# Animal Biotechnology: Potential Applications and Benefits for Arab Countries

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## Summary

Animal biotechnology takes laboratory biochemistry one step further, by applying that knowledge to real world problems, usually requiring a new set of rules incorporating scale up, stability, robustness, reproducibility and customer needs. For example, animal biotechnology utilizes DNA technology (DNA assays, cloning from animals, genetic engineering, expression in animals), RNA (assays, suppression and activation), proteins (purification from animals and applications thereof), antibodies (production in animals and use in bio-assays), biopolymers (production/purification from animals and their uses), cell biology (cell culture of animal cells, microscopy, manipulation of signalling pathways), rumen microbiology and many other techniques. This paper provides an overview on available animal biotechnologies and focuses on their applications and benefits for Arab countries.

**Keywords:** Biotechnology; Genetic engineering; Embryo transfer; Probiotics; Cloning; Rumen biotechnology.

## Introduction

Agriculture today is more than just care and feeding of animals, the new frontier has arrived. Biotechnology is just as much a part of the animal business as reproduction and nutrition. Major agricultural corporations around the world utilize biotechnology in their day to day to business, an effect that ripples down to farmers in the form of improved animals, better reproduction, novel ways to control and test for pests, new drugs and improved nutrition.

Animal biotechnology allows for production of animals that have the desired characteristics for the Arab world. These animals might be more drought resistant, or more resistant to local disease, or be easier to breed, thereby, providing animals which can increase food self sufficiency, ultimately leading to a healthier population. In addition biotechnology also incorporates methods that modify animals for new purposes, such as vaccine production and new biomaterials to replace plastics. However there are ethical and possibly safety issues to consider as well when deciding to use biotechnology and we shall discuss these in this paper.

## Reproductive biotechnologies

Reproductive technologies encompass artificial insemination and embryo technologies. The ultimate aim of any reproductive program is to increase the productivity of the animal. For example, cloning drought tolerant or disease resistant livestock, modification of milk to produce extra vitamins or in vitro fertilization using superior bloodlines. The most obvious advantage is production of a large number of animals with desired traits. These methods can also be used to preserve rare and endangered animals native to the Arab world.

### 1. Artificial Insemination (AI) and Cryopreservation:

AI has been commercially available for almost two centuries. Bloodlines exist for drought tolerance and disease resistance. Government agencies and agricultural research institutes could manage bloodline importation and selection, depending on local conditions, as well as training AI operators; while a mix of private and government trained AI operators could manage the "business" of AI, depending on local government circumstances. This would include breeding programs to identify ideal animals for local conditions. Affordability to local farmers will be an issue, as will education of those farmers not familiar with the potential benefits. These will have to be handled by the national and local authorities, some contributions from private operators might be possible where farmers have the resources to pay for their AI services. AI equipment is inexpensive, and many Arab countries do utilize AI techniques, for example Egypt has had AI programs in place for many years, and the lessons learned in these countries could be used to develop programs in countries where AI is less prevalent.

### 2. Embryo Transfer (ET):

Embryo transfer involves the transfer of embryos from a superior animal to a less valuable female animal. In smaller animals, such as sheep and goat, this requires surgery, in larger animals non-surgical procedures may be adequate. Usually hormonal treatments are used to generate multiple embryos in the donor. 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). Embryo transfer is a more complex and costly procedure than AI, requiring much more specialized equipment and training and therefore recommended for regions where other livestock improvement have already been introduced. Embryo transfer is in use in the Arab world (Khatir and Anouassi, 2006), for example in the production of racing camels (Al Ain-based Embryo Transfer Research Center for Racing Camels and the Camel Reproduction Center in Dubai). The existing expertise in the Arab world could be used for training scientists in other regions that desire to learn this technique for improvement of valuable and rare livestock.

