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INTERGOVERNMENTAL GROUP ON MEAT

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BIOTECHNOLOGY DEVELOPMENTS AND THEIR POTENTIAL IMPACTS ON THE LIVESTOCK AND MEAT SECTORS

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INTRODUCTION

1. The Committee on Commodity Problems (CCP) made a preliminary review of the present state of biotechnology developments and their possible impact on trade in agricultural products at its 61st session of February 1997 (Document CCP:97/17). There was widespread agreement in the Committee on the need for the IGGs to undertake studies assessing the current and future impact of biotechnological developments on the commodities under their mandate. A specific request was also made to extend the future work on the subject beyond crops to cover livestock and livestock products.

2. This report, therefore, summarises the biotechnology developments in the livestock and meat sectors and makes an initial attempt to assess their potential impacts on the competitiveness and trading patterns of the products concerned. The study is based on a review of the nature of patents for basic animal biotechnological procedures and manipulations, for methods of improving animal productivity and facilitating animal reproduction, and for new veterinary capabilities and other purposes[1], as well as a general review of literature on the subject.

BIOTECHNOLOGY DEVELOPMENTS IN THE LIVESTOCK AND MEAT SECTORS

CONCEPTUAL FRAMEWORK

3. The livestock and meat sectors account for a substantial part of the value of global agricultural production (more than half in developed countries and a quarter in developing countries). Moreover, global output of livestock products has been increasing faster than that of other sectors of agriculture, a trend expected to continue for some time into the future. The contribution of improvements in animal productivity to growth in meat output has been nearly three times greater than that of increased livestock numbers. For the future this trend will have to continue in order to meet the demand over the next 15-20 years.

4. Most of the technological developments to date have led to improved efficiency through increases in animal productivity per unit of input and/or time and to improvements in the quality of the derived products and as well as in animal health. Applications enhancing the natural reproductive processes of animals so as to improve offspring selection carrying the desired characteristics were the first to be introduced, and some, such as artificial insemination, have been around for many decades. More recently, molecular genetics and recombinant DNA (deoxyribonucleic acid) techniques have been applied to improve traditional dam and sire selection procedures. Some of these more advanced techniques are also being employed to develop new inputs into livestock production processes in the form of veterinary products and/or improved feeds to increase animal productivity. Indeed, use of such inputs is widespread and is likely to be the most important means of distributing the new technologies for some time to come[2]. Similar techniques

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[1] While patent information is not a perfect tool for analyzing the future of agricultural biotechnology, its strength is that it reflects actual financial commitment and interest. At the same time, issued patents run some years behind scientific research underpinning them. Moreover, it is frequently difficult to predict the investment and licensing behaviour of the firms involved.

[2] It should be noted that improved technologies for the protection of animal welfare, conservation of genetic resources and management of livestock-environment interactions would also be needed to address the concerns related to the sector. No specific database search was conducted to extract patents for products or processes related to these topics. The general searches that underpin the discussion in this document, however, did not yield many patents on the subject.

have also been used in the cloning of animals, which when coupled with selection procedures may prove to be a useful method of animal genetic improvement. However, the procedures of animal cloning itself need to be significantly improved, before they can be gainfully employed. It should be noted that some of these new techniques have proved to be controversial as they raise health and ethical concerns and are likely to generate debate also in the future.

REPRODUCTIVE TECHNOLOGIES

5. Most of the technologies being employed for improving the reproductive processes of animals do not directly deal with manipulation at the cell level, as does modern biotechnology. Techniques of artificial insemination (AI), embryo transfer and production (ET) and embryo cryopreservation, have been the traditional means of speeding up the reproduction process with the aim of facilitating the breeding of those animals carrying the characteristics that are of value to livestock producers.

6. AI is being used especially in dairy herds[3] in both developed and developing countries, but mostly in the former. Nevertheless AI is becoming important in many developing countries to meet the needs of intensive peri-urban dairying systems. ET allows the recovery, storing and implanting of embryos so that the reproductive rate of a female animal, and thus average rates of genetic gain, can be increased. Recent developments in the ET techniques permit almost all of the reproductive processes to take place in the laboratory. But it must be noted that achieving economically viable success rates is still a problem.

