock development programmes and overall development objectives for the solution of specific problems. International and national institutions alike should identify ways of improving cooperation to address issues pertaining to animal biotechnologies. North-South and South-South collaborative programmes and partnerships should be developed and fostered through the consistent and long-term provision of sufficient funds.

International funding agencies should allocate increased funding to R&D in animal science in developing countries and support the training of personnel in quality research, because research competence is a prerequisite for harnessing the benefits of animal biotechnologies. Support for capacity-building should extend beyond training for the adoption of a specific biotechnology to investment in improvement of higher education in general. Institutions of higher learning in developing countries should be strengthened to provide the intellectual base for understanding the problems of livestock production and determining the most appropriate solutions. Public awareness of advanced animal biotechnologies should be encouraged and enhanced by international organizations providing science-based information regarding their efficacy, safety, costs and benefits in the development context.