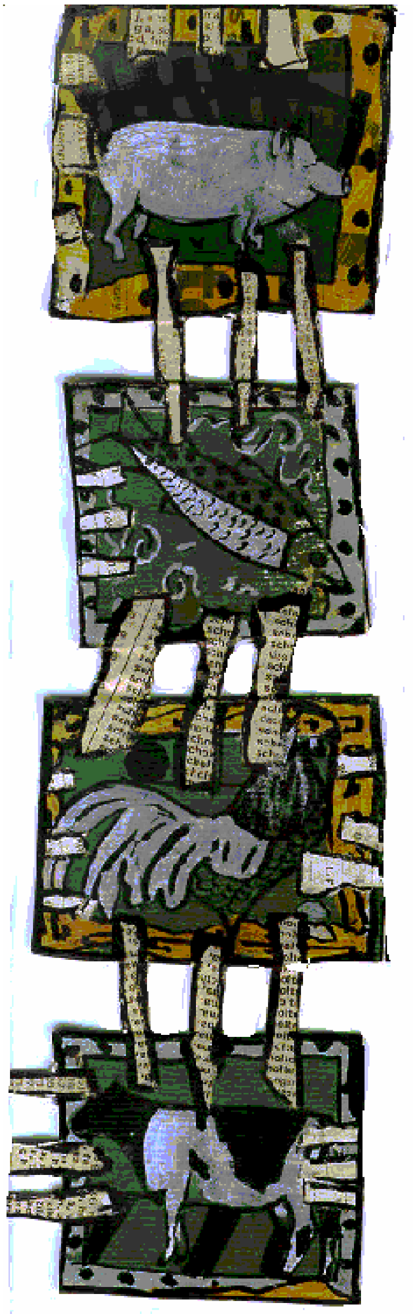
Farm Animal Industrial Platform *(FAIP)*



The future developments in farm animal breeding and reproduction and their ethical, legal and consumer implications

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The future developments in farm animal breeding and reproduction and their ethical, legal and consumer's implications

Farm Animal Breeding and Society

Proceedings

Thursday, 3 June 1999

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Contactpersons European Commission:
Laurence Cordier, Maurizio Salvi. **Laurence.cordier@dg12.cec.be** **Maurizio.salvi@dg12.cec.be**

Coordinator project:
Anne-Marie Neeteson, FAIP/IPG, Oosterbeek. **Neeteson@iaf.nl**
Partners project:
Jan Merks, IPG, Beuningen. **Jan_merks@ipg.nl**
Alessandro Bagnato, Università degli studi di Milano. **abagnato@imiucca.csi.unimi.it**
Peter Sandøe, Royal Veterinary and Agricultural University Frederiksberg, Copenhagen. **psand@coco.ihi.ku.dk**
Christine Noiville, Centre de Droit des Obligations, University Paris I. **noiville@univ-paris1.fr**
Arie van Genderen, Consumer and Biotechnology Foundation, The Hague. **avgenderen@consumentenbond.nl**

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CONTENTS

ELSA Workshop Farm Animal Breeding and Society

Thursday 3 June 1999
Utrecht, The Netherlands

Programme

Chairman Jan Merks

9.00	Registration, coffee/tea
9.30	Welcome
9.45	**S. Keeble,** Member Parliament UK: **Farm animals - their role in society**
10.05	**J. Merks**, Chairman FAIP: **Farm animal breeding and society**
10.15	Coffee/tea
10.50	**A. Bagnato**, Università degli studi di Milano / **A. Neeteson**, FAIP: **The reproduction and selection of farm animals**
11.10	Questions and discussion
11.25	**P. Sandøe**, Royal Veterinary and Agricultural University Frederiksberg: **Ethical perspectives on breeding and biotechnology**
11.45	Questions and discussion
12.00	LUNCH
13.20	**J. McInnerney**, vice chairman Farm Animal Welfare Council: **Economic Pressures, Livestock Productivity and Animal Welfare – Seeking the Balance**
13.40	**A. van Genderen**, Consumer & Biotechnology Foundation: **Farm animal breeding and the consumer**
14.00	Questions and discussion
14.15	C. Noiville/ C.Labrusse, Faculty of Law Paris University I: **Farm animal breeding and the law**
14.35	Questions and discussion
14.50	Coffee/tea
15.20	<u>Discussion panel</u> Members panel propose one statement for the discussion
16.20	Conclusions
16.30	END

Farm animal breeding and society

Jan Merks[1]

Since mankind started the domestication of farm animals, we have tried to get progeny from the animals that seemed best fit for the purpose we had in mind. Since the beginning of this century, initiated by governmental organisations by the set up of herdbooks, the farm animal reproduction and selection organisations are doing this important job. They provide the farmers with genetically high value animals to produce milk, meat, eggs or wool. All towards enough food at low cost.

Nowadays, not the opinion of the farmers about the quality of their product or production system is important for animal breeders, but the opinion of society and the 'licence to produce' determines the goal of farm animal selection and reproduction. The awareness of the European public concerning diseases in farm animals and new technologies in use for transgenic crops, animals for xenotransplantation and cloning has been the challenge for the European reproduction and selection industry to start a dialogue with society about the future of farm animal breeding. Especially new technologies may raise questions that involve consumers, the moral values of society and the legal rights of animal breeders and farmers. In order to enable that dialogue the project "The future developments in farm animal breeding and reproduction and their ethical, legal and consumer's implications" has been initiated, of which we will discuss the results today. The project is a research project, funded in the Fourth EC Framework Programme for Research and Technological Development. It started at 1 September 1998 and is expected to be finished by September this year.

The goal of project farm animal breeding and society is making farm animal breeding and reproduction developments more transparent for society, and to look at these developments from an ethical, legal and consumer viewpoint.

Before we start with the presentation and discussion of the project results, the partners in the project are:

1) Farm Animal Industrial Platform *(FAIP)* and Institute for Pig Genetics (IPG). Their task was to make an inventory of the present and future aspects of breeding and reproduction, together with the
2) Zootechnical Institute of the University of Milan;
3) Veterinary and Agricultural University, Frederiksberg Copenhagen. Their task involved the ethical aspects of farm animal breeding and reproduction;
4) Centre de Droit des Obligations, Faculty of Law Paris University I investigated the legal aspects, and

5) Consumer and Biotechnology Foundation from the Netherlands is responsible for the viewpoint of consumer organisations.

Each of the partners has executed part of the project. During the project, numerous contacts by e-mail and telephone, and a few fruitful personal meetings with a lot of discussion enabled a consistent project with all necessary interaction.
The breeding part is developed together with working groups from the breeding industry, all FAIP members. Furthermore, three future scenarios: a conventional path, a modified path and a low cost path have been worked out. These scenarios give an overview of what is possible, and how breeding, technologies, production systems, consumer quality and cost price can be linked. Above all, they are meant to be a basis for discussion on the future of farm animal breeding and production.
Looking at reproduction and selection of farm animals from an ethical viewpoint, Peter Sandøe and Stine Christiansen will review those aspects of the breeding and reproduction of today and tomorrow that concern the ethical values of society.
Research and development, costing a lot of money, need to get a return from the products and processes that result from it. Christine Noiville very clearly will address the impact of the legal protection of biotechnological inventions by patents for farm animal reproduction and selection. Furthermore, she has made an overview of the role that animal welfare legislations could play on the future breeding work.
Last but not least, the role of the consumer – who is THE consumer – is the subject of the study and the survey that Arie van Genderen has made. How does THE consumer react to new technologies? How important is consumer's choice? What can we expect?

The aim of today is to open a dialogue between social parties that did not meet before to discuss common interests in farm animal breeding and reproduction.
Today, the results of the first part of that dialogue will be presented to you, for further discussion. In this way, the farm animal industry wants to start a dialogue between producers and consumers – together with the providers of legal and political conditions – to achieve a better finetuning of possibilities, wishes and expectations. This will help breeding industry, consumers and politicians in making well informed decisions.

[1] Jan Merks. Chairman steering committee Farm Animal Industrial Platform *(FAIP)* and director IPG, Institute for Pig Genetics BV, P.O. Box 43, 6640 AA Beuningen, The Netherlands

The Reproduction and Selection of Farm Animals

Anne-Marie Neeteson[1], Alessandro Bagnato[2], Jan Merks[1], Raffaella Finocchiaro[2], Egbert Knol[1], Cliff Nixey[3], Pierrick Haffray[4], Duncan Pullar[5]

Farm animal industry is on the threshold of the application of new biotechnologies in farm animal reproduction and selection. The developments in breeding and livestock production have resulted in the farm animals of today producing high quality products at relatively low cost. Both the new technologies and the traditional breeding of farm animals may raise questions that involve society. Milk, meat, fish and eggs are an important part of our daily food consumption. Before a consumer buys a product, it has made its way through the food production chain, making the origin of the product and the way it is produced very distant. However, consumers influence livestock production directly with their purchases. Farmers produce the food that will be bought by consumers. Breeders breed the animals that will be used by the farmers. The aim of this article is to make farm animal breeding and its role in animal food production more transparent. To achieve this, the European reproduction and selection industries of cattle and other ruminants, pigs, poultry and farmed fish, represented in the Farm Animal Industrial Platform *(FAIP)*, have jointly made an overview of the history and state of the art in breeding (Farm Animal Industrial Platform, 1999) and of the factors that will affect the development of farm animal breeding. Furthermore, possible future models of farm animal reproduction and selection have been worked out. These models are meant to be the subjects for discussion on the possible and desired developments in farm animal breeding.

The contribution of farm breeding to food production.

The breeding of farm animals takes place at the beginning of the food chain. From consumer purchases it is a long road from the retailer to the processor, to the farmer and finally to the animal breeder. Animal production takes place on farms where farmers fit both the market's and the consumer's needs by choosing with great care replacement animals for their own production. In this way farmers gradually bring the population characteristics in the direction of the consumer needs. This is called *genetic improvement*. The role of animal breeders and breeding companies is to produce and disseminate improved animals to the farmers.

Breeding farm animals takes place in three steps. A breeding goal is determined. The animals that answer best to the breeding goal are identified and selected. Then, they are reproduced and disseminated to the farmer.

Definition of the characteristics to improve (breeding goal). In general, farm animal populations do not have all the desired characteristics. The first step in a selection programme is the definition of a breeding goal. This is a description of the qualities an animal should ideally have in certain circumstances or, in other terms, the definition of the characteristics to improve. Different markets and different farming systems may need different animals and consequently different traits need to be improved to achieve the breeding objective. Most of the time the breeding objective involves more than one trait, for example laying hens should produce more eggs with better shell quality, lay longer and have stronger legs. When more than one trait is included in the selection programme it must be decided for each trait how important it is compared to the others. One should also bear in mind that improvement for a trait can influence positively or negatively other traits.

Moreover a breeding goal must be determined a long time in advance. Depending on the species, (i.e. the biology of the animal and the characteristics of the population), on the tools available to realise the desired improvement, and on the number and the characteristics of traits one wants to bring nearer to the goal, it takes three, five, ten years or more to achieve appreciable results. The definition of a breeding goal is then a long term prediction of the consumer and of the market needs. Besides that the breeding goal may change in time, one should be aware that the decided breeding goal will influence the management of animals, and consumer appreciation for a relatively long period.

Identification and selection of superior animals. To achieve improvement for the characteristics in the breeding goal, animals must be identified, and a value (selection index) given to each animal indicating their ability to improve the desired characteristics. Those animals fitting the breeding goal best are preferred when producing the next generation. This is called “selection”. The performance of an animal (phenotype) is a mixture of its genetic make up (genotype) and of the environment. Animals are selected according to their phenotype (mass selection), estimated genotype (index selection) or measured genotype (Marker Assisted Selection). Only heritable traits can be selected for.

An animal does not necessarily have to express the trait one wants to select for. This is the case for sex limited traits like milk production. Males can carry excellent genes for milk production and one can measure the genetic value through the daughters or directly in the genes of the animal itself.

Furthermore in poultry and pigs, dam and sire lines are selected separately for reproduction traits and for production traits. These lines are then crossed to achieve the benefits of both, and to benefit from heterosis in the form of vitality and production. Heterosis is the improved performance of offspring gained by crossing unrelated populations.

Reproduction. Reproduction is simply the ability of an animal to produce offspring. This is not always an easy process, e.g. zoos sometimes have to try hard to get some of the animals reproduce. Farmers and breeding organisations are involved in various phases of the reproductive process such as identification of optimum time of insemination, health status of the reproductive organs, semen production and conservation, embryo transfer and ovum pick up. Control of reproduction enables a more optimal distribution of breeding stock to distant farmers. It also is an important tool in disease prevention. A certified artificial insemination station does not spread disease as easily as a natural mating male going from farm to farm. Furthermore, semen and embryo conservation can be important tools in the conservation of biodiversity.

The size of the farm animal reproduction and selection sector is small. Despite this, its impact on livestock production is high because genetic improvement is permanent (improvements are genetically determined), cumulative (every effort is built upon the improvement reached in the previous generation), and disseminated widely through the production chain. For that reason a discussion about farm animal breeding and breeding developments is a discussion about the kind of animals that are or will be used in livestock production.

<u>History and state of the art in farm animal breeding</u>

Today's farm animal breeds originate from a few wild species. The domestication of most of the farm animals took place millennia ago (Zeuner, 1963). At first, only animals which were easy to handle, easy to reproduce and which survived the winter period were actually used for breeding, thus domesticating the animal. It took until the 19th century before the first official herd books and breed societies appeared in cattle, sheep and pigs. They registered family records and/or production information. Early selection procedures were based on individual performance only. Later, selection was carried out by using family information to determine differences between non-heritable management and heritable animal effects on the performance of an individual animal (Van Vleck, 1993). Own performance and family information were combined in indexes enabling the selection of top animals, best fitted for the breeding goal. Improved availability of computers and improved statistical methods allow much more accuracy and allow more traits to be included in the selection index.

In poultry, extensive family records are kept of the low heritable reproductive traits such as egg numbers, egg size and hatchability. For growth and conformation characteristics, which are more highly heritable, the techniques in poultry breeding are based on mass selection on phenotypic characteristics. Poultry and pig breeding programmes work with several unrelated lines to select for a number of traits, in the end crossing these (two or three) breeds for the extra vitality and performance of the heterosis effect.

Although fish farming has been practised for more than 4000 years, fish breeding programmes are still at the initial phase, and in some breeds no selection takes place. Most of the genetic improvement in fish is based on mass selection without pedigree information. In several countries selection programmes incorporating genetic information are in place, enabling selection for several traits or traits that need to be collected from families (quality traits, disease resistance). Fish hybridise naturally in the wild (carps, salmonids, sturgeons). Hybrid fish can be created by farmers, e.g. fish resistant to certain diseases. Oysters and molluscs are mainly coming from wild spats collected form natural spawns. Hatcheries use wild breeders without a breeding programme.