7. The patent search, completed early 1998, yielded inventions that were, in general, improvements in the current processes for AI and for cloning of embryonic cells. This list may well expand as the full implications of the cloning of adult transgenic animals enter agricultural research practice more widely.

TECHNIQUES FOR CREATING GENETICALLY MODIFIED ANIMALS

8. Although cloning is a complete replication of a particular animal, it is also possible to selectively alter particular genes in their DNA structure. A great deal of basic research has already been undertaken to establish the genome maps of animals that are economically valuable, including cattle, sheep, pigs, chickens and horses. The eventual goal of livestock genome scientists is to produce sufficiently saturated genetic linkage maps to assist in the search for single gene traits[4] or a group of genes that contribute to particular biological processes, such as milk production.

9. Several methods are used to produce genetically modified animals. One takes the new DNA, inserts it into a fertilised egg of the species that is to be transformed and then transplants

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[3] Farmers do not use AI extensively on beef herds because the costs, including heat checking, are higher and benefits lower than for dairy cattle.

[4] Some examples include: identifying the genetic trait repsonsible for porcine stress syndrome, or malignant hyperthermia, that results in sudden death or deterioration in the meat of domestic pigs; identifying the trait in the Booroola line of Australian Merino that increases the ovulation rate and hence the litter size; mapping all the relevant genes that controll milk production in cattle so as to enable yield increases and changes in the fat and protein content of milk.

the transgenic egg into a female to be carried to term in a normal pregnancy. If the DNA has successfully become part of the genome, the new offspring will be a transgenic animal[5].

10. A rather different approach to producing transgenic animals involves the culturing of embryonic stem cells, which have the ability to develop into any cell in the body, including germline cells. When these cells can be cultured and grown in quantity, transformed and successfully inserted into an early embryo, they can create a chimera, i.e. an animal in which different cells contain different genetic material. Any germline cell that comes from the transformed stem cells can then be the source of transgenic animals containing the transformation in all cells. The technique was first used in mice and has been available for some time only for laboratory animals.

11. Techniques for inserting the DNA into a particular (rather than a random) place in the genome of mammals have also been developed. They are used at the time of preparing the genes or of the DNA construct to be inserted into a fertilised egg or stem cell (through what is called "homologous recombination"). By use of these techniques the risk of disrupting an existing gene can be reduced and, possibly, ways found to replace or modify the action of an existing gene that is conferring undesired effects.

12. Comparable techniques also exist for poultry, where the practical biology is quite different, because the embryo develops within an egg. It is possible to use modified viruses that infect cells and insert the genetic material they carry into the cell's genome. This, of course, is a completely different means of transforming an organism. Analogous means are already used for transforming plants and for transforming cell cultures. Other techniques use a variety of procedures for culturing avian cells.

TECHNIQUES FOR IMPROVING YIELDS

13. Many of the techniques described above are designed to reshape the animal's reproductive processes so as to accelerate the multiplication of those animals that have the desired qualities and to modify them genetically so that they exhibit those desired qualities directly. There are also other methods designed to alter the animal's metabolism or digestive processes so as to increase growth rates and improve the efficiency of converting feed into meat. Commercial viability is the primary reason determining whether growth-oriented improvements are implemented through feeds and hormones or through inserting the relevant genes into the animals. In fact, essentially all the improvements found in this area are implemented through feed or dietary additives, some of which might themselves be produced through biotechnological fermentation.

14. Most of the innovations related to yield and quality of the livestock products deal with hormones that regulate or affect certain biological processes of the animals. Thus, for example, somatotropin, a hormone secreted by the anterior pituitary in all mammals, has a regulatory effect, among others, on growth. It was one of the first biotechnology products developed by genetic engineering techniques that transferred the DNA sequences responsible for somatotropin synthesis into bacteria and allowed it to be produced in bacterial cultures. Industrial production of bovine somatotropin (BST) is now possible and can be administered through injections or feeding regimes to increase milk yields, improve carcass quality and feed conversion efficiency. Although most of the applications are for bovine animals, some also apply to pigs and sheep.