### 3. Cloning/Nuclear Transfer:

Cloning is used to produce a genetically identical animal, often by splitting an existing embryo into two (natural clones) or by transferring a nucleus from very early embryos or a somatic cell into an egg whose own nucleus has been removed. This was done successfully in sheep in 1996, when

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Scottish researchers injected the nucleus from a cell line made from Welsh Mountain sheep into eggs from Scottish Blackface sheep mothers (Wilmut *et al.,* 1997). Of five lambs born, only two survived more than 10 days. Same group was able to grow a sheep from a nucleus from an adult mammary gland cell (i.e. Dolly). Like embryo transfer this technique is more complex and costly than AI. Therefore cloning could be considered for regions where AI is already introduced, if ethically acceptable. Like embryo transfer, cloning could be considered for regions that want to preserve high value and rare animals, for example endangered species. Cloning is generally inefficient with a small number of viable embryos, so has limited potential for large scale agriculture. However, it is useful because it offers an opportunity to carefully to copy a genetically desirable animal and make many more with exactly the same genes. It could be seen, if used at all in the Arab world, as a last chance for endangered species that might otherwise be lost forever.

**4. Sex Determination:**

Semen can be sexed prior to AI in order to generate offspring of one sex. In meat animals males might be preferred for their muscle; in milking animals females might be preferred for milk production. Application of sexed semen allows dairy producers to select among their herds' potential dams and produce dairy replacement heifers from only the genetically superior animals. Sex determination is not widely used, due to expense and a reputation for inaccuracy. More recent developments have increased accuracy, with the introduction of modified centrifugation and/or fluorescent activated cell sorting (FACS) techniques. Other major adoption constraints are the lower fertility, higher prices and marketing (Schenk *et al.,* 2006 and De Vries *et al.,* 2008). As with the other techniques above, this can only be implemented in regions that have already established AI. Private companies are providing this service in the non-Arab world (e.g. XY Incorporated) but it remains to be seen if they will be commercially viable in the long term.

## Animal Genetic Technologies

Animal genetic technologies include any technique that modifies the genes of an animal. The complement of genes contained in the DNA makes an animal what it is. Unlike cloning genetic engineering involves altering the gene sequence, adding or deleting a gene. The purpose of modifying a gene might be to introduce a beneficial trait, remove a less desirable trait or introduce something that humans might harvest from the animal. This process is sometimes called "animal pharming" when it refers to the production of drugs for human use. Recent development in this field is the discovery and development of Nanobodies, a novel class of antibody-derived therapeutic proteins based on a single-domain antibody fragment. These Nanobodies were first isolated from the dromedary camel, but later produced at large scale by bacterial or yeast cells using recombinant gene technology. Nanobodies are encoded by a single gene and therefore are easier for microbes to synthesize. Extensive research programs are underway for the use of Nanobodies to treat serious life-threatening human diseases such as cancer, Crohn's disease, Alzheimer's, and rheumatoid arthritis. Other examples for animal genetic technologies is the introduction of mammalian gene for insulin in to bacteria to produce insulin. Growth hormone gene could be transferred in the same way.

## Animal Biomaterials

Animal biomaterials refer to the use of any part of the animal to manufacture anything. More advanced is the use of animal product as replacements for plastics or as nanomaterials. Most parts of the animal can be broken down and re-assembled to make something else. For example collagen as a wound dressing, use of animal organs for human transplantation (xenotransplantation), and gelatine to make capsules and foodstuffs.

## Animal Molecular Diagnostics

Molecular animal diagnostics refers to any technique for determining health and/or disease state of livestock developed using biotechnology. Diagnostic techniques that are currently in use in the Arab countries include polymerase chain reaction (PCR), monoclonal antibodies and recombinant antigens. However, there is shortage in trained scientists, technicians and fieldworkers to develop and apply these technologies, both in the government and the private sectors. The ultimate aim of any molecular diagnostics program is to develop rapid tests for disease that can be used in the field with little training. The simplest examples are the drug testing kits where a small sample is placed in a bag and the solution contained within the bag changes colour if a drug is present.

## Animal Nutritional Biotechnology

Animal nutritional biotechnology encompasses the uses of biotechnology to improve livestock nutrition. It refers to modification of feeds and digestion to improve feed quality and utilization, rather than to plant biotechnology to generate improved feeds. The following sections will focus on the beneficial use of rumen biotechnologies to the producer, the animal and the environment.