Recently, the first DNA tests in farm animals to detect genetic defects have been developed (Lenstra, 1999). The best known single gene is the one for stress susceptibility in pigs, causing sudden death if the animal is stressed (Ollivier *et al.*, 1975). A DNA test is available to detect this

defective allele and to avoid the use of animals carrying it as reproducers.
The breeding goal of farm animals has changed over the years. Many cattle breeds were originally dual purpose, used for milk and meat production and occasionally draught purposes. Even now a lot of breeds are dual purpose breeds, combining relatively high milk production with good meat production thus providing significant extra revenue for the farmers. Beef recording and specialisation into beef breeds has mainly developed in the last 40 years – starting in the 1960s with weight recording on farm, later followed by performance testing in test stations allowing direct comparison of animals. Breeding goals in pigs in the early 1900s was also dual purpose (litter size and growth) and based on phenotype. Pig breeding was almost entirely pure breeding until 1960. In the late 1980s, improved computing technologies and statistical methods allowed to select for traits with a low heritability, followed by further specialisation into sire and dam lines. Before the 2nd World War all poultry breeds were dual purpose as well. The females would be used for table egg production and the males were grown for meat consumption. Other species of poultry such as turkeys and ducks had no organised breeding programme. After 1945, in the USA, breeding programmes were developed, with specialised lines and breeds for table egg chicken (layers) and meat chicken (broilers) instead of dual purpose chicken. At a later date, also breeding programmes for turkeys and ducks emerged.
Furthermore, the possibility of incorporating more traits into selection programmes did change the breeding goal from purely aiming at production towards the incorporation of health, reproduction and behavioural characteristics. There are differences in Europe between the breeding goals of companies and between regions. For instance Scandinavian countries have routinely recorded health and functional traits like mastitis and fertility in their system (Interbull Bulletin n.13). Some poultry firms, starting from having only production characteristics like carcass quality in the breeding goal, have moved towards incorporating taste and health, and later also welfare in the breeding goals as well.
In cattle, artificial insemination is used in most of the cases. Non-surgical embryo transplantation is possible, but is mainly used for highly valuable animals because it is a relatively costly procedure. In goats and sheep artificial insemination is not common practice, because semen cannot be frozen easily and fertility, after thawing and insemination, is still not acceptable (Barillet, 1997). The reproduction period of sheep and goats is usually seasonal. Oestrus synchronisation is practised occasionally. The exchange of genetic material in pigs is mainly by fresh semen, since frozen semen technology in pigs is still underdeveloped (Meredith, 1995). Non surgical embryo transfer might be available for commercial use in one or two years. In poultry breeding, mainly artificial insemination is used nowadays (Surai & Wishart, 1996). Eggs can be transported world wide, thus enabling the use of breeding eggs from the USA or Europe in e.g. the Far East. In most fish, the season of spawning can be managed with control of e.g. light or thermo-period. Most fish species ovulate or give semen by gently stripping of the flanks. In marine species hormonal synchronisation is the only possibility to get ova and semen. Freezing semen is possible, but mainly practised for conservation purposes. Embryonic eggs can be transported,

and disinfected to prevent disease risks.
A more detailed description of breeding technologies and developments in research is provided in Appendix 1.

Factors influencing the future of farm animal breeding

An exercise is made to determine which factors most probably will influence and determine the farm animal breeding of tomorrow in Europe. The implication of consumers, legal climate and bio ethics on breeding will be worked out by the other partners. The main scientific, technological, and economical factors are described below.

Sustainability. Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs (Brundtland, 1987). Sustainable agriculture aims at production systems that can provide man with food in a balanced way. European animal production is characterised by no use of additional hormones nor growth promoters. Many by-products from human food industry (e.g. soybean and citrus extractions) find their way in animal feed. A lot of farms are family farms, and an active part of their local rural environment. Compared with other continents, in Europe there is more concern about animal welfare and sustainable production. Breeding can be directed towards animals having the ability to digest by-products in a better way, to use feed more efficiently, or to produce in extensive environments. The art will be to find the right balance between animal production, animal welfare, environment, product quality and consumer price.

Structure of farms. The size of farms is expected to grow continuously. In the first place the profit per animal decreases year after year. Consumer prices tend to get lower. Production costs increase. The result will be increased production per hectare, per litter, per animal. Also automation, hygiene regulations and a controlled food chain may force small farmers to give up business, because the investments needed are too high. On the other hand, high quota prices (Europe, Canada) keep farm sizes from expanding. European (cattle) farmers, but also Canadian poultry and dairy farmers currently protected by import barriers and subsidies, will have to adapt to world market prices. Farms where the farmer lives near the farm will disappear more and more. In the USA farms with one million pigs or a hundred thousand beef cows already exist. Exceptions will occur for farmers producing for niche markets or in a special production system (e.g. organic) who will be able to get a higher return per animal. However, with the increase of organic production prices tend to go down because of the power of the intermediates that buy and sell the products. More and more primary producers will have less control on the marketing of their products.

Global markets/international developments. A great deal of breeding knowledge and a number of international breeding companies are situated in Northern Europe and North America. Farm animal breeding will globalise more in the future, especially in cattle and pigs, while poultry breeding is already organised globally. The push for borderless organisation will not come from the scientific communities, but from breeding companies that need to stimulate the development of international genetic programmes in order to finance the necessary investments in software development (Lohuis, 1999) and DNA technology.

Structure of animal breeding. The structure of breeding companies differs between species, mainly due to the biology of the species. In ruminants there is mainly an open structure, in which a proportion of the day to day producing female animals can become future breeding animals. Dairy bulls are even compared world-wide by the International Bull Evaluation Board (INTERBULL) and frozen bull semen is traded globally. In poultry all the breeding work can be done in house and a few companies can and do provide the world with breeding stock. Pig breeding is in an intermediate situation. In aquaculture breeding is at the very start of developments, but in a few decennia a few breeding companies may provide the world with breeding fish. In the future cattle breeding companies may merge to form fewer world-wide operating companies, providing farmers with semen and embryos. Furthermore, in cattle breeding nucleus herds, and maybe hybrid lines, will become part of the picture. The number of pig and poultry breeding companies may reduce further and their size increase. Alongside that there may be smaller companies serving niche markets in cattle, pig, poultry and aquaculture breeding.

Computing and handling data. Handling information is very important in animal breeding. More sophisticated hardware and software will improve these possibilities. ‘On farm data’ can be sent electronically to any estimation company . The improved computing capacity makes it possible to analyse all these data together. For example pig breeding companies will increase involvement of the farmers by using on-farm data for the genetic evaluation and reproductive management of breeding animals. Specially designed or adapted breeding programmes can prevent small breeds from having too much inbreeding and at the same time the maximum genetic improvement (Gandina & Oldenbroek, 1999; Meuwissen, 1999).

Biotechnologies. New technologies are DNA technologies from Marker Assisted Selection to transgenesis, and reproduction technologies like gamete sexing, embryotechnologies or cloning. Some DNA tests or embryotechnology in cattle are already applied. Others are under research and could be used in the near or more distant future. Marker Assisted Selection could be used to detect genes for genetic disorders (Hoeschele & Meinert, 1990; Georges *et al.*, 1993), disease resistance, product quality (Andersson *et al.*, 1994; Georges *et al.*, 1995; Ashwell *et al.*, 1997) or other traits of interest. Transgenic animals would have a special feature, e.g. in New Zealand there are plans to set up a flock of genetically modified cows producing milk that is similar to human breast milk. Cloned animals could be used to determine the genetic component of important traits, or to disseminate valuable production animals from top breeding population to production populations more quickly. Technologies can only be applied if their use is economically viable. Furthermore, the question is whether public opinion and consumer purchases would favour the application of new technologies.

The development of new technologies and the high cost involved in research, may force the market players legally to protect their research efforts by means of patents or to use trademarks in order to get a return for the research efforts. The possibility of their legal protection may introduce exclusive rights for certain applications and thus influence the structure of breeding and the technologies applied by the several market players. Furthermore, the need to fund research that is too expensive for one market player may stimulate companies to become partners in research or to amalgate their companies.

Biodiversity. Breeding companies rely, for their selection possibilities, on the genetic diversity that is available in the species/the populations they work with. It is only possible to select for a certain trait, if the animals you select from show variation for this trait. Breeding companies carefully take care of the variation within their breeding stock. It is part of their breeding policy to maintain the available genetic variation, to maintain a 'zoo of special animals or species' and to keep an eye on the extremes of the genetic horizon. However, the genetic make-up of the breeding animals is not known, only estimated via performance measurements of the animals and their relatives. In general, information is available about traits that are taken into consideration. Although more traits are incorporated in the breeding goal than a few decennia ago, there can be genes or gene combinations for traits that are presently unimportant or that we are not aware of yet. Loss of genetic material can take place invisibly, as the role and exchange of genetic material between populations, selection and crossing take place gradually. For instance, it is not known what exactly is the definition of European lines and breeds, e.g. German and Dutch Landrace. Knowledge about their real genetic distance (Nei, 1987; Eding & Laval, 1999) and relationships is insufficient. Research on the consequences of 'invisible loss' through genetic drift, selection or crossing could give a better picture of this.

Breeding often concentrates on a few breeds per species. Also, 'popular' breeds like the Holstein Friesian cattle get mixed with local breeds world wide. The consequences for biodiversity of farm animals need further consideration (Farm Animal Industrial Platform, 1998).

Animal genetic improvement and conservation of genetic diversity need and use the same tools and technologies (data analysis, reproductive technologies). Co-ordination at the European level of efforts undertaken in different countries is necessary.

Future models of farm animal production systems

Global market, technological, biotechnological, animal welfare, management, political, economical, legal and societal developments may force animal production systems to change. In order to be able to consider new evolutions with care, and to have future pathways for discussion, three models are worked out in this section.

Partly they represent an extrapolation of today’s reality into the future as, currently, diversification of breeding is already part of the reality in Europe. Different organisations, different countries or different farming systems work with their own breeding goals. Several models can be applied in one country or within one organisation, each serving part of the market. The drive behind the differentiation is historically determined, following market demands and/or motivation comes from pressure for animal welfare and other societal demands.

In the first model (*conventional path*) farm animal breeding and production develop further

towards a system similar to the current one. There is no need to change the actual animal production system, mainly taking place at family farms.
In the second model (*modified path*) the emphasis is on welfare, disease resistance, environment (pollution), niche markets, organic products, regional and special products. Consumers with differentiated demands for food and societal needs are the main drive behind this scenario.
The drive behind the third model (*low cost path*) is the demand of consumers for cheap and safe products in a global competitive market.
In all models the quality of products must be good. The first and third models are targeted on economic characteristics taking into account certain thresholds for e.g. mortality, welfare etc.
In general a breeding goal is determined by economic motives of farmers, mainly based on market and economy. Next to this, political or societal conditions may determine the breeding goal.
Animal breeding is associated with reproductive technologies, like Artificial Insemination (AI) and Embryo Technology (ET) and with DNA technologies, like Marker Assisted Selection (MAS). Although in principle newly developed techniques (Ovum Pick Up, cloning, transgenesis) could be used to achieve the different goals described in all models, their application may be less likely or would have to be adapted, in order to meet public demand or to reach the breeding goal faster in a specific model. Table 1 and Table 2 represent today's perception that traditional aspects and technologies will be used in the several models.

Table 1. Today's perception that traditional aspects may be used in the conventional, modified or low cost path

Traditional aspects	**Conventional path**	**Modified path**	**Low cost path**
Decrease production costs	++	+/-	++++
Increase uniformity in breeds/goals	+	---	++++
Balanced breeding	++	++++	+

++++ used routinely, +++ likely to be applied, ++ will probably be applied, + may be applied, +/- may (not) be applied, - not likely to be applied, -- very unlikely to be applied

Table 2. Today's perception that technologies may be used in the conventional, modified or low cost path

Technologies	**Conventional path**	**Modified path**	**Low cost path**
Marker Assisted Selection	+++	+++	++++
Artificial Insemination and Embryo Technologies	+++	++	++++
Transgenesis	-	--	++
Monosexing (fish)	++	-	+++
Triploïdy (fish)	+	+/-	+++
Cloning	+/-	--	+++

++++ used routinely, +++ likely to be applied, ++ will probably be applied, + may be applied, +/- may (not) be applied, - not likely to be applied, -- very unlikely to be applied

1. Conventional path

In the actual production system, mainly taking place on family farms, the breeding goal aims at improved efficiency of animal production in order to provide consumers with high quality animal products (milk, eggs, meat) at a reasonable cost price. In the conventional path, more genetic information on functional traits would be considered in the breeding goal because of factors limiting increase of production, e.g. milk quotas, and the awareness that genetic improvement for high production efficiency may produce undesirable side effects (Rauw *et al.,* 1998). There would be more emphasis on quality traits and disease resistance, to increase food quality and food safety. International competition would be likely to favour those companies that provide breeding stock that will improve general animal efficiency and/or deliver improved products.
Technologies available today like Artificial Insemination, and Embryo Technologies would also be used in the management of populations in the conventional path. Developments in research would enable the use of Artificial Insemination routinely in all species and Embryo Technologies in all farmed mammals. The development and use of new biotechnologies would not be seen as a primary need to achieve more quickly breeding goals.

<u>Description of conventional path in cattle, sheep, goats, pigs, poultry and aquaculture.</u> As high producing cows may exhibit lower fertility, some metabolic disorders, and some health problems, the breeding goals in milk cattle would incorporate, next to milk production and body structure, issues related to health, metabolism, non productive traits, and longevity (Groen *et al.*, 1997). The quota system which does not allow farmers to increase their production, and thus stimulate more efficient and profitable production, would favour selection for traits other than production in order

to decrease the costs of production and increase the farmers' income although production will remain the main selection criterium. DNA tests would be available to detect animals carrying genetically transmittable diseases or genes improving better milk quality, e.g. k-casein (Lenstra, 1999). The aim in beef cattle and meat sheep would be to produce more meat in less time, with the minimum amount of feed, and with the best possible reproductive rate. Characteristics considered in the breeding objective would be mainly growth, carcass, and reproductive traits. Traits like meat quality that are now only measurable on slaughtered animals would be measured on live animals due to improved technologies. The double muscle would be present in some beef breeds, although double muscle causes mainly caesarians in e.g. the Belgian Blue. (Hanset, 1996). DNA tests on the myostatine gene (beef) (Ott, 1990; Grobet *et al.,* 1997; Masabanda *et al.*, 1998) or the Callipyge gene (less fat and more muscles in meat sheep) (Cocket *et al.*, 1993) would assist further selection. Milk composition and milkability, udder traits, and prolificity could be included in the breeding goal of milk sheep and goats next to milk production traits.

In pigs, selection would be aimed at strong, efficient, and high producing animals. To achieve this, selection criteria would be further differentiated between males and females lines, to take advantage of extra productivity and vitality due to the heterosis effect. Special crosses would be developed for specific housing systems. Information of the individual farms would be used to decide which families within the population contain valuable genetic characteristics and which do not. DNA tests would be available to detect deviant alleles.

The selection of poultry for table eggs (layers) would mainly aim at larger numbers of eggs per hen housed, optimum egg weight, efficient feed conversion, and improved egg quality. Demand for eggs from non cage-systems would change the layers farming system, especially in Northern Europe.

In broilers, turkeys and ducks (poultry meat production) there would be continued selection for growth rate, feed conversion, eviscerated yield and breastmeat yield. The improvements in growth and yield characteristics would be achieved with increasing emphasis on quality and fitness traits through improved population structure, statistical methods and selection technologies. Examples of improved selection technologies include real-time X-ray technology to improve assessment of skeletal quality. Also other than production traits, e.g. skeletal quality, heart and lung function, disease resistance and other traits related to fitness or welfare would be incorporated in the breeding goal. Broiler breeding has used marker-assisted selection for many years in the form of serological determinants of resistance to Mareks Disease virus. Other markers could be used to improve disease resistance.

Currently selection in aquaculture has taken place for less than six generations in salmonids and two generations in marine species. No selection of breeders is recorded in molluscs. Breeding programmes would initiate selection for quality traits to decrease fat content in the muscle, improve yields at harvesting, and decrease the variation of the repartition of the lipids in the filet that causes variation of smoking success and the taste of smoke and salt. Furthermore, the development of lean strains could improve feed efficiency and decrease waste. This improvement could be extended to new lines and other species.