15. There are also techniques that induce and regulate the responses of the immune systems of animals to antigens or proteins originating from both outside the organism (i.e. foreign molecules) and from within (i.e. hormones). The response of the immune system is through production

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[5] This is very similar to the process used to produce the cloned sheep, Dolly. In the case of Dolly, the original genome found in the egg is completely eliminated, and a new nuclear genome--a whole nucleus--taken from a mature cell of the sheep being cloned, is inserted.

of neutralising antibodies. The techniques are designed to modify those responses through the control of the level of production of the antibodies, the level of feedback regulating them and the receptors, in order to affect fertility, growth, lactation and body weight and composition (e.g. leanness). There are many patented techniques falling into this category that deal with the use of the substance, the processes used in the production of the substance and the substance's insertion into feed or even crops. Some examples are: use of insulin-like growth factors to mediate the effects of somatotropin; use of an antigen as an immunogen to reduce fat in pigs; and use of sucrose thermal oligosaccharides as a way to alter the microflora within poultry digestive tracks to increase body weight.

STRESS RESISTANCE AND VETERINARY MEDICINE

16. The techniques in this section reduce some of the risks associated with livestock management. These include veterinary improvements and modification of organisms for stress tolerance. Some of the techniques comprise fundamental discoveries that may contribute to resolving a large number of diseases. These techniques range from identification of proteins for manipulating the immune system for resistance to parasites to insertion of genes into mice for protection against viral diseases. Another category covers the vaccines themselves. Biotechnology has provided the ability to sequence a disease organism (or portions of it) and to create vaccines using particular proteins, produced in quantity through biotechnology, or significant genetic modifications of the organism. It is thus possible to stimulate the immune system response with less risk of spreading the disease, as is sometimes the case with a vaccine based on an attenuated strain of the disease. A large number of patents exists for foot-and-mouth disease, as well as for other diseases, such as the Newcastle disease, bovine viral diarrhoea, porcine reproductive and respiratory syndrome viruses, etc. Patents covering disease resistant animals and diagnostic tools were not prominent. However, these may be important areas of research in the future, especially for use in poultry where the economics will favour use of transgenic animals rather than treatment of individual animals and for developing disease diagnostics to enhance meat and livestock trade.

NEW USES OF ANIMALS AND LIVESTOCK PRODUCTS

17. Transgenic animals are now being developed or utilised for a number of non-food purposes, including medical research, the production of pharmaceutical products in the animal's milk and the production of organs for transplantation to humans. These special purpose animals are unlikely to have significant implications for trade in livestock, but they may create a financially significant market for a few specialist firms and they show some of the potential for future animal biotechnology.

18. Another important research area is to produce biologically-significant substances (e.g. certain types of human proteins) in animal milk, as it is believed that this will be more efficient than chemical synthesis or biological fermentation in cultures. These ideas are being developed for application in mice, but cattle, sheep, or goats are likely to be used for producing these substances on a commercial scale. Because of the potential financial benefits, there are many patents, some which cover alteration of the mammary cells in living organisms while others extend to the use of certain promoters to produce the substances in the mammary glands.

19. Finally, there are efforts to modify animals to produce organs for transplantation purposes. Because of strong ethical and religious concerns or concerns that insertion of animal organs into humans might bring viruses, this may not be done at a larger scale for some years. Most of the efforts are concentrating on finding ways of avoiding immunological rejection of the organ.

NEW PRODUCTS THAT MAY DISPLACE LIVESTOCK PRODUCTS

20. Any invention designed to increase the protein production or protein balance of agricultural crops or to increase the palatability of vegetable protein might tend to displace livestock meat production. Two specific directions of research oriented toward substitutes for meat were found. One consists of methods of improving the marketability of fish protein, covering various methods of producing food products (and, in some cases, the food products themselves) from fish; the products are expected to be of significantly higher value than the fish from which they are made. A second group consists of fat substitutes that could be used in low-fat diets.