## Rumen biotechnology

In many of the Arab countries ruminant livestock, such as cattle, sheep, goats and camels, are vital sources of income for farmers and contribute to the national economies of these countries. The digestive system of these animals is dominated by a fermentation vat known as the rumen and who regurgitate and masticate their food after swallowing. In a well-balanced rumen, the microbial metabolism of feed components occurs sequentially without the accumulation of intermediates. However, when diets are changed, the rumen microbial ecosystem is unbalanced for some time. An example of this, is when ruminants go from high fibre diets (e.g. pasture) to starch diets (e.g. grain). When ruminants are on grain diets, rapid production of lactate by lactic acid bacteria can occur leading to lactic acidosis where the rumen pH can drop to 5 (Schwartz & Gilchrist, 1975; Owens *et al.,* 1998; Huntington, 1993 and Al Jassim & Rowe, 1999). This does not occur if the rumen has a well-established population of lactate utilising bacteria or if the numbers of lactate producers are controlled. Although antibiotic feed additives can be used in the prevention of fermentative acidosis, in recent years there has been an increasing pressure to discontinue their use, as there are concerns for the emergence of antibiotic-resistant "super bugs". It is therefore important to identify alternative methods, such as probiotics, that can be used in animal feeds as effective and economical methods of controlling acidosis in ruminants. Important features of a successful probiotic microorganism are that it must be:

1. a normal inhabitant of the gut;
2. resistant to a number of antibiotics, coccidiostats, bile salts; and
3. able to tolerate acid shock.

One good example is the use of lactic acid utilizing bacteria such as *Selenomonas ruminantium* (Ghali *et al.*, 2008) and *Megasphaera elsdenii* (Kung & Hession, 1995 and Klieve *et al.*, 2003) to reduce or minimize the risk of acidosis. The use of microbial supplement containing yeast and bacteria in dairy cattle during the post-partum period proved to be beneficial (Nocek *et al.*, 2003). Another good example is the use of the bacterium *Synergistes* jonesii that is capable of preventing leucaena (*Leucaena leucocephala*) toxicity in ruminants (Allison *et al.*, 1990 and Jones & Megarrity, 1983). Leucaena toxicity is caused by the amino acid mimosine and its rumen metabolite 3, 4-dihydroxypyridone (3,4-DHP). Animals experiencing toxicity exhibit a variety of symptoms, but most importantly animal growth rates are suppressed by 30-50% due to appetite suppression. Leucaena toxicity in Australia was overcome in the 1980's by inoculation with *Synergistes jonesii*.

In tropical Australia, leucaena/grass pastures are the most productive, profitable and sustainable option for beef cattle producers. At present>150'000 ha of leucaena has been established in Queensland. At current rates of adoption this area will expand to 300-500'000 ha in the next 5-10 years.

Ruminal microbial biotechnology therefore can give the ruminant animal industries a significant, reproducible production boost.

## Ethical and Safety Considerations

Most these techniques aim to improve livestock quality by using the genetic material from a small number of superior animals. It is necessary to ensure that the livestock population in a region maintains its genetic diversity and not become too reliant on a limited number of superior animals. If loss of diversity occurs, then a population may become overly susceptible to disease. It is also important to note that not all these techniques have 100% success rates and much depends on the training of the persons performing the technique. Success rates and improvements in livestock will need to be monitored and additional training performed where deficiencies are identified.