2. Modified path

The production system, and consequently the breeding goal, would aim at moderate production levels, specific products (niche markets, organic products, regional products), health and welfare of the animals, environment and improved feed efficiency. The breeding goal would be towards balanced breeding, avoiding possible negative effects of breeding for production on other biological traits, e.g. mobility, reproduction, disease resistance. Not all technologies available today would be used to allow a product to be advertised and marketed with certain characteristics, e.g. organic products. Specific technologies or recently developed biotechnologies would be an exception. They could be used when there would be a strong need to reach a specific breeding objective. Examples could be the use of Embryo Transplantation and Embryo Sexing to ensure the survival and development of small and endangered breeds, the use of Artificial Insemination and Embryo Transfer, allowing the dissemination of genetic material free of diseases, or the use of Marker Assisted Selection to improve longevity, feather pecking, stress resistance, or a desired animal behaviour characteristic.

Three possible production systems are described:

a) <u>Animal Welfare</u> Non productive traits that can improve animal welfare would be emphasized in the breeding objective. Selection for increased production has also increased the danger that the homeostatic balance of animals gets affected. In a literature study Rauw *et al.* (1998) have presented over a 100 references of undesirable side effects of selection for high production efficiency for broilers, pigs and dairy cattle. High productive animals seem to be more at risk for behavioural, physiological and immunological problems. When selection and farming is aimed at higher production, the individual resources would be used mostly for production, and less for other demands, and the buffer capacity of the animals could be affected (Resource Allocation Theory, Beilharz *et al.*, 1993). Reducing emphasis on production would accelerate genetic improvement for non-productive functional traits. If the economic benefit of “welfare traits” does not overcome the decreased revenue due to limited improvement in production, consumers may be ready to pay for the animal welfare through the higher prices of products.

b) <u>Link region-breed-product / niche markets</u> Products of high quality and limited in quantity represent the typical production in different geographical areas. Usually these products are part of the local culture. Breeding objectives should be addressed to maintain breeds and production systems that guarantee the variety of local food (Gandini & Giacomelli, 1997). Associations between region of production and breed or particular product (cheese, meat) could increase the value of the production, especially in areas where intensive farming cannot take place. The farming system could be addressed to maintain a balance between production and environment, by subscribing a maximum amount of animals of a breed on a specific extension in order to produce a limited amount of product, guaranteeing a good price to the farmers. Moreover, the presence of farmers is important for land conservation in areas otherwise destined to be

abandoned.
c) Organic products The demand for organic products is rising. The definition of organic products could lead to the application of particular breeding objectives. It will depend on the final EC regulation on organic production concerning what will be allowed or forbidden, and which technologies can be applied.

Description of modified path in cattle, sheep, goats, pigs, poultry and aquaculture. Next to the selection criteria mentioned in the conventional path, other reasons would be brought forward to change breeding goals and to consider alternative traits on top of the production criterion. Traits, like longevity, calving ease, udder health, somatic cell counts, control of mastitis, fertility, would be weighted heavier in the breeding goals in dairy cattle than would be the case in conventional breeding. For example, instead of obtaining a genetic improvement of 100 kg a year for milk production with no benefit for other characteristics, one could decide to improve milk production only 50 kg and reduce in the meantime health problems and metabolic disorders. Another example comes from beef cattle. Here the selection criterion could be to avoid the use of animals carrying the double muscle characteristic as reproducers to increase calving ease. Furthermore, selection could be aimed at animals able to adapt to difficult environments and able to produce a live healthy new-born calf each year. Some examples of regional products, produced by local breeds are the Fontina from the Aosta Red Pie and the Reblochon cheese from the Abbondance breeds. Niche markets could request particular products, as is the case for the “Parmigiano Reggiano delle Vacche Rosse” made from the milk of the Reggiana cattle breed, today counting only 1000 head (51,000 in 1955). Multiple Ovulation and Embryo Transfer (MOET) could improve selection schemes in breeds limited in size but with an economic importance (niche markets) and help their maintenance and their survival.
In the modified model for pigs wishes from society would be integrated in a rural production system with medium sized isolated family farms, evenly spread over the country, with high healthy animals. The breeding goal would aim at animal friendly production, possibility for display of natural behaviour, and residue free pork, incorporating traits like litter size, piglet survival, mothering abilities, ease of growing and lack of fat accretion. Farmers could combine these estimates in a personal index. In this way uniformity within a farm could increase, while at the same moment genetic variation between farms could be maintained. Import of new genetic material would be by means of semen or embryos because of the limitation of disease risk. There would be niche markets with local breeds or regional products (e.g. Iberian ham). Single gene technology could help to assess the presence of deleterious alleles, responsible for among others congenital disorders like atresia ani and tremor piglets.
Poultry breeders for table egg chicken (layers) would respond to customer preferences for eggs from non-cage systems in having a slower genetic progress for conventional traits and extra emphasis on behaviour traits and liveability in order to decrease the tendency towards feather pecking and/or cannibalism, and to minimise the incidence of floor eggs i.e. eggs not laid in a

nest. There is some evidence that selection against undesirable behaviour could be effective. Breeding programmes could be developed for certain niche markets. The further development of the egg products market may require selection for the egg components.
Poultry meat breeding programmes (broilers, turkeys, ducks) would emphasise the quality and welfare of individual birds, skeletal quality, and improved heart and lung function, next to continued selection on meat production and feed efficiency. Although some progress has been made in improving disease resistance, new technologies could accelerate this and make further improvements to bird welfare. Breeding programmes could be developed for certain niche markets, e.g. a particular type of broiler based on specific requirements such as colour, regional breed, organic production system etc. There is a growing niche market for Bronze and Black feathered turkeys. Slow growing turkey breeds with an increased subcutaneous fat content over the breast represent a market for traditional farmed Christmas turkeys.
In fishes and molluscs, the development of resistant strains could be one of the solutions to avoid diseases in open farming conditions, limiting the use of drugs and increasing product safety. Furthermore, specialised breeding lines would be developed for fish species not yet farmed (halibut, char, cod, sole, pagrus, sar, pageot, ombrine, perch, catfish), in order to provide consumers with a high diversity of products. Some have potentially very high growth rates (thunnus, seriola). Others originate from other geographic areas in Japan, Chile, South America, Asia or Australia.

3. Low cost path

In the low cost path the goal would be to provide safe food at the lowest production costs. New methodologies to reach the objective of improved production efficiency would be explored and expensive research funded. Economic interest would be the pushing drive to use the most effective technologies available. Biotechnologies like cloning or transgenesis would most likely find their way here. Their application would mainly be related to ensure higher production at lower cost. This path is expected to be followed by producers at the global market: USA, South East Asia, South America, Canada, and maybe Europe. It can affect a large part of the food supply and may be of great interest to public opinion.

<u>Description of low cost path in cattle, sheep, goats, pigs, poultry and aquaculture</u>. In cattle, sheep and goats all breeding objectives would be aimed at reducing the cost of production. The cost/benefit ratio would determine which technologies and production systems could be used. Intensive farming would be the main instrument of production. In beef cattle there would be selection for double muscle. In sheep the Boorola gene to produce more offspring per delivery would be used.
In pig farming, family farms would gradually or rapidly be replaced by industrial farms, large well organised farms with very low labour input per animal. The selection for this environment would be on strong animals with a very good and adaptive digestive tract able to grow and farrow with

little human intervention. Pig families with easy farrowing and good interaction between sow and piglets would be best adapted to this environment, even if litter size would be a little lower than usual in the conventional path. Uniformity in start of oestrus, in size of animals, in birth weight and quality of piglets etc. would be very important. A reduction in on farm variation would inevitably mean a reduction in genetic variation. Large farms grow large numbers of animals close together, causing increased disease risks. In large populations it is easier for pathogens to survive, making subdivisions within farms necessary or selection for animals with higher resistance.
The breeding goal for poultry table egg production (layers) would be for low cost safe production systems, although the rates of progress for egg mass and feed conversion are expected to be lower in poultry, due to approaching biological limitations. Genes or genetic markers for desirable behavioural or disease resistance may be found and applied. When more cost-effective screening methods could be found, transgenic animals would also contribute to the genetic progress.
Genetic progress in poultry for meat production would be mainly aimed at growth rate, feed conversion, eviscerated yield and breastmeat yield in a cost-effective production system. Progress would be accelerated if marker genes or the trait genes themselves are identified. A fuller knowledge of Quantitative Trait Loci (QTL) affecting disease resistance would allow more accurate estimation of breeding values for such traits. Since pathogens evolve faster than the domesticated populations, it is vital that the new technologies do not narrow the genetic resource.
The genetic variability of all the traits in fish is 2 to 3 times higher than in the livestock species as fish species are still wild species. This means that an important potential of genetic progress exists. The benefit of the increase of the return rate of investment per kilogram produced and the decrease of the cost of raising would rapidly decrease the cost of the products. For example, Atlantic salmon costs have decreased from 12 US $ per kilo in the 1980s to 3 to 4 US $ per kilo in 1998. The part due to the genetic progress is still difficult to estimate as very few estimations have been published, but it could be expected that this cost would continue to decrease in the next decades. Furthermore, monosexing or triploïdy could be induced by external factors, e.g. temperature. Monosexing fish would allow fish of commercial size without hormonal treatment. Triploïdy, already present in the wild and giving sterile animals, would prevent selected fish from reproducing in the wild.

Discussion

This article has given an insight into the mechanisms and structure of breeding, in order to enable society to understand and direct livestock breeding and production. It has outlined which technological, economical and global factors will most probably influence the future of breeding and the animals used in livestock production. The future developments in production systems would differ according to species mainly because of biological differences. Nevertheless, many examples carried out previously for a particular case could be extended to different species or productions. For example feed conversion efficiency in all the species and production systems reduces the necessary amount of arable land.

The scenarios mentioned are model scenarios, meant to facilitate a discussion on the future of breeding. Differences between countries, farmers and breeding companies have resulted in a variety of breeding goals and practices. The conventional, modified and low cost model can therefore also be seen as an extrapolation of today's reality into the future. The overall picture of future possibilities - moderate, alternative or just convenient for the consumer - gives an idea of the choices that can be made (Figure 1).

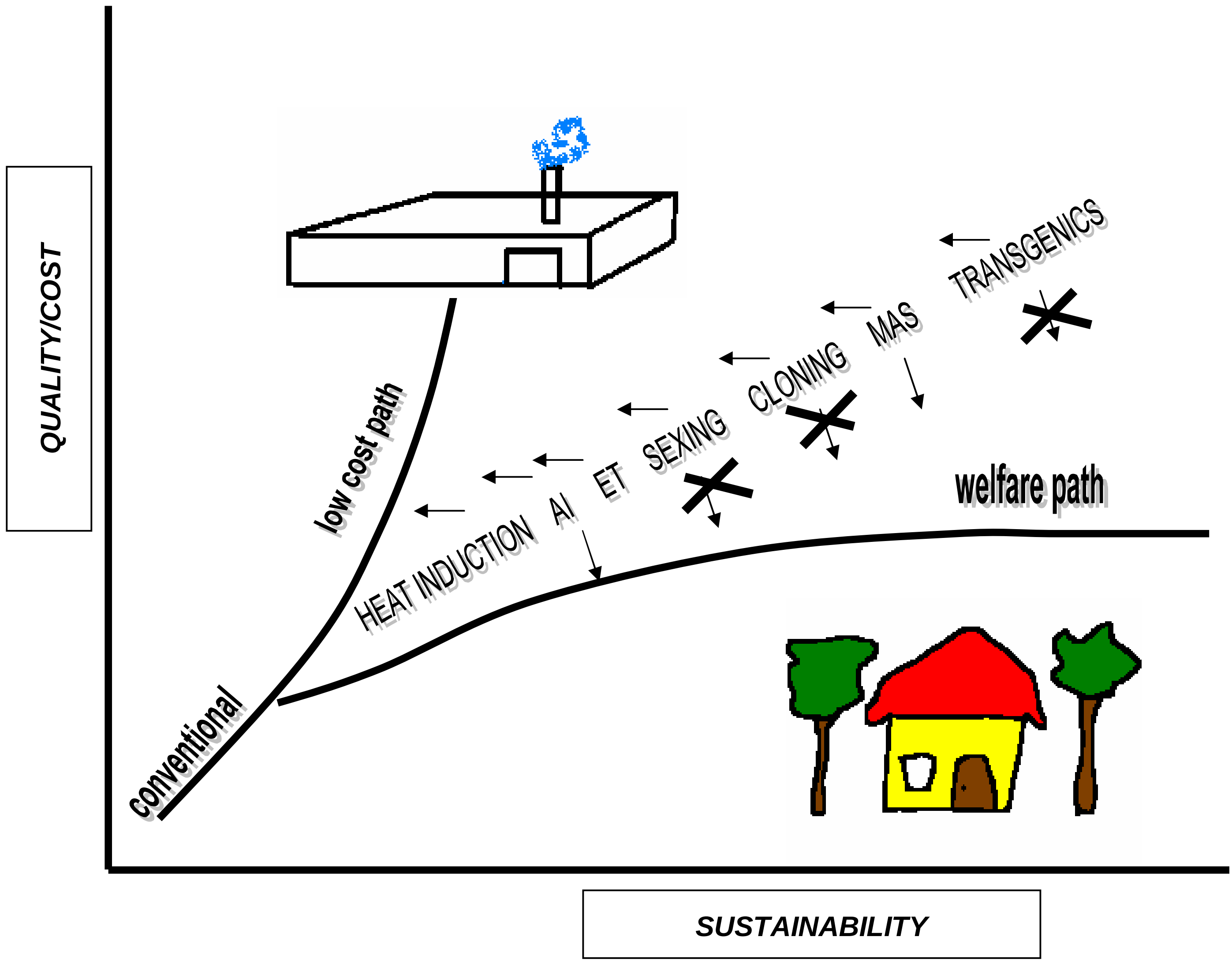


Figure 1. The overall picture of possibilities – moderate, alternative or just convenient for the consumer – gives an idea of the choices that can be made

Directly livestock production and thus animal breeding are influenced by the consumer purchases. This is the most powerful way of influencing the way food is produced. Any discussion to influence decisions in selection programmes and farming systems should address the consumer needs and the public desire, bearing in mind that

a) changes in breeding goals will not give results now but in five or ten years or more from now. In setting breeding goals, the consumer and societal wishes of a future that lays a decade or more ahead need to be predicted,
b) the actual economical system is moving towards market globalisation, and
c) not everything can be reached by breeding. Breeding is a tool that can be used alongside other management tools. Genetic improvement is a part of the production chain, dealing with the choice of the parents of the next generation, and with the production of this generation. The farming system and the technologies involved (the environment) play the other large role in animal production. Even for characters with a very high heritability of 40 %, 60 % of the eventual expression for this character would still be determined by factors in the environment.