IMPACT OF BIOTECHNOLOGY ON TRADE IN LIVESTOCK PRODUCTS

OVERALL ASPECTS

21. It should be noted that most of the modern biotechnology developments discussed above are not as yet in most cases widely applied by livestock and dairy producers on a commercial basis. This is despite the concentration of current research activities in the field in private rather than public institutions, thus destined essentially for commercial use. Whether the biotechnological improvements are embodied in the genome of the animals or are inputs to be used in the livestock/dairy production, the "products" of the new technologies have to be purchased by the agricultural producers, wherever they may be located. The decision to "adopt" the new production technology, will depend essentially on the expectations regarding the level of average returns and its variability as well as the costs of using the technology.

FACTORS AFFECTING THE COST STRUCTURE

22. Although the structure of the costs of production of livestock products is expected to be affected by biotechnology developments to some extent, the influence of factors other than that of biotechnology will continue to dominate and, thus, determine international trading patterns for the products concerned. In the case of those produced under intensive systems, i.e. in feedlots and poultry plants, feed is expected to continue to be the most important component of overall costs, with trade in feedstuffs constituting an alternative to trade in livestock and meat products. In the case of extensive production systems, on the other hand, the economics of the alternative uses for the land are likely to dominate the factors determining the competitive advantage of livestock production.

23. To the extent that modern biotechnology does affect competitive advantage, however, the biological aspects of the animal production processes will be an important determinant of the structure of costs and, hence, the extent to which a particular application will be commercially successful. Some of the new technologies, for example, may not prove to be effective in some strains of animals or under some climatic or disease conditions. As already noted, most of the current research and development activities are conducted by private companies for commercial exploitation and are designed to meet the requirements of developed markets and thus may not be very suitable for the conditions of small-scale subsistence farmers in the tropical regions of the world. For example, an invention that affects the microbial population of a ruminant stomach and significantly improves the efficiency of conversion of typical temperate zone feed ingredients may not prove to be very useful for animals bred in tropical zones using different feedstuffs. However, there may be other applications, such as the use of hormones, new reproductive methods, or new vaccines for disease/quarantine control, that may be “portable” in this biological sense and could be useful in developing as well as developed countries. Nevertheless, the issue of

adapting new technologies to different conditions remains to be addressed, as the existing institutional capacity to achieve this in many developing countries may fall far short of the requirements.

24. Using transgenic animals as a way of altering the cost structure in livestock production is not likely to become widespread in the near future. They will probably be used first in processes involving small animals and may be less widely available and more difficult to access by developing countries, as the technology will be "embodied" in the animals themselves. The costs of obtaining and using an improved transgenic animal are still relatively high when compared to those technologies embodied in other inputs, such as feed additives, vaccines, hormones etc. This, of course, could change, especially if new discoveries allow higher than natural rates of reproduction to be achieved.

25. The scale of operations could also be a factor in determining the cost structure of the processes that use the new technology, and hence the extent of its adoption. Particular technologies may prove useful only at a large scale of management. This was one of the issues raised about the use of bovine somatotropin (BST) to stimulate milk production, as it was deemed to be practical only in large-scale, technologically-sophisticated dairies. Similarly, the new technology permitting better management of coccidial diseases in poultry is likely to favour large scale operations and, hence, have an impact on local production patterns, especially in countries where consumption is rapidly growing. In light of recent rapid growth in poultry meat trade, wide-scale adoption of the technology might affect international trade patterns, depending on which countries find its adoption commercially more beneficial.

FACTORS INFLUENCING EARNING POTENTIAL OF PRODUCTS OF BIOTECHNOLOGY APPLICATIONS

26. There are also other reasons, apart from considerations of costs of producing livestock products, for the development of the new technologies to be concentrated in the field of improving inputs of production for some time to come. For instance, consumer acceptability of the final products and regulatory processes may be influential. Consumer concerns, based on biosafety[6] and ethical considerations, in some countries may affect the earning potential of the applications[7]. Thus, for example, disease resistance obtained through vaccines or improved productivity through feed additives rather than through transgenic means may prove to be preferable from a consumer's point of view. Moreover, intellectual property rights applied to improvements to animals may be weaker in many countries than those applied to chemical products.