Of all these techniques cloning is the most controversial, as destruction of an embryo usually takes place to provide a "shell" for the superior embryo. The other non-cloning techniques are much less controversial and some of them are already used in the Arab world. Objections raised to cloning technology generally fall into several areas; the first claims that these procedures are artificial and we run the risk of generating animals that cannot reproduce without human help. The second claims that we should not destroy an embryo to create a life. The third claims that animals produced by cloning are too genetically similar and so susceptible to disease. The fourth claims that animal cloning is the first step to human cloning and support of the one will inevitably lead to support of the other. The fifth worries that errors during the cloning procedure may introduce dangerous side effects that could affect humans eating the animal product. However, latest report by the U.S. Food and Drug Administration released January 15, 2008 concluded that "meat and milk from clones of cattle, swine and goats, and the offspring of clones from any species traditionally consumed as food, are as safe as food from conventionally bred animals" (US FDA, 2008). The assessment was reviewed by independent experts in cloning and animal health, who found the methods used by FDA to evaluate the available scientific evidence were adequate and agreed with the conclusions set out in the document. It is important to note here that unlike genetic engineering cloning does not change the gene sequence, and therefore an animal clone is a genetic copy of the donor animal. In the Arab world there are some ethical and religious concerns that need to be satisfied before starting any cloning program. Eminent scholars and religious leaders in the Arab world are engaged in debate about the ethics of animal cloning and those discussions could be used to guide any policy to be developed in the Arab countries.

There are also intellectual property issues related to any program in genetic technology. Some of the technology is subject to patent considerations and many of the important genes that might be modified could be subject to patent considerations. Any patent considerations would be subject to the relevant laws and treaties in each country. In contrast, genetic technologies are controversial. In 2003 the FAO and WHO published a detailed analysis on safety issues of foods from genetically modified organisms (FAO/WHO, 2003). They concluded that safety must be considered from the beginning of any attempt to generate a modified animal and that any safety analysis could be conducted along the lines of a standard food safety analysis. They further concluded that pre- and post-market safety monitoring were essential. Public participation was also considered essential in the safety evaluation process.

Ethically there are considerations to generating a genetically modified animal. Perhaps the major consideration is interference in the natural process of generating life. Another concern is animals bred to be resistant to disease treatments might have abnormal chemical or hormone levels. There is also concern that new genes may transfer to another species. Others are concerned about new animal proteins causing allergies in humans. There needs to be public discussion of the potential drawbacks and benefits of any animal biotechnology program in the Arab world as part of the process.

## Conclusion

Animal biotechnology offers great opportunities for the development of animal industries in the Arab world. The most obvious advantage is production of a large number of animals with desired traits. These methods can also be used to preserve rare and endangered animals native to the Arab world.

In addition biotechnology also incorporates methods that modify animals for new purposes, such as vaccine production and new biomaterials. As with any new biotechnology it will need to be monitored with clear goals. When these goals are not being met, identified by careful monitoring, adjustments will need to be made. However there are ethical, religious and possibly safety issues to consider as well and need to be addressed and satisfied before adopting these technologies.

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# التقانات الحيوية في الحيوان: التطبيقات المتاحة وفوائدها في الدول العربية

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## الخلاصة


إنَّ التقانات الحيوية هي بمثابة تطبيقات للكيمياء الحياتية لحل المشكلات التي تعاني منها الزراعة الحديثة في العالم، حيث يتطلب ذلك وضع وتنفيذ مجموعة من الشروط والقوانين التي تكفل تطوير واستمرارية نظم التطبيق بما يحقق العائد المنتظر من هذه النظم. وكمثالٍ على ذلك فإنَّ التقانات الحيوية في الحيوان تشمل تقانة الحمض النووي دي أوكسي رايبوز DNA (تحليل DNA والاستنساخ في الحيوانات والهندسة الوراثية والتعبير في الحيوانات) وتقانة الحمض النووي الرايبوزي RNA (تحليل RNA والتثبيط والتفعيل) والبروتينات (الاستخلاص والتنقية من الحيوانات واستخداماتها) والمضادات الحياتية (إنتاجها من الحيوانات واستخدامها في التحاليل البيولوجية) والبوليمرز (الإنتاج والتنقية من الحيوانات واستخداماتها) وبيولوجيا الخلية (الزراعة النسيجية الخلوية والميكروسكوب وتحوير المسالك المؤثرة) وميكرو بيولوجي الكرش وتقانات أخرى عديدة.

تستعرض هذه المقالة مجموعة من التقانات المستحدثة عالمياً والتي يمكن استخدامها في الدول العربية بغرض تحسين إنتاجية الحيوان وتلبية احتياجات المستهلكين من المنتجات الحيوانية المختلفة.


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