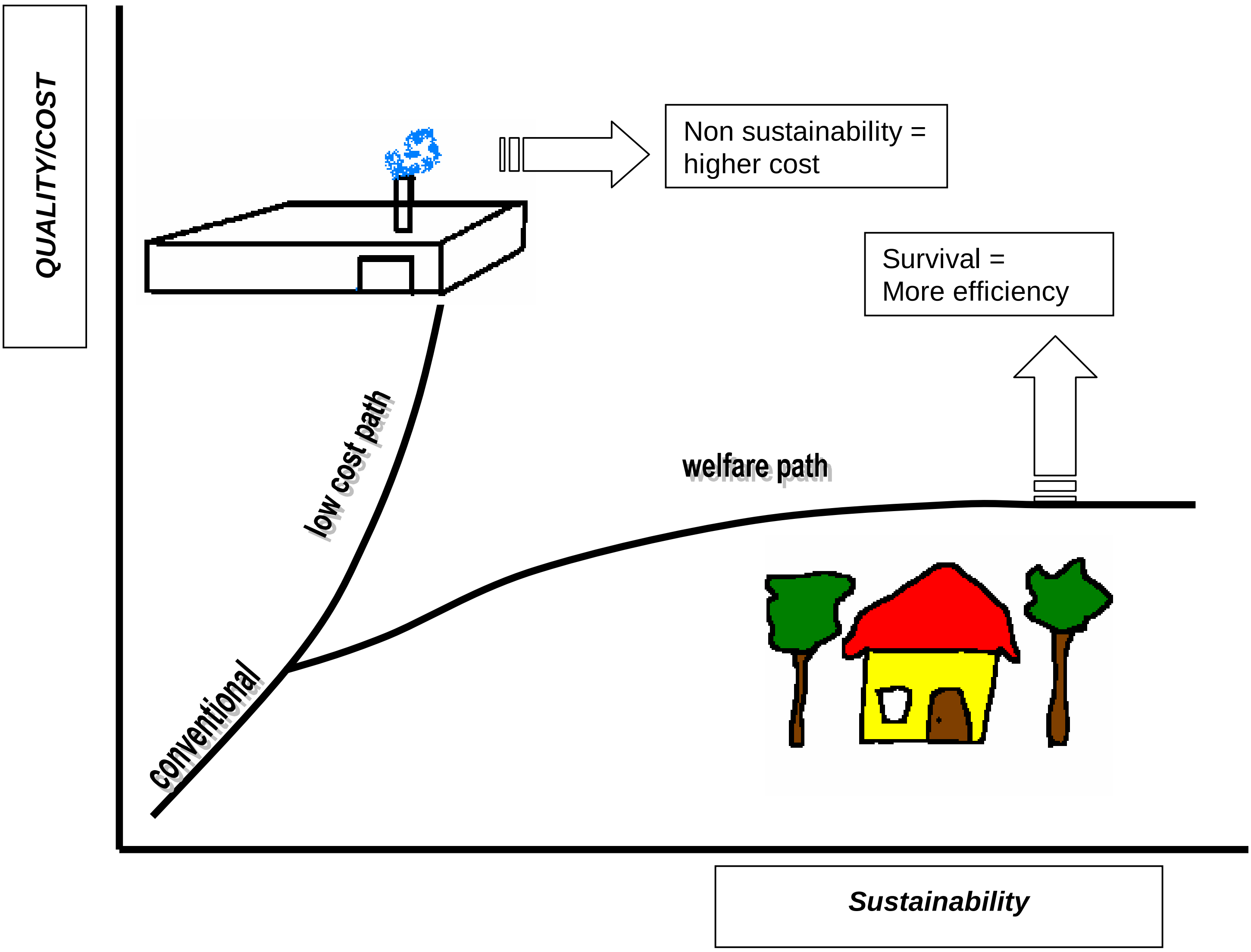


Figure 2. The ideas and experience in the modified path can be used by the farmers in the low cost path and vice versa

The future reality could fit into the pre-described conventional, modified or low-cost path, but it could also present a variety of the different production systems. There is no clear answer to what should be the future scenario. They could co-exist and the one could benefit from the other. The ideas and experience in the modified path could be used by the farmers in the low cost path and vice versa (Figure 2). Also in the future, the wish to express cultural differences in Europe could lead to different farming systems. Part of the differences might be due to different levels of acceptance of technologies involved in the production system or different perceptions of quality and price. Furthermore, consumers may want to have a freedom of choice in their purchases.
In order to be able to adapt to the wishes of society, it will be important to know what society really wants. How much would one be willing to pay in terms of money, sustainability, or land that could not be used for leasure, nature or tourism if it should be used for more extensive production? What could be the value of food labelling and trademarks for production systems? How important is the right to have local and cultural differences in Europe? What would Europe be willing to pay in WHO negotiations in terms of trade barriers? Hopefully the scenarios can initiate a fruitful discussion on the future of farm animal breeding in which users and producers weigh the possibilities and price of the different breeding goals, using all or part of the available technologies, and representing different production systems.

References

Andersson L., Haley C.S., Ellegren H., Knott S.A., Johansson M., Andersson K., Andersson-Eklund L., Edfors-Lilja I., Fredholm M., Hansson I., Håkansson J., Lundström K. (1994) – Genetic mapping of quantitative trait loci for growth and fatness in pigs – Science, 263: 1771-1774.

Ashwell M.S., Rexroad C.E. Jr; Miller R.H., Van Raden P.M., Da Y. (1997) - Detection of loci affecting milk production and health traits in an elite US Holstein population using microsatellite markers- Animal Genetics, 28: 216-222.

Barillet F. (1997) - Genetic of milk production-In: “The genetics of sheep” ed. Piper L. & Ruvinsky A. 611 pp.

Beilharz R.G., Luxford B.G., Wilkinson J.L. (1993) – Quantitative genetics and evolution: Is our understanding of genetics sufficient to explain evolution? J. Anim. Breed. Gen. 110, 161-170.

Brundtland G.H. (1987) - Our Common Future. Oxford University Press.

Cockett N.E., Jackson S.P. Shay T.L., Nielsen D., Moore S.S. Steele M.R., Berendise W., Greene R.D., Georges M. (1993) – Chromosomal localisation of the *Callipyge* gene in sheep (*Ovis aries*) using bovine DNA markers. Proceedings of the National Academy of Sciences USA 91, 3019-3023.

Eding J.H., Laval G. (1999) – Measuring genetique uniqueness in livestock - In :”Genebanks and the conservation of farm animal genetic resources” ed. Oldenbroek 119 pp.

Farm Animal Industrial Platform (1998) – Biodiversity of Farm Animals 4 pp.

Gandini G.C., Giacomelli P. (1997) – What economic value for local livestock breeds? –

48th Annual Meeting of EAAP.

Gandini G.C., Oldenbroek J.K (1999) –Choosing the conservation strategy- In :"Genebanks and the conservation of farm animal genetic resources" ed. Oldenbroek. 119 pp.

Georges M., Dietz A.B., Mishra A., Nielsen D., Sargeant L. S., Sorensen A., Steele M.R., Zhao X., Leipold H., Womak J.E. (1993) – Microsatellite mapping of the gene causing weaver disease in cattle will allow the study of an associate quantitative trait loci – Proceedings of the National Academy of Sciences of the United States of America, 90 (3): 1058-1062.

Georges M., Nielsen D., Mackinnon M., Mishra A., Okimoto R., Pasquino A.T., Sargeant L. S., Sorensen A., Steele M.R., Zhao X., Womak J.E., Hoeshele I. (1995)- Mapping quantitative trait loci controlling milk production in dairy cattle by exploiting progeny testing- Genetics, 139: 907-920.

Grobet L, Martin L.J., Poncelet D., Pirottin D., Brouwers B., Riquet J., Schoeberlein A., Dunner S., Menissier F., Massabanda J., Fries R., Hanset R., Georges M. (1997) - A deletion in the bovine myostatin gene causes the double-muscled phenotype in cattle- Nature Genetics 17(1):71-74.

Groen A., Steine T., Colleau J.J., Pedersen J., Pribyl J., Renisch N. (1997) – Economic values in dairy cattle breeding, with special reference to functional traits- Report of EAAP- working group. Livestock Production Science, 49: 1-21.

Hanset R. (1996) – Animal Selection and Welfare. The Case of the Belgian Blue. 14pp.

Hoeshele I. , Meinert T.R. (1990) – Association of genetic defects with yield and type traits: The Weaver Locus Effect on Yield- Journal of Dairy Science, 73: 946-952.

Lenstra J.A. (1999) – DNA technology and animal husbandry: state of the art and perspectives – In: "Production diseases in farm animals" ed. Wensing Th. Proceedings of the 10th International Conference on Production Diseases in Farm Animals. Wageningen Press. 390 pp.

Lohuis M. M. (1999) - Dairy Breeding Research & Development Discussion Paper. Canadian Cattle Breeding Research Council. 33 pp.

Masabanda J., Pirottin D., Poncelet D., Grobet L., Georges M., Fries R. (1998): A cytogenetic map of the muscular hypertrophy (MH) region on bovine chromosome 2. Animal Genetics (1): 33 suppl. 1.

Meredith M.J. (1995) -Pig breeding and infertility- In: "Animal breeding and infertility" Ed. M.J. Meredith. 508 pp.

Meuwissen T.H.E. (1999) – Operation of conservation schemes- In :"Genebanks and the conservation of farm animal genetic resources" ed. Oldenbroek 119 pp.

Nei M. (1987) -Molecular Evolutionary Genetics- Columbia University Press, New York, 511 pp.

Ollivier L., Sellier P., Monin G. (1975) – Determinisme génétique du syndrome d'hyperthermie maligne chez le porc de Pietrain- Annales de Gènètique et de Sélection Animale 7: 159-166.

Ott RS (1990) - Muscular hypertrophy in beef cattle: déja vu.- J. Am. Vet. Med. Assoc. 196(3): 413-415.

Rauw W.M., Kanis E., Noordhuizen-Stassen E.N., Grommers F.J. (1998)- Undesiderable side effects of selection for high production efficiency in farm animals: a review- Livestock Production Science, 56: 15-33.

Surai P.F & Wishart G.J. (1996) - Poultry artificial insemination technology in the countries of former USSR- World's Poultry Science 52, 27-43.

Van Vleck L.D. (1993) – Selection index and introduction to mixed model methodsThe green book 481 pp.

Zeuner F.E. (1963) – A history of domestic animals- ed. Harper and Row, New York. 560 pp.

[1] Anne-Marie Neeteson, Jan Merks, Egbert Knol. Institute for Pig Genetics (IPG), P.O. Box 43, 6640 AA Beuningen, The Netherlands. Farm Animal Industrial Platform (FAIP), Benedendorpsweg 98, 6862 WL Oosterbeek, The Netherlands

[2] Alessandro Bagnato, Raffaella Finocchiaro. Istituto di Zootecnica, Veterinary Faculty, Università degli Studi di Milano, Via Celoria 10, 20133 Milan, Italy

[3] Cliff Nixey. British United Turkeys (BUT), Broughton, UK

[4] Pierrick Haffray. SYSAAF, Rennes, France

[5] Duncan Pullar. Meat and Livestock Commission (MLC), Milton Keynes, UK

This paper has been prepared in cooperation with the members of the Farm Animal Industrial Platform *(FAIP)*, represented by Ole Andersen, The Danish AI. Societies; Roland Aumüller, Zentralverband der Deutschen Schweineproduktion; Alessandro Bagnato, Semenitaly; Paul Bampton, UKMASCP; Ejner Boersting, Scanbrid; Peter Bradnock, Association of British Primary Breeders & Exporters; Caroline Brown, PIC; Luca Buttazzoni, ANAS; Philippe Chapaux, CIA Linalux; Pierre Cherel, France Hybrides; Nanke den Daas, Holland Genetics; Jean-Louis Donal, Hubbard-ISA; Bernard Eivers, The AI Cooperatives of Ireland; Dieter Flock, Lohmann Tierzucht; Ulla Gam Hansen, Federation of Danish Pig Breeders and Slaughterhouses; Magnus Haard, Svensk Avel; Rudolf Hahn, Claus Leiding, AI Neustadt a/d Aisch; Pierrick Haffray, Michel Reffay, SYSAAF; Barbara Harlizius, Arbeitsgemeinschaft Deutscher Rinderzüchter; Jarmo Juga, Finnish Animal Breeding Association; Egbert Knol, Ton van Erp, IPG; Sven Korsvoll, Norsk Laksaevl; Siem Korver, Euribrid; Joachim Krieter, Schaumann Besitz-Hülsenberg; Giovanna Lazzari, LTR/CIZ; Alain Malafosse, UNCEIA; Brian McGuirk, Genus; Jim McKay, Ross Breeders; Cliff Nixey, BUT; Marina Pelipenko, Selonda Aquaculture; Arne Ola Refsdal, Norsk Rodt Fe; Emilio Torlini, ELPZOO; Ronald van Giessen, Altapon; Frans van Sambeek, Hendrix Poultry Breeders; Chris Warkup, Meat and Livestock Commission.

Ethical Perspectives on Breeding and Biotechnology

Stine B. Christiansen[1] & Peter Sandøe[1]

Introduction

Modern genetics has had an incalculable impact on domestic animal breeding. We now possess powerful tools with which we can change animals and make farm animal production more efficient. However, some of the genetic alterations made in pursuit of breeding goals have had unintended negative side-effects on animal welfare and integrity. The fact that we are now aware of some of the potentially harmful consequences of genetic manipulation, and the fact that we are able to control these, places an ethical responsibility on us.

Despite their growing awareness of this responsibility, people today take quite different views about what is acceptable in farm animal breeding. The use of biotechnology within farm animal breeding and reproduction, e.g., gives rise to a range of ethical concerns and worries in many quarters (Rutgers *et al.*, 1996; Sandøe *et al.*, 1999). Others point to positive applications and an obligation not to dismiss these options (Thompson, 1993; Smidt, 1994; Seidel, 1998). It is therefore important to discuss what breeding goals and reproductive tools are acceptable. A good starting point for an ethical discussion regarding breeding and the use of biotechnology, then, would be an attempt to set out and understand what it is that people are concerned about. There are a number of different, complementary, ways of gaining such an understanding. One way, which is pursued in another part of the present project, is by means of surveys or interviews. In this paper the task is approached using a different method: we try to assess specialist opinion by reviewing recent papers and reports within agricultural bioethics.

The review is based on an automated literature search, covering material published since 1992, and in it the focus is on understanding rather than criticism. We think it is important, before engaging in a more critical form of discussion, to try to present the various viewpoints in a clear, unbiased manner, which allows one to see how the views contrast with each other. We begin by explaining briefly what we understand by the term “biotechnology” in relation to breeding. Then we present the various concerns, including some animal welfare problems which have been mentioned in the reviewed literature, consider cultural differences, and describe different ways of weighing the concerns against each other. Finally we discuss different ways of handling the concerns in practice.

Breeding and biotechnology

'Biotechnologies' can be defined as technologies intended to change the biological functioning of animals, plants or micro-organisms. Within animal production the aim may be to change: 1. What the animals take in - by giving them genetically modified feed and feed additives. 2. Existing animals - by giving them hormones and similar substances promoting growth, feed conversion, milk production and the like. 3. Future animals - using reproductive technologies and genetic modifications. The latter may not only improve the efficiency of selective breeding, it may also present options that would otherwise not be possible. In the following, the focus is on the use of reproductive technologies and genetic modification to change future animals.

The oldest and least technical method of producing desirable characteristics in future generations of animals is *selective breeding.* This has developed rapidly during this century by means of modern genetics. Equally, some biotechnologies can be seen as means of making selective breeding more efficient. Thus, freezing of semen, artificial insemination (AI), embryo transfer, cloning of embryos, trans-vaginal oocyte recovery followed by in vitro embryo production, and other *reproductive technologies* can be used to ensure, that animals with good genetic potential produces more offspring than they would otherwise have had and furthermore, with a reduced generation interval. In this way the process of selective breeding is accelerated. Sex selection is another biotechnology, which could prove useful in improving breeding efficiency. A new and more radical biotechnology introduces into the fertilised egg, or the early embryo of a host, genes from the same or another species and thus creates so-called *transgenic animals.* So far no transgenic animals have been put into use in ordinary farm animal production, but gene technology is interesting in ways other than as a means of creating transgenic animals and may become an effective and commonly used tool in animal breeding. (This will be just one possible outcome of current efforts to map the genome of the most important species used in animal production.)