27. Hence, it appears likely that, for some years, there will be relatively few livestock biotechnology innovations disseminated widely through distribution of transgenic animals; the innovations will probably, at least at first, be distributed through the existing agrochemical and veterinary channels. This trend may change should public attitudes about transgenic organisms change; as intellectual property systems for protecting animals become stronger and as the innovations become more complex and, therefore, biologically available only through genetic engi-

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[6] A joint FAO/WHO Expert Consultation in 1990 concluded that the use of this technology did not result in food which was inherently less safe than that produced by conventional technologies. In October, another Joint FAO/WHO Expert Consultation on Biotechnology and Food Safety confirmed the findings of the 1990 Consultation and also provided valuable recommendations to national governments on biotechnology safety assessment and strategic advice for the future.

[7] Information obtained from FAO's Dairy Information Exchange System on the use of bovine somotatropin to increase milk yields in dairy cows in 29 countries indicate that only in five, Brazil, Israel, the Republic of South Africa, the USA and Zimbabwe, the use of the hormone is not currently banned. Of these five countries, only in the USA is it used extensively.

neering of the animal itself. Should such changes occur, their commercialisation may take place most quickly in those sectors where the reproduction rates are greatest (e.g. poultry), the vertical integration of the industry is most enhanced and the costs of animal-by-animal treatment are the highest. Moreover, the absence of patent protection may encourage the development of vertically integrated production units, especially in situations where use of transgenic animals is economically more favourable.

28. The new technologies may also allow for some displacement effects, parallel to the way in which high-fructose corn syrup has displaced sugar in some applications. However, there are few special-purpose meat products analogous to high-fructose corn syrup, which has substituted for sugar. Displacement seems most likely to come through alternative methods of producing protein for human consumption, and there are already new technologies for producing surimi and for developing fat substitutes. These and similar technologies will almost certainly have an impact, although, for at least a generation or so, it is likely to be small. The impact of changing relative prices of vegetable and animal proteins caused by factors other than biotechnology developments such as changes in health and social attitudes toward meat consumption, is likely to be more important than the impact of biotechnology developments.

29. One aspect that may prove to have a significant trade impact is that these technologies may facilitate trade by helping to overcome quarantine barriers. The most obvious example is that they may assist in either the eradication of foot-and-mouth disease or the development of improved detection methods for this disease. The result would be to remove this barrier that has affected international trade in beef products severely, as testified by a number of recent examples, including the trade impact of bovine spongiform encephalitis in British cattle and avian influenza in Hong Kong chickens.

CONCLUSIONS AND RECOMMENDATIONS

30. This document presents a first assessment of the biotechnology developments that have taken place in the sector for livestock and livestock products and their possible impact on international trade. The assessment suggests that many of the trade effects of the new technologies are likely to be marginal, at least initially, though current trends towards increasing productivity is expected to continue. Initially, the three most important technologies from a trade perspective will most likely be those for disease control, which support large-scale production, as in pigs and poultry, those for quarantine-oriented disease, which could significantly increase (and also restructure) beef trade, and those oriented toward improving feed efficiency. Transgenic animals will come only later — they will probably be used first for smaller animals and may, because of proprietary technology concerns, be less widely available, particularly in developing countries. It is here that it may be most important to support public-sector research and to explore ways to develop appropriate intellectual property arrangements to ensure that these technologies can be available universally. These tendencies imply that the current concentration of research efforts in those areas where expectations of commercial success are the greatest may raise the comparative advantage of producers in the most developed countries. Without offsetting developments this could mean increased exports of livestock products from developed countries to the developing countries. Moreover, because of the complex technical issues involved there could well be a growing number of trade conflicts involving WTO panels.

31. In the light of the above, the Group may wish to consider recommending the monitoring in future developments in the application of biotechnology in the sector and their trade impacts. The following studies could be undertaken by the Secretariat if the Group wished, always bearing in mind resource constraints:

i) monitoring and regular reporting to the Group on developments in application of biotechnologies in the sector and their impact on the competitiveness among different types of meat and among countries**;**

ii) analysis of the particular issues facing the developing countries.