The increase in power, and the potential increase of speed and efficiency that modern breeding and biotechnology presents, force us both to recognise our moral responsibility and to discuss the limits of acceptability (Schroten, 1992; Habgood, 1993). In such discussion ethics provides a way of ensuring systematic and rational reflection on the moral issues involved within a framework of values and principles guiding behaviour (Schroten, 1992; Brom & Schroten, 1993). Our efforts to breed for higher production efficiency and our use of biotechnology raise concerns regarding both animal welfare and animal integrity. These concerns can usefully be explored further: the ethical significance of breeding goals and biotechnologies can thus be evaluated according to their potential to damage animal welfare and violate animal integrity (Mepham, 1993*b*; Mepham, 1995). In addition to the concerns regarding animals, concerns relating to humans or biological and environmental issues may be considered.

Ethical concerns relating to animals

Ethical concerns associated with the animals themselves can, then, be divided into two categories – these relating to animal health and welfare on the one hand, and the integrity of the animal on the other. It should be borne in mind that these categories interrelate (Vorstenbosch, 1993).

Animal welfare

Although it is presently a focus of scientific research, the concept of animal welfare is hard to define, especially when one wants to extend it beyond just animal health. What is meant by welfare and how is it to be measured? Usually animal welfare is taken to include both physical health and behaviour and is evaluated with regard both to the animal itself and how it copes with its environment (Sandøe *et al.*, 1996). Potentially, several types of animal welfare problems associated with breeding for high production efficiency and the use of biotechnology can arise. These problems can be related to a variety of factors, such as the genetic expression (e.g. rapid growth or high milk production), the breeding technique itself (e.g. a certain form of biotechnology), or mutations in transgenic animals.

Ethical concerns relating to animal health are often linked to a subsequent reduction in animal welfare. E.g., increased milk production is likely to cause a higher incidence of mastitis in cows (Boer *et al.*, 1995), which will in turn cause a reduction in animal welfare. Several authors think that the use of biotechnology is likely to cause animal suffering (Rollin, 1994; Boer *et al.*, 1995; Hahn, 1996; King, 1996; Rollin, 1997; Schroten, 1997). One reason for this is the potential of the technologies to make farm animal production even more efficient, and thus put higher pressure on the animals than is seen today, worsening conditions already considered unacceptable. To date, if pain, suffering or disease has not interfered with production efficiency, the condition has often been ignored, as happens with production-related diseases (Rollin, 1996). This priority of productivity over animal welfare is an ethical problem in farm animal production as such, and is not specific to the use of biotechnologies (Irrgang, 1992; Roenningen, 1995; Idel, 1998). Thus, discussion of the use of biotechnologies becomes part of a wider discussion concerning the ethics of farm animal breeding. However, the use of biotechnology towards the same goals of high efficiency as are set in conventional breeding is considered by some much more powerful and dangerous as biotechnology will increase the speed and efficiency of selection (King, 1996;

Rauw *et al.*, 1998). Furthermore, selection and genetic manipulation is likely to affect more than one trait (Rauw *et al.*, 1998), and thus, additional animal welfare problems may arise as an indirect consequence. However, biotechnology may also be used to redress welfare problems created through selective breeding (Irrgang, 1992).

One of the first cases exposing welfare problems associated with the use of biotechnology is the case of the "Beltsville pigs". The "Beltsville pigs" contained human growth hormone genes to accelerate growth, but suffered from health problems such as lameness, ulcers, cardiac diseases and reproductive problems (King, 1996; Rollin, 1997). However, animal welfare has been impaired by conventional selective breeding as well. There are several reports of animal welfare problems relating to breeding for high production efficiency and the use of biotechnological breeding techniques. It is reasonable to assume that ongoing selection for high production efficiency is likely to cause ever more welfare problems, regardless of the reproduction method used. In the following two sub-sections we give some examples of these welfare problems. Some are connected with breeding goals, some with the techniques involved in the reproduction.

Animal welfare problems related to breeding goals

Today the broiler chicken grows to a weight of approx. 2 kg in around 40 days. This is half the time it took 30 years ago and the age of a broiler chicken at slaughter weight is still reduced by one day per year. The muscles and gut grow fast but the skeleton and cardiovascular system do not follow, resulting in leg problems and heart failure (Broom, 1998; D'Silva, 1998; Rauw *et al.*, 1998). Turkeys have been bred for large muscular development and male turkeys are now too heavy to mount the females, so they need artificial insemination to reproduce. The turkeys suffer from severe leg problems, as their bone structure cannot support the heavy weight (D'Silva, 1998; Rauw *et al.*, 1998). Both broilers and turkeys have been found to have a reduced immune response, making them more susceptible to disease (Rauw *et al.*, 1998). Pigs, having been selected for high growth rate and lean tissue have leg problems (D'Silva, 1998; Rauw *et al.*, 1998). They are also more likely to become stressed or die during activity than their ancestors due to a different muscle composition and size of heart (Broom, 1998). The dairy cow now produces 10 times as much milk as her calf would suckle from her - if it were allowed (D'Silva, 1998). Breeding for this level of milk production increases the risk of mastitis. Furthermore this breeding goal results in digestive disorders, foot rot, skin and skeletal disorders, udder edema and teat injuries (D'Silva, 1998; Rauw *et al.*, 1998). In beef cattle, the breeding of double-muscled cattle is leading to birth difficulties (Broom, 1998).

Animal welfare problems related to biotechnology

The very carrying out of some reproductive techniques, such as superovulation, insemination and embryo transfer, can cause stress and pose a risk to animal welfare. E.g. in smaller animals, such as sheep and pigs, embryo transfer requires surgery (Seamark, 1993; Broom, 1998; D'Silva, 1998). Furthermore, techniques where the embryo is manipulated *in vitro* may create offspring that are too large for normal birth. Thus, research exists showing that the offspring of sheep and cattle developing from *in vitro* produced embryos cause longer gestation, display increased birth weight, a higher incidence of birth difficulties (and therefore Caesarean sections), and increased frequency of genetic anomalies (Mepham, 1994; van Reenen & Blokhuis, 1997; Broom, 1998). This diminishes the welfare of both the mother and her young. In contrast with this it should be noted that positive effects on animal welfare can result from biotechnology. The use, e.g., of artificial insemination and embryo transfer, means that breeding animals need to be transported less often.

In addition to the problems of oversized offspring, which are found in relation to the *in vitro* manipulation of the embryo, cloning and transgenesis may cause harm to the animals. Many cloned calves have difficulties surviving. They are behaviourally retarded and may also have joint problems (Mepham, 1995; Rollin, 1997; D'Silva, 1998). Transgenic calves have also been found to be behaviourally retarded (Mepham, 1995; Rollin, 1997). Attempts to create transgenic sheep with increased growth have resulted in unhealthy animals (Rollin, 1996); and equally, an attempt to produce transgenic cattle with double-muscling resulted in a calf, which within one month was unable to stand up on its own (Rollin, 1996).

The conduct of research on transgenesis is itself beset with welfare problems. E.g., current techniques used to produce transgenic animals are very inefficient. Less than 1% of the embryos result in live transgenic animals and several of these animals will develop serious abnormalities and thus must be expected to suffer before being killed (Mepham, 1995; King, 1996). However, as these techniques improve, the production of transgenic animals may become more efficient. Finally, there is a risk of unrelated, harmful mutations. When creating transgenic animals foreign DNA is inserted into the host's DNA. The foreign DNA may, however, be integrated in the genome in a way, which causes mutations. Such unpredictable responses from totally unrelated genes have been reported in mice showing lethal or deforming mutations (Mepham, 1994; King, 1996; Rollin, 1996; van Reenen & Blokhuis, 1997).

A possible application of biotechnology is the introduction of genes that code for disease resistance. This may reduce suffering and improve animal health and welfare (Mepham, 1995). However, the targets of research on disease resistance are often production-related diseases like mastitis (King, 1996; Idel, 1998), which might encourage higher production and thereby recreate the same problems just at a higher production level. One concern is that genes associated with resistance to disease may have unforeseen consequences which override the expected improvement (Mepham, 1994). Some additional concerns are a potential reduction in the susceptibility to metabolic or environmental stress (in which case an even higher metabolic pressure may be put on the animals) (Mepham, 1995), or the creation of new, questionable production practices (Thompson, 1997). Furthermore, our current understanding of physiology is inadequate – e.g. the relation between growth hormone genes and diabetes, kidney diseases and bone malformations is unclear (Mepham, 1994) – and this makes it hard to foresee what the consequences for animal welfare would be of the selected traits. Some ask us to consider whether animals are not already at their biological limit before we proceed with transgenesis for increased production (Broom, 1998). Finally, there is a fear that genetic engineering poses a risk to welfare by introducing changes in phenotype or animal experience which make it harder to detect welfare problems. Standard methods for the evaluation of welfare continue to be applied, but these may well be ineffective if transgenic animals have altered sensory or physiological responses (Mepham, 1995; Thompson, 1997; Broom, 1998).

Animal integrity

Animal integrity is as hard to define as the concept of animal welfare. Some describe integrity as a naturally evolved, unharmed wholeness of either an individual, a species or an ecosystem. In respect of this integrity, or the intrinsic value of animals, they therefore conclude that human beings should leave animal genomes intact (Vorstenbosch, 1993; Thompson, 1997). Others argue that respecting an animal’s integrity does not necessarily mean that it is wrong to use animals as such, but it does imply that they may not be reduced to mere instruments for human interests (Brom & Schroten, 1993). Thus, some people feel that the integrity of the animals is not respected when biotechnology is applied (Brom & Schroten, 1993; Sandøe & Holtug, 1993; Schroten, 1997). According to some integrity is specifically violated by using invasive procedures to increase reproduction – e.g., through embryo transfer in sheep and goats, and transvaginal oocyte puncture in cows. Besides posing a risk to animal welfare, several authors find that this use of non-therapeutic surgery also requires a special ethical justification (Seamark, 1993; Boer *et al.*, 1995; MAFF, 1995; The Veterinary Record, 1995; Rutgers *et al.*, 1996). The integrity can be considered violated even by non-invasive biotechnologies – e.g. a change in the composition of the milk in a transgenic cow – although this technique will not necessarily pose any risk to the welfare of the animal (Seamark, 1993). Finally, the potential to change the animals so that they are better suited for intensive farming instead of solving the problems with e.g. housing conditions, and the fact that some animals can no longer reproduce unassisted may be considered violations of animal integrity.

The perception of animals as things, or instruments for human interests, is according to some reflected in the option of patenting (Schroten, 1997; Habgood, 1993). However, the treatment of animals as things already takes place in intensive farming and is therefore not particularly associated with biotechnology, although the use of biotechnology may be seen as another step in the process (Sandøe & Holtug, 1993; Schroten, 1997). Also, the externalisation of the whole reproduction process as such may be seen as an interference with animal integrity (Boer *et al.*, 1995).

Other ethical concerns

Besides the concerns regarding animals, biotechnology raises additional ethical concerns relating to humans and to biological and environmental issues; and some people are concerned with the use of biotechnology itself.

Concerns relating to humans

One of the major concerns relating to humans is the "slippery slope" argument, i.e. the fear that what can be done with animals will also be done with humans (Schroten, 1997). Thus, the "slippery slope" argument is concerned not only with a potential technological development, but also a potential change in attitudes regarding what is considered acceptable. In fact, many of the techniques were developed for, and used on, humans first before being applied in farm animal breeding. A technique like cloning from somatic cells, which is developed for use in animals, is not at present generally considered morally acceptable for use on human beings (Boer *et al.*, 1995), nor is it yet technically possible. And as some argue, if at some stage it does become possible to clone humans, it still does not follow that we have to do so (Sandøe & Holtug, 1993).

Another concern is that of human health and welfare. An example would be the potential risk to human beings when eating meat from genetically engineered animals (Brom & Schroten, 1993; Alestroem, 1995; Rollin, 1996). Others argue that biotechnology may bring better or healthier food, e.g. meat with less fat or more easily digested milk. Finally, some argue that there may be a potential risk for humans, either directly through the intake of antibiotic residues in e.g. the meat, or through development of antibiotic resistant pathogens due to medication used to mask animal welfare problems (Mepham, 1994).

The ability to produce better, cheaper food more efficiently is often mentioned as an argument in favour of modern breeding and its reliance on biotechnology. Here lies a potential for lower food prices and increased food production in developing countries. Means to achieve this are, however, already available, and it is questioned whether the use of biotechnology would make any moral difference (Thompson, 1997). It is obvious that developing countries could benefit greatly from the use of some biotechnologies, and therefore it is argued that these countries could more easily justify using the techniques than the developed countries, which already have a surplus food production (Sahai, 1997). But this presupposes that the technologies become available for these countries' own food production. Increased production in the developed countries is considered unlikely to benefit developing countries (Hahn, 1996). Finally, one last concern stated is a potential military application, e.g. using animals to carry human pathogens (Rollin, 1996).

Concerns relating to biological and environmental issues

Several authors express serious concern about the risk of loosing genetic diversity through biotechnology (Brom & Schroten, 1993; Sandøe & Holtug, 1993; Mepham, 1994; Boer *et al.*, 1995; Rollin, 1996; Rollin, 1997; Idel, 1998). Although this would allow a standardisation of e.g. dairy products (Boer *et al.*, 1995), the loss of genetic diversity makes the animals more vulnerable to diseases and other challenges (Mepham, 1994; Boer *et al.*, 1995; Rollin, 1996; Rollin, 1997). In a group-housing situation it may also be more difficult for the animals to form groups if the variation between individuals is too small (Boer *et al.*, 1995). The loss of individuality may be a concern in itself (Boer *et al.*, 1995), but as is seen in identical twins, the repetition of a genotype still allows individuals to develop as a consequence of environmental influences (Milani-Comparetti, 1997). However, some see a potential increase in genetic diversity, as genes are more often added to a species than removed. This gives rise to another concern, however, since distinctions between species may become less distinct, or blurred (Sandøe & Holtug, 1993). The loss of genetic diversity may be considered irreversible (Boer *et al.*, 1995), although the potential exists to preserve genetic material (Sandøe & Holtug, 1993; Mepham, 1994; MAFF, 1995), which could prove useful in the preservation of endangered species. Some also argue that an extensive gene pool may still be available from hobby breeders (Rollin, 1997).

If transgenic animals should escape or be released in the wild the consequences are unknown, and there is a concern that such a change would upset the ecological balance (Kohler *et al.*, 1992; Brom & Schroten, 1993; Sandøe & Holtug, 1993; Hahn, 1996; Rollin, 1996; Rollin, 1997). There is a potential for these animals to replace existing animals in nature, e.g. if they manage better in that habitat or pass on infections to other species. Such infections may develop due to an introduced disease resistance or unpredictable pathogens (Sandøe & Holtug, 1993; Rollin, 1996; Rollin, 1997). Precautions against escape and genetic disadvantages of the transgenic animals are considered to make this scenario unlikely (Sandøe & Holtug, 1993; Alestroem, 1995), although aquaculture animals, e.g., have been known to escape into natural aquatic ecosystems (Kohler *et al.*, 1992).

One advantage of using biotechnology and thus making farm animal production more efficient is the potential to produce the same amount of food using fewer animals. This could reduce problems of pollution. If it did it would be of great benefit to the environment (Mepham, 1994).

Concerns with biotechnology in itself

The use of biotechnology may in itself cause concern. This may be due to "fear of the unknown", ignorance or misunderstandings (Hahn, 1996). It may also be because the techniques are considered "unnatural" (Brom & Schroten, 1993; Schroten, 1997), or inherently wrong (Rollin, 1994; Rollin, 1997), or a violation of the animals' integrity (Mepham, 1994; Boer *et al.*, 1995; Rollin, 1996). These concerns, however, are not restricted to biotechnologies. They must be viewed in the context of our ways of handling animals and nature in general. Thus, some find it hard to see why biotechnology is dismissed on the basis that it is unnatural if it is acceptable to e.g. dam rivers and build cities (Rollin, 1996). Furthermore, some point out that all conventional breeding can be dismissed as a violation of species integrity (Sandøe & Holtug, 1993; Rollin, 1996). Although the effect on the animals' integrity may thus be considered an "either-or"–issue, and something which may therefore be used against selective breeding as such, it can also be questioned whether one can draw a non-arbitrary line. One suggestion is to draw the line at the technical changing of the DNA, as happens in the creation of transgenic animals, as some consider the transfer of genes between species to be ethically relevant (Boer *et al.*, 1995; Idel, 1998).

To sum up, there seem to be two central issues regarding animals in ethical discussions concerning breeding and the use of biotechnology. These are animal welfare and animal integrity. Although animal welfare research may give some insight into how animals are affected by our treatment, such studies will provide primarily indirect answers, which do not in any simple way tell how badly animals are affected. The concern for an animal's integrity goes beyond that of concern for health and welfare (Rutgers *et al.*, 1996). One of the observed differences between welfare and integrity is that welfare can be affected by natural circumstances. In contrast, human action is required to affect integrity, and thus integrity demands human respect. Another difference is that the consequences of affecting an animal's welfare can be dealt with in empirical terms, whereas the question of integrity is more of a philosophical issue.

Cultural differences

The findings of this literature review were expected to reveal some information on cultural differences across Europe over what ethical aspects of breeding and biotechnology are being raised and handled in different countries. However, the majority of the literature was from Northern Europe and the United States, and virtually no references from Southern Europe were found. Our search profile was pretty general and is unlikely to have caused this difference. However, papers of Southern European authors which have been published only in national journals in the original language may not have been covered by the data bases. A recently held conference on agricultural ethics attracted participants from those same countries as the literature was representing, although it was advertised in Southern European countries as well. We have been informed that in Southern Europe the focus of bioethics is primarily on issues concerning humans, e.g. biomedical ethics. It is not clear which social, cultural and religious factors may explain these differences (Zechendorf, 1998).

Weighing concerns against each other

As a starting point for a dialogue about the acceptability of a particular breeding goal or biotechnology one may consider the implications for all the parties involved – i.e. for the animals, the humans and the environment. Next, those implications – potential risks and benefits – must be weighed against each other. In moral decision making one seeks a balance between intuitions, principles and relevant facts, notwithstanding the fact that our intuitions may change with new information (Boer *et al.*, 1995). To enable the detection and identification of the issues, and the weighing of the concerns, different models have been developed.

The general view in our society is that it is acceptable to use animals in e.g. farming and research if this is done humanely. This view is reflected in principles of humane use of animals, such as animal protection laws, which state e.g. that no harm must be done unless necessary, that the harm must be outweighed by benefits, and that some types of harm should be prohibited (MAFF, 1995). This attitude towards the use of animals is based on two of the most important groups of ethical theories, utilitarianism and deontology (Mepham, 1993*a*; Boer *et al.*, 1995; Fisher, 1997).

Utilitarianism

In utilitarianism an action is judged to be right or wrong according to its consequences. The consequences are estimated in a cost-benefit analysis, and what is right depends on what among the available lines of action will produce the greatest net benefit (Mepham, 1993*b*; Boer *et al.*, 1995; Fisher, 1997; Thompson, 1997). Thus, one will always seek to maximise the benefit for all parties involved. In practice this usually means an evaluation of the implications for humans and animals. This way of arguing may easily justify using biotechnology in biomedical research, where the potential risks for animal welfare will be outweighed by the benefits of, e.g., life-saving treatments for human beings. In contrast, farm animal production for better and cheaper food is unlikely to improve human well-being to the same extent, and so on utilitarian grounds any technology that increases the risk of animal suffering will be unacceptable (Irrgang, 1992; Thompson, 1997). However a problem with this ethical theory arises when we seek to define what is considered beneficial and harmful, and to qualify, quantify and balance the good and bad against each other.

Deontology

A group of views object to the utilitarian claim that a decision of what is morally right or wrong should be made solely in terms of the consequences (Mepham, 1993*b*; Boer *et al.*, 1995; Fisher, 1997). Thus some will claim that we in our moral decisions rather should focus on what we *do* to the animals than on what happen as *a consequence* of what we do. E.g., in the case of biotechnology used to make breeding more efficient, utilitarians may accept the use of the technology, including negative side-effects on animal welfare, if the overall consequences of the breeding programme are better than the alternatives, and if the use of biotechnology is necessary to make the programme competitive. Deontologists will on the other hand say that we cannot justify the use of the technology if it is bad to the animals – i.e. the end cannot justify the means. Another related consideration is that the use of evil means to a good goal may have an adverse effect on the character of the person who uses these means (Thompson, 1997).

A specific version of the deontological views is the so-called animal rights view according to which each animal should be protected against being used as a means to promote the general good – comparable to how individual persons in our culture are protected. For example, we do not accept that people are used in biomedical research against their will, even when the research may have very beneficial consequences. Radical versions of the animal rights view will ban all use of animals for food production. But there may also be more moderate versions of the view which claim that there are certain minimum requirements for the care and protection of the individual animal which should always be complied with.

Both ethical theories can reasonably be regarded as inadequate to deal with issues like specific breeding goals and biotechnology. Other ethical theoretical frameworks have been suggested – e.g. the "ethics of intervention", which recognises the fact that simply by pursuing our own existence, humankind must intervene in nature, including in animal lives, but insists that we must still regard ourselves as part of nature (Donnelley, 1993).

Some have argued that there is a need for a decision model that recognises several ethical principles. One such "pluralist" model, which was originally developed in medical ethics, has been modified and applied to animal ethics issues such as those arising in connection with the use of biotechnology. The model is based on four principles (Mepham, 1993*a*; Mepham, 1993*b*; Boer *et al.*, 1995; Mepham, 1995; Rutgers *et al.*, 1996; Fisher, 1997):

"Beneficence": one should care for and promote animal health and welfare, and beneficial outcomes like pharmaceuticals and disease resistance.

"Non-maleficence": one should refrain from doing harm to animals, humans and the environment, e.g. not jeopardise animal welfare.

"Autonomy": one should ensure that freedom is not diminished, e.g. freedom of behavioural expression.

"Justice": one should treat animals of comparable species equally and ensure a fair distribution of good and evil between humans and animals. The animals' integrity should be respected. Real benefit should be achieved.

Other principles may be added (Brom & Schroten, 1993; Boer *et al.*, 1995):

"The principle of irreversibility": always act in such a way that the consequences of your actions may be redressed.

"The controllability principle": the far-reaching consequences of biotechnology require the availability of public debate and effective democratic control.

Besides animals, these principles must be applied to the different interest groups, e.g. producers, consumers and society (Mepham, 1995). Not all of these principles are necessarily given any weight in the final decision, but considering them may be part of the evaluation process. The application of these principles in a given case is a three-step process, which involves (Brom & Schroten, 1993):

1: Collecting any facts which are morally relevant to the project.
2: Assessing the consequences of the project to each of the involved groups.

3: Weighing the harms and the advantages of the project, using the information that becomes available in step 1 and 2.

If it is possible, the risks involved must be assessed before attempting to make any changes to the animals. However, the overall interpretation and the priority we attach to implications will still be determined by our own ethical view – e.g., what we understand as the meaning of integrity and animal welfare, what we consider good reasons, and how we weigh the interests of the animals against those of human beings and the environment (Schroten, 1992; Boer *et al.*, 1995; Fisher, 1997; Sandøe & Holtug, 1998).

Handling ethical concerns in practice

In recent years public awareness of the moral status of animals has increased. This is reflected in e.g. legislation relating to the protection of animals. In Holland legislation has developed in three phases, each recognising a new dimension of moral status in animals. First an anti-cruelty law was introduced (recognising that cruelty to animals is morally wrong); next an animal-protection law (recognising that animal experiments have to be justified); and then a law ensuring that conflicting interests are weighed (recognising that animals have intrinsic value and are not purely instrumental to man) (Brom & Schroten, 1993). On a European level animals kept for farming purposes are e.g. protected against natural or artificial breeding which is likely to cause suffering. Furthermore, they may not be kept for farming purposes, if they can not be kept without detrimental effect on health and welfare (Council Directive 98/58/EC, 1998).

The concept of "no, unless"-policies has been suggested as a way of expressing whether or not e.g. a particular biotechnology is acceptable for a certain purpose. The idea of the "no, unless"-policy is, that the biotechnological activity is to be prohibited unless the relevant values are not violated or the aim is so important that a violation of these values is overruled. The "no, unless"-policy thus balances good against bad, while still taking into account the principles of doing good and avoiding harm. Furthermore, the burden of proof is on the side of the person who wants to engage in biotechnological activities, and thus forces the scientists and policy-makers to back their moral judgements with an argued case. Alternatively one can adopt a "yes, but"-policy, taking into account the fact that this shifts the burden of proof to those who wish to limit the use of biotechnology.

On either approach, a final decision could be taken by an assessment committee of experts (Brom & Schroten, 1993; MAFF, 1993; Boer *et al.*, 1995; MAFF, 1995). Such expert committees might have an advisory and/or licensing function. Their tasks might be to look at the benefits –

e.g. progress in breeding, health, performance and food quality – and to consider the ethical concerns and consequences on such factors as animal welfare, the economy, and the environment. Also, the objectives and proportionality of the means and ends could be examined, as well as the possibility of alternatives (Hahn, 1996; Schroten, 1997; van Vugt & Nap, 1997). It is unclear whether such a committee would be better placed on a national or international level. In a European survey one third of those questioned believed that international organisations, such as the United Nations, are best placed to regulate biotechnology (Eurobarometer, 1997), even though the working procedures of such organisations are often too slow to keep up with the new technical developments.

Some authors have claimed that, in order to comply with some of the concerns associated with biotechnology, it is important to ensure that research is performed in accordance with animal welfare legislation and subject to the same control as other animal experimentation (Donnelley, 1993; Smidt, 1994; MAFF, 1995; Hahn, 1996; Seidel, 1998). In addition, some encourage assessment of the breeding goals rather than the methods by which these goals are obtained (Irrgang, 1992). Policy makers are expected to have a range of strategies available to control the use of biotechnology (Mepham, 1995). Certain applications are felt by some to be best prohibited – e.g. use on humans or as biological weapons (Hahn, 1996). Extensive application of some of the technologies is considered inadvisable at present due to lack of safety, and part of the funds therefore could be used to estimate potential adverse effects (Hahn, 1996). Ethical assessment is by some considered necessary on a case by case basis, both in the research phase and when it comes to general application (Irrgang, 1992; Schroten, 1992; Smidt, 1994; MAFF, 1995). In such an assessment attention is drawn to the importance of considering not only the ethical acceptability of future applications but also the likelihood that good or bad effects will happen (Sandøe, 1997). Furthermore, it has been suggested that forums, or platforms, should be created to stimulate the dialogue between science, industry and the public (Schroten, 1997). Several point to a strong and obvious need for open ethical evaluation if these technologies are to be accepted by the public (Mepham, 1993*a*; Alestroem, 1995; MAFF, 1995; Rollin, 1997; van Vugt & Nap, 1997; Seidel, 1998). Finally, some recommend that food products from genetically modified animals should be labelled to allow consumers to make an informed choice (MAFF, 1993).

Conclusions

In discussions of breeding goals and biotechnology, one of the primary concerns is that of animal welfare. However, many of the problems arising in relation to animal welfare arise also with conventional selective breeding. Regardless of the method of breeding, questions arise about whether the purpose of the breeding goal is necessary, and whether that goal can justify certain risks (e.g. of reduced animal welfare). For medical research, such risks are more easily accepted, since here the expected benefit may be vital to humans. However, in farm animal production - especially in our part of the world - it may be more difficult to accept risks if those risks are being taken in order to produce cheaper food.

There seems to be general agreement that the use of biotechnology should be controlled, although it is unclear what type of organisation, and at what level, is best suited to carry out such a control. It is, however, important to realise that current legislation already offers some protection of animal welfare, regardless of the method of breeding. Alternatively, efforts could be made to improve, enforce and control the existing legislation to protect animals from potential threats to their welfare. However, even if the risks of reduced animal welfare were eliminated, other concerns and risks would still be present and call for open public evaluation.

References

Alestroem, P. 1995. Ethical aspects of modern biotechnology - transgenic fish. In: Ethical aspects of modern biotechnology, Proceedings from a conference10-11 November 1993, eds.: Kaiser, M. & Welin, S., Centrum foer Forskningsetik, Goeteborg, Sweden, 117-121.

Boer, I. J. M., Brom, F. W. A. & Vorstenbosch, J. M. G. 1995. An ethical evaluation of animal biotechnology: the case of using clones in dairy cattle breeding. Animal Science, 61, 3, 453-463.

Brom, F. W. A. & Schroten, E. 1993. Ethical questions around animal biotechnology: The Dutch approach. Livestock Production Science, 36, 1, 99-107.

Broom, D. M. 1998. The effects of biotechnology on animal welfare. In: Animal biotechnology and ethics, eds.: Holland, A. & Johnson, A., Chapman & Hall Ltd., London, UK, 69-82.

Council Directive 98/58/EC of 20 July 1998 concerning the protection of animals kept for farming purposes.

Donnelley, S. 1993. The ethical challenges of animal biotechnology. Livestock Production Science, 36, 1, 91-98.

D'Silva, J. 1998. Campaigning against transgenic technology. In: Animal biotechnology and ethics, eds.: Holland, A. & Johnson, A., Chapman and Hall Ltd., London, UK, 92-102.

Eurobarometer 46.1. 1997. European Commission, Brussels, Belgium, pp. 87.

Fisher, M. W. 1997. Agricultural ethics - a role in animal production. Proceedings of the New Zealand Society of Animal Production, 57, 88.

Habgood, J. 1993. Ethical restraints on biotechnological inventiveness. In: Biotechnology - friend or foe? The social, ethical, political, religious and economic impacts. A report of the First Annual Meeting of the BioIndustry Association. BioIndustry Association, London, UK, 23-25.

Hahn, J. 1996. Biotechniques and ethics in livestock breeding - Can differences in opinion be attenuated? Landbauforschung Voelkenrode, Sonderheft, 164, 57-61.

Idel, A. 1998. Gen-manipulierte Tiere - Kritik des gentechnischen Ansatzes. Tierarztliche Umschau, 53, 2, 83-87.

Irrgang, B. 1992. Ethische Aspekte der Biotechnik. Schriftenreihe der Schaumann-Stiftung zur Foerderung der Agrarwissenschaften, Huelsenberger Gespraeche, 14, 36-46.

King, D. 1996. Animal biotechnology. New Farmer & Grower, 49,18-19.

Kohler, C. C., Muhlach, W. L., Phillips, P. C. & Paleudis, G. A. 1992. Environmental and ethical concerns associated with transgenic fishes. Journal of the World Aquaculture Society, 23, 2, 97.

Mepham, T. B. 1993*a*. Biotechnology: The ethics. Animal Production, 56, 3, 425.

Mepham, T. B. 1993*b*. Approaches to the ethical evaluation of animal biotechnologies. Animal Production, 57, 3, 353-359.

Mepham, T. B. 1994. Transgenesis in farm animals: Ethical implications for public policy. Politics and the Life Sciences, 13, 2, 195-203.

Mepham, B. 1995. Ethical aspects of animal biotechnology. Journal of the Agricultural Society - University of Wales, 75, 3-21.

Milani-Comparetti, M. 1997. Bioethical considerations on cloning and twinning. Acta Geneticae Medicae et Gemellologiae, 46, 3, 135-137.

MAFF (Ministry of Agriculture, Fisheries and Food). 1993. Report of the committee on the ethics of genetic modification and food use. HMSO Publications Centre, London, UK, 43 pp.

MAFF (Ministry of Agriculture, Fisheries and Food). 1995. Report of the committee to consider the ethical implications of emerging technologies in the breeding of farm animals. HMSO Publications Centre, London, UK, 77 pp.

Rauw, W.M., Kanis, E., Noordhuizen-Stassen, E. N. & Grommers, F.J. 1998. Undesirable side effects of selection for high production efficiency in farm animals: a review. Livestock Production Science, 56, 15-33.

Roenningen, K. 1995. Gene technology - ethics - livestock farming. In: Ethical aspects of modern biotechnology. Proceedings from a conference 10-11 November 1993, eds.: Kaiser, M. & Welin, S., Centrum foer Forskningsetik, Goeteborg, Sweden, 69-75.

Rollin, B. E. 1994. Ethical considerations for livestock breeding and biotechnology. Journal of Dairy Science, 77, suppl. 1, 247.

Rollin, B. E . 1996. Bad ethics, good ethics and the genetic engineering of animals in agriculture. Journal of Animal Science, 74, 3, 535-541.

Rollin, B. 1997. Send in the clones...don't bother, they're here. Journal of Agricultural & Environmental Ethics, 10, 1, 25-40.

Rutgers, L. J. E., Grommers, F. J. & Colenbrander, B. 1996. Ethical aspects of invasive reproduction techniques in farm animals. Reproduction in Domestic Animals, 31, 4/5, 651-655.

Sahai, S. 1997. The bogus debate on bioethics. Biotechnology and Development Monitor, 30, 24.

Sandøe, P. & Holtug, N. 1993. Transgenic animals: Which worries are ethically significant? Livestock Production Science, 36, 1, 113-116.

Sandøe, P., Giersing, M. H. & Jeppesen, L. L. 1996. Concluding remarks and perspectives. Acta. Agric. Scand., Sect. A, Animal Sci. Suppl. 27, 109-115.

Sandøe, P. 1997. Foundational research: response from an ethical point of view. In: Transgenic animals and food production: proceedings from an international workshop in Stockholm, ed.: Nilsson, A., KSLA, Stockholm, Sweden, 55-56.

Sandøe, P. & Holtug, N. 1998. Ethical aspects of biotechnology in farm animal production. Acta. Agric. Scand., Sect. A, Animal Sci. Suppl. 29, 51-58.

Sandøe, P., Nielsen, B. L., Christensen, L. G. & Sørensen, P. 1999. Staying good while playing God - the ethics of breeding farm animals. Animal Welfare, (accepted for publication).

Schroten, E . 1992. Embryo production and manipulation: ethical aspects. Animal Reproduction Science, 28, 1-4, 163-169.

Schroten, E. 1997. Animal biotechnology, public perception and public policy from a moral point a view. In: Transgenic animals and food production: proceedings from an international workshop in Stockholm, ed.: Nilsson, A., KSLA, Stockholm, Sweden, 151-156.

Seamark, R. F. 1993. Recent advances in animal biotechnology: welfare and ethical implications. Livestock Production Science, 36, 1, 5-15.

Seidel, G. E. Jr. 1998. Biotechnology in animal agriculture. In: Animal biotechnology and ethics, eds.: Holland, A. & Johnson, A, Chapman & Hall Ltd., London, UK, 50-68.

Smidt, D. 1994. Biotechnologie: Forschung und Anwendung im Licht der Verantwortung fur Mensch und Tier. Archiv fur Tierzucht, 37, 121-129.

The Veterinary Record. 1995. Banner committee reports on the ethics of breeding technologies. The Veterinary Record, 136, 230-231.

Thompson, P. B. 1993. Genetically modified animals: Ethical issues. Journal of Animal Science, 71, suppl. 3, 51-56.

Thompson, P. B. 1997. Ethics and the genetic engineering of food animals. Journal of agricultural & environmental ethics, 10 (1), 1-23.

van Reenen, C. G. & Blokhuis, H. J. 1997. Evaluation of welfare of transgenic farm animals: Lessons from a case study in cattle. In: Transgenic animals and food production: proceedings from an international workshop in Stockholm, ed.: Nilsson, A., KSLA, Stockholm, Sweden, 99-105.

van Vugt, F. & Nap, A. M. P. 1997: Regulatory and policy isues as viewed within a cultural framework: A European perspective. In: Transgenic animals and food production: proceedings from an international workshop in Stockholm, ed.: Nilsson, A., KSLA, Stockholm, Sweden, 31-36.

Vorstenbosch, J. 1993. The concept of integrity: Its significance for the ethical discussion on biotechnology and animals. Livestock Production Science, 36, 1, 109-112.

Zechendorf, B. 1998. Agricultural biotechnology: Why do Europeans have difficulty accepting it? AgBioForum, 1, 1, 8-13.

[1] Stine B. Christiansen, Peter Sandøe. The Royal Veterinary and Agricultural University.

Grønnegårdsvej 8, 1870 Frederiksberg C, Copenhagen, Denmark

Farm animal breeding and the law

Christine Noiville[1]

Industrial property on farm animal inventions has become clearer in Europe since the recent adoption of the E.U. patent directive. In many respects, the situation is satisfactory, since a patent is a useful tool. It confers a 20-year monopoly to the inventor of a new and useful product or process, as long as it is disclosed to the public. As such, a patent is a fair return to innovators and an incitation to technical progress. This paper analyses the impact of new patent law on farm animal breeding and selection. It first examines what is patentable in farm animal breeding technologies and products. It then turns to the potential problems that may be associated with such patents. In the final section, the paper examines if animal welfare, a concept that is gaining a growing legal importance, may put special constraints on future breeding work.

I. An equitable return for farm animal breeding innovations

European Patent law requires that any invention be novel, inventive and has industrial applicability. The invention has also to be a patentable subject matter (not excluded by patent law) and must meet the requirements concerning enabling disclosure (a person skilled in the art may actually reproduce the invention) and clarity (the language must be comprehensible). Since most of these requirements could not traditionally be met with animals, European patent law excluded animal varieties and most methods of producing animals.
With scientific and legal evolution, things are far more favourable today. It is now possible to patent a gene and its application in an animal, an animal itself and methods of breeding.

A. Patents may be granted on technical processes for the production or selection of animals

a) Production methods

The rule is that patents cannot be granted for essentially biological processes for the production of animals, but microbiological or other technical processes are patentable.
It is logical that essentially biological processes for the production of animals are not patentable, because they consist entirely of natural phenomena. No one can be granted an exclusive right on traditional, widely used methods like crossing or interbreeding.
Conversely, microbiological processes ("any process involving or performed upon or resulting in microbiological material") are patentable, as well as other technical processes. As soon as a process incorporates a stage that cannot naturally occur, this is considered to be technical and

can be protected. The question of whether a process is "essentially biological" (non-patentable) or "essentially technical" (patentable) is therefore one of the degree of technical intervention by man in the process and its impact on the desired result. When, in a process for the production of animals, biological as well as technical elements are present, one has to find out where the core of the invention lies. If human intervention plays a determining - and not only supporting - role in the invention, if it plays a significant part in controlling the result to be achieved, if the quality of this intervention is more than routine manipulation of a known and naturally occurring biological event, if the result of the process is substantially different from those provided by natural phenomena or classical breeding processes, then the human intervention is seen as decisive and the process considered as patentable.

In this context, a large number of new processes that are being presently developed are theoretically patentable. This is the case for methods to produce transgenic animals, cloning techniques, methods to increase fertility of farm animals, or multi-step processes like the method of inducing polyploidy in oysters, which are to be seen "technical" even if they involve a purely biological stage at one point or another.

b) Marker-assisted selection methods

Apart from this new kind of method, a large number of processes do not "produce" new animals but help to select animals with desirable traits: marker assisted selection, DNA genotyping, genetic fingerprinting, ovum pick-up, etc. As none of these methods are "processes for the production of animals", they only have to satisfy classical patentability requirements. But two things must nevertheless be kept in mind. Firstly, they must not be "methods for treatment of animal body by surgery or therapy" nor "diagnostic methods practised on the animal body", because they would then be excluded from patent law (which will not be the case for most current methods). Secondly, using DNA information for the choice of a breeding animal does not make the animal genetically modified; only the use of the process by laboratories or breeders will give the right to a royalty payment.

B. Patentability of animals

Inventors generally seek a stronger protection than process patents and try to have animals as such patented as well. The E.U. patent directive confirms that such a protection is possible. Each new animal, as long as it is also inventive and applicable in industry (which will be the case either if the animal is used for milk or meat production or if it is raised for the production of organs or therapeutics), is patentable as such. This is the case for genetically modified animals (transgenic, knockout, etc.) in which part of the DNA has been technically changed in a way which would not occur by natural processes. Should a patent be granted on the animal as such, no one can reproduce it - whatever the technical mean used - without being authorized by the company or the researcher holding the patent.

Some have feared that the patentability of new animals would nevertheless be hampered by the exclusion of animal varieties. As a matter of fact, for historical reasons, both EPC and the E.U. directive exclude animal varieties from patentability. But it is far from being a source of legal insecurity. The main reason is that inventions currently developed in the biotechnological field may be applied not only to a particular variety, but also to a whole higher taxinomical degree. For example, a company that discovers a coding gene for a substance increasing muscular growth or a new cloning technique can apply this invention to any animal. The exploitation of the invention is not only possible in the form of an animal variety, like a cloned charolaise. The company will then claim exclusive rights over any cloned or transgenic non human mammal as exemplified in the patent, not only over a "cloned charolaise". Once the invention is applied to varieties - charolaise, holstein, etc. - by breeders, the company will be entitled to collect royalties.

C. Patentability of animal genes

Patents are frequently written with a number of claims, which may cover genes or gene sequences. Such products are patentable, even if their structure is identical to that of natural elements present in the animal body. As long as the gene has been isolated from the animal body and the inventor has disclosed its concrete use, it is no longer considered as a discovery but as an invention. In such cases as developing a selection test based on the sequence information, utilising the gene to produce a transgenic animal or as a marker gene etc., the gene itself may be patentable.

One thing which must be well understood is that such patents have no effect on traditional breeders: patent holders are not able to claim rights on farm animals naturally carrying this gene; they may only claim rights on the use they proposed of this gene.

One can see that European patent law will duly reward research efforts in the farm animal breeding sector and that ideas sometimes expressed by companies and breeders - appropriation by a patent of "mere conventional breeding practices", impossibility to patent new animals because of the "animal variety" exclusion - are wrong. But it is now necessary to focus attention on the potential risks of the new patent law in the practice of breeding.

II. Potential problems associated with patents in farm animal breeding

This part of the analysis is naturally more speculative. This is only the beginning of a patent registering period, which makes it difficult to have a general view of who possesses what and what are the strategies adopted. The opportunities of delivered or claimed patents for major innovations in breeding are still unclear. The impact of new technologies will depend on the way these technologies are marketed, and at what price. Will they be embodied in G.M. animals as such or in processes, like vaccines? In some cases, there may be a direct choice available between these alternatives, depending on economical and acceptability factors.

Three problems have nevertheless been identified: a risk of competition between patentees and traditional breeders; a potential problem attached to broad patents on products or processes; application of the "farmer's privilege" and traceability of patented animals.

A. Risk of competition between the patent holder and traditional breeders

A simple example will help understand the situation. A company gets a patent on a genetic modification process making cows resistant to mastitis infection. Obviously, this invention will present an economic interest for him only if it is applied to bovine varieties. The company will then claim protection for "any transgenic cow resistant to mastitis infection" and will be entitled to collect royalties for any commercialization of any bovine variety genetically modified as exemplified in its patent. The company may then sell the genetically modified animals, without any authorization from the developer of the traditional varieties used. The latter won't be able to fight it and won't obtain any return from it since traditional breeding practices are not protected under any intellectual protection law.

Traditional breeders are becoming aware of this potentially unbalanced situation and are beginning to organize some form of protection of their breeding work. A first type of protection is currently organized through sales agreements: by using sales contracts, breeders intend to allow biotechnology companies to take advantage of their breeding practices only if the companies buy the varieties. A second type of protection is to get animal varieties protected under tradenames: several breeders in the pig sector are currently trying to protect new pig varieties by a trademark. Neither of these two types of protection really appears satisfactory. The first one implies a constant and difficult control of the use of breeds. In fact, the breeder will sell breeds to farmers, some of them reproducing the breeds. Even though farmers generally commit themselves not to sell breeds to anybody, there is a risk that such a situation may arise. The breeder cannot do anything, neither to effectively prevent such releases, nor to fight against the patent holder who will modify and commercialize the breed since he is not a counterfeiter. Protecting animal varieties by trademarks does not work much better. Actually, trademarks only protect a name: by being the only one to use this name, the company gets a competitive position on the market. But trademarks do not protect the genetic improvement realised by breeders. Should a biotechnological company apply its invention to the variety and sell the genetically-modified variety, the breeder could not oppose it, even though his variety is protected by a trademark.

From a legal point of view, a better system would be to create intellectual property rights for animal varieties. Certainly, such a project comes up against several difficulties, like the legal definition of varieties. But in any case, such rights would provide better protection than the two types seen above.

B. Patents and effects on research and development in animal biotechnology

Theoretically, patents promote innovation and stimulate industry and academia to constantly pursue innovation. But as far as biotechnological inventions are concerned, it has been feared that patents may hamper the research and development of new innovations, for patents in this field are sometimes very broad.

a) Research exemption

It must be recalled, nevertheless, that patent law has a "research exemption" rule, whose goal is precisely not to block fundamental research. Any breeder or any company has a free access to patented animals or genes and may experiment in order to develop a new application of the gene or to perfect a protected method. But as its name suggests, research exemption is only valid within the confines of research. As soon as the breeder or the company develops an invention closely related to the patented one (for ex. a new application of a patented gene) and wants to commercialize it, he may be obliged to get the authorization of the patentee. The latter is not obliged to grant a license and may prevent the second invention from being commercialized. Such a position is uncomfortable, for the current trend in biotechnology is to deliver broad patents conferring wide monopolies. In this field, the risk that an invention be dependent on another one is therefore high. Is this also the case in animal biotechnology?

b) Effects of broad claims

Although the few wide patents found today in this field particularly concern animals used as experimental models or bioreactors, there are also some examples of wide patents regarding breeding of farm animals. For instance in aquaculture, one patent claims "all transgenic fish" expressing a growth hormone gene. Wide claims are also numerous in patents covering animal genes, such as genes encoding bovine prolactin, porcine growth hormones or salmon growth hormone, which already seem to be protected by a large number of potentially overlapping patents. A first inventor has a patent on the gene and its use, which is described in a relatively abstract manner ("the muscular growth regulation function operated by the myostatin gene"). A second inventor holds claims on a more specific part of the same gene for a more specific application ; a third one...etc.

In some of the above examples, the wide monopoly is legitimate because if the inventor was only protected for what he actually achieved - a specific transgenic salmon or a specific gene - anyone could freely carry out his invention by using a slightly different gene performing the same activity or by crossing the patented gene into a different species. The patent would therefore be commercially worthless. From a business perspective, wide claims are therefore essential to obtain effective control of breeding technology. But with regard to the future of research and development in this field, important questions must still be answered. For example, should insertion of a growth hormone gene into a pig always be a basis for claims over other farm animals, even if the effectiveness of the transformation techniques on these other strains may not be known at the time of patenting? In a similar vein, in a research sequence moving from a relatively abstract idea - for ex. "a fish gene having an antifreeze function" - to detailed implementation - a more precise description and application of this gene -, who should have what rights? As a matter of fact, excessively wide monopolies can prevent the useful improvement of inventions. Several patent-law directions should be considered by patent offices and courts, such as a strong non-obviousness principle and a reasonably limited scope of patent claims.

c) Patents on biotechnological processes

Fears are more concrete here because of the numerous patents on animal breeding and reproduction inventions, many of which are already distributed in the form of processes and some are licensed, so that effects on the breeding sector are easier to anticipate.

Some of these patents apply to specific and quite narrow situations (cloning of bovine embryos, method of producing transgenic pigs, process of culturing avian embryos, etc.) but others are broad patents on basic processes of animal breeding. For example, several broad patents cover basic approaches to the production of transgenic animals, such as a patent on genetic transformation of zygotes. Above all, a similar situation of broad patents exists in the field of marker-assisted selection tools. Here, a growing number of patents - especially in the pig sector - protect methods of detecting genetic mutations or genetic variations in functional genes that directly influence production traits, for example pigs that are resistant to stress or more likely to produce larger litters or to develop less intramuscular fat.

As the first generation of patents with a real impact in the animal biotechnology field, such patents have sometimes caused concern in the animal selection sector. The owners of these patents are in a position to require royalties from a very large number of persons working in the pig sector and the patent may be very difficult to bypass because of the broad monopoly. For instance, a Canadian company holds a patent on a "mutant RYR1 gene" and a method of identifying said gene in a pig. Claims are drafted in such a way that any method to determine the presence of the mutation is protected by the patent. Any improved process proposed by another company would be considered counterfeiting, which is all the more inconvenient when the requested royalties seem high. In these areas, it may be necessary to support public sector research and to explore ways to develop intellectual property arrangements in order to ensure that these techniques are available to the whole breeding sector at fair commercial conditions. This is particularly important for patents on methods of detecting diseases such as mad cow disease. In such situations, it would seem necessary to make adjustments to the patent system, which could rely upon a compulsory licensing mechanism tailored to this problem of broad patents.

C. "Farmer's privilege" and traceability of genetically modified animals

With the farmer's privilege, which is an exemption from traditional patent law, the E.U. directive tries to establish an equitable solution whereby both the farmer and the patentee will benefit from the invention.

a) The exemption

As far as he is concerned, the farmer appears to have the legal right to mate the patented animal and to perpetuate offspring without royalties. As long as it is for an agricultural purpose (milk, slaughter...) and not for a commercial reproduction purpose, it is not an act of infringement to reproduce a patented transgenic farm animal through breeding, to use such animal in the farming operation, or to sell such animal or the offspring of such animal. Though it is still difficult to know whether this exemption will be worthwhile for the farmer - because little is known on the genetic drift of transgenic animals - such a rule will be important especially for small farmers who intentionally reproduce animals.

Acting as a breeding company, however (selling the germ cells, semen or embryos of a patented animal) is considered to be commercial reproduction and is forbidden, as it is in direct commercial competition with the patentee. The patent holder has the legal right to forbid such use of his invention or to claim royalties. Nothing is clear, however, about application of the derogation, which is left up to the different countries' responsibility.

b) Application of the derogation

Firstly, states will have to specify exactly what the exemption means: does "pursuing of the agricultural activity" include the reproduction, by a farmer, of a patented transgenic sheep producing a therapeutic molecule in its milk? Does "livestock" include aquaculture fish? Secondly, states will have to take a position a more fundamental issue: the control of transfers of genetically-modified, patented animals between farmers.

In fact, although this may vary according to the species, patented animals will be dispersed from farm to farm. For example, in the beef cattle sector, transfers between farms are frequent and types of use are varied (bulls sold for immediate slaughter, for breeding purposes, etc.). Logically, the patentee should then sell breeding stocks with a side contract specifying the requirement to indicate any transfer of semen, embryos or animals. He could then monitor each transfer of patented animals, identify transfers for "commercial reproduction", test each animal and check which ones carry the patented genetic modification, and finally ask for royalties. But such monitoring seems highly difficult: is it realistic to expect farmers to become involved in such patent enforcement? Is a monitoring of sales and collection of royalties possible given the large volume of sales and numerous changes of ownership? Facing such difficulties, the patentee may find that policing to collect royalties is unnecessary and that marketplace solutions present the most efficient method of allocating the cost of enforcement. He may carry out no monitoring and claim no residual rights to fees but merely sell the animal for a higher price.

Today, national authorities tend to let companies and patentees find such marketplace solutions. Their first reaction is to transcribe the farmer's privilege "a minima", without any special rules, and to let things evolve as regards choice of companies commercializing G.M. animals. But such a solution may not be satisfactory, for two reasons. Firstly, a "pricing policy" could make the cost of the patent prohibitive and ruin the usefulness of the farmer's privilege, whose idea is to prevent, for practical but also for economic reasons, the payment of excessively high prices. Secondly, although patent law does not itself require any monitoring of animal transfers and uses, such monitoring may soon become mandatory since traceability requirements are emerging in the field of GMOs, in order to prevent ecological consequences or sanitary risks and to establish separate channels - genetically/non genetically modified animals and food derived from them - leaving the consumer free to choose. In the same way as it is already enforced in the bovine sector, traceability may oblige those concerned to organize the close monitoring described above, instead of simply choosing "pricing policies". For this reason, it appears necessary for States to participate, alongside breeders and farmers, in a global reflection on the articulation of patentees rights, farmer's privilege and traceability issues (which system, who pays ?...).

III. New breeding technologies and animal welfare

As seen above, the development of new breeding technologies is supported by the law. But at the same time, it may be limited for reasons of animal welfare, a concept which is gaining a growing legal importance and which could put special constraints on future breeding work.

A. Such a constraint is already reflected in patent law itself.

As such, patent law does not create any welfare or ethical problems. A patent only constitutes intellectual (not real) property. Moreover, a patent is only a monopoly for commercial use but does not make the invention acceptable to society. Even if a patent has been granted, the use of the invention may require authorization. Conversely, a ban on patenting does not prevent development and use of inventions that could make an animal suffer. Nevertheless, in accepting patenting, the patent directive makes a strong choice in favour of the development and use of biotech. inventions. It has therefore become necessary to put limits in the text. As far as animals are concerned, "processes for modifying the genetic identity of animals, which are likely to cause them suffering without any substantial benefit to man or animal, and also animals resulting from such processes" are not patentable. More broadly, "inventions shall be considered unpatentable where their commercial exploitation would be contrary to public order or morality". Any application for patent in the animal field will be subjected to a systematic ethical assessment. It will then need to have a clearly stated purpose so that its justification can be assessed by patent examiners. Well-being is not the only concern expressed by the E.U. directive, which also expresses a more philosophical concern - the identity of animals - about the mixing of human and animal genes or the creation of outrageous chimeras. But welfare nevertheless gets a determining role that may hamper patentability. The patent examiner must find out which human benefits are at stake and in cases where animal welfare is adversely affected, find out whether the "costs" in animal welfare will outweigh any reasonably expected human benefits. Inventions fighting against animal diseases and developing healthier animals would probably be patentable even if there is no clear human benefit. On the other hand, transgenic animals with enhanced productivity are a benefit, but some of them are subject to so many health disorders or discomforts that they may not be patentable.

Though the directive's measures are mere guidelines still open to interpretation by patent offices, it illustrates a very new legal trend. Traditionally, patent law has been considered as merely technical: novelty, non-obviousness and industrial applications were the only criteria determining patentability, public order and morality being very rarely applied as an exclusion. The directive illustrates a new trend where ethical matters - although subjective - and especially welfare matters may partly determine the protection of new animal inventions. It is likely that such a trend foreshadows a broader legal evolution, where animal welfare puts increasing legal constraints on breeding and selection.

B. Animal welfare may become a legal constraint for the future of breeding

Dealing with welfare in patent law only is not entirely satisfactory. Unpatented methods and animals may still develop freely, outside welfare considerations. Besides, patent law's primary objective is to stimulate the development of biotechnological inventions, so that in cases where negative effects are not clearly established (for ex. in vitro production of bovine embryos which could lead to problems with offspring), patent law will rarely use the so-called "precautionary principle" and wait for clearer justifications. And lastly, patent law considers welfare at quite a late stage in the development of inventions, while it would be more logical to think about it earlier. Welfare issues should primarily be dealt with elsewhere, in the current legal framework of breeding licenses.

This is not really the case today. Most rules on animal welfare apply to experimentation or farming practices (bad treatment, etc.) and do not put special constraints on breeding work. When a breeding program is approved by national authorities, there is generally no legal obligation to consider its welfare implications. In most European countries, the development of new transgenic animals will be assessed for its ecological and human health effects, for its zootechnical aspects and the genetic input it provides, but rarely for its consequences on welfare, this aspect being a matter of "moral conscience" for the breeders.

But for three combined reasons, it is anticipated that welfare will soon become a legal imperative in this area too. Firstly, welfare has become a key concept in law, which is more and more legally binding and more and more widely interpreted, beginning to extend to issues like adaptation to the environment, normal behaviour, not breaching the identity of species, and even to breeding and selection goals. A recent case brought before the European Court of Justice thus questioned the ethics of breeding Belgian-blue cows, which generally need caesarians to deliver. Secondly, even if welfare problems are not limited to biotechnology - which sometimes may indeed help to preserve farm animal welfare -, biotechnology has amplified the need for a global reflection on what is or is not desirable in the breeding sector. Thirdly, because the techniques are new and often lack public support, biotechnology has a propensity to push towards new and generally strict regulations, calling for an assessment of risks and opportunities.

With biotechnological developments, recommendations and regulations of animal breeding have multiplied over recent years. Many national administrations or committees are thinking about the direction breeding programs should take in terms of desirability, according considerable importance to welfare considerations (cf. French CNAG and English Farm Animal Welfare Council). For example, some reports suggest that broiler breeding companies now put emphasis on reduced leg problems and that turkey breeders are producing a less aggressive strain of turkeys which do not require beak trimming. The Danish Ethical Council also made a statement on the breeding of animals that are prone to birth difficulties, stating that performing caesarian sections is not a welfare problem in itself but it is unacceptable to continue breeding animals that are expected to need this procedure.

Legal rules have also been set up by the Council of Europe, which tend to take welfare into account when setting up a new breeding program. In particular, a measure has been systematically introduced in each amendment of the European Convention for the protection of animals kept for farming purposes, and now appears in some Community law texts. It says that "no animal shall be kept for farming purposes unless it can be reasonably expected, on the basis of its genotype or phenotype, that it can be kept without detrimental effects on its health and welfare". A transgenic swine whose genetic modification provokes arthritis or a featherless hen intended for rearing in cold conditions, cannot be "kept", which means a fortiori that they are not to be developed.

In national laws, some dispositions are even more explicit. For example, the German Tierschutzgesetz enables the authorities to take into account suffering caused to surrogate mother animals in IVF or embryo transfer techniques. In Denmark, the law on animal protection offers the Ministry of Justice the possibility to prohibit the application of biotechnology for production of animals in the agricultural sector, particularly for welfare reasons. The Netherlands recently passed a law imposing a mandatory license for each project on genetically modified farm animals. Under that text, no animal may be modified unless the Minister of agriculture grants a license on the basis of health and welfare.

C. No general ban for welfare reasons but a case-by-case assessment

Even if stricter or looser regulations may emerge at first in different countries, nothing suggests in the present evolutions that new farm animals or breeding techniques, taken as a whole, will be banned by the law. Rather, they will probably be subjected to a "yes, but" approach, which implies that new selection techniques are not per se unacceptable but that their use should be regulated and each project assessed. A case-by-case assessment of each breeding project may be performed under the current licensing procedures, in the early stages of the program rather than once the new farm animal line has been established. Every breeding project would then be subjected to a cost-benefit analysis, as exemplified in current patent law. Indeed, current welfare regulation itself is generally driven by such a cost-benefit analysis. Pain, suffering and distress must be avoided, but when they are "necessary" and "unavoidable", they may be accepted as long as they are kept to a minimum. In order for a breeding project to be acceptable, each breach of welfare would then have to be justified and proportionate.

[1] Christine Noiville. Centre de Droit des Obligations, Faculty of Law, Paris University I, Panthéon – Sorbonne, 75004 Paris, France

Farm Animal Breeding and the Consumer

Arie van Genderen[1] & Huib de Vriend[1]

1. Introduction

In general, the breeding of farm animals is not exactly an issue that appeals to the regular consumer because it is an activity that is not clearly visible at the very beginning of a production chain. The quality of the end product, the meat, the milk or the eggs is of more importance to them than the way in which those products are produced. Discussing the future of farm animal breeding is even more out of sight.
On the other hand, consumers all around the world have clear opinions about the large-scale introduction of genetic modification. Through the genetic modification of farm animals the farm animal breeders find themselves on the brink of a whole new era in their sector. It is exactly this development that could trigger a dialogue on farm animal breeding at large.
This creates an opportunity for more consumer involvement in a debate about the future developments and animal breeding techniques including genetic modification and cloning. Those subjects are the main areas of expertise of our organisation.

2. Hypothesis

Looking into the future is tricky business. Especially when it comes to issues about which one can only speculate. There is a lot of information available about the research that is going on in regard to farm animal breeding. Nevertheless, it is extremely difficult to predict which application will reach the point of large-scale introduction and how and when.
With the introduction of the genetically modified (gmo) soy and maize in several European countries, a debate is triggered on several aspects of farming and food security. Aspects which are not always directly related the technology of genetic modification. Questions that arise are on sustainability of modern agriculture, the role of seed companies, the use of pesticides, environmental and ecological safety, food safety and the possible allergy of gmo's. The genetic modification as such does create some concern with consumers and is the focus of the discussion at this moment for a relatively small, but rather noisy group.
Although genetic modification of farm animals for production purposes seems far away, the modifications aimed at production of medicines and organs already started and are gaining momentum. Very recently the set up of a flock of 10.000 sheep in New Zealand, for the production of a medicine in the milk, was announced. The sheep are genetically modified and cloned. And also in New Zealand they are planning to set up a herd of cows, genetically modified to produce milk that equals human breast milk. Also recently the company Genzyme announced

the cloning of goats. And last but not least the genetic modification of pigs, aimed at producing organs for xenotranspantations, is coming up strongly.
It is not very clear whether those sheep, goats, pigs and cows are a special breed to be kept separated from the 'ordinary' animals or just plain farm animals. Further questions that will arise concern the wool, the meat and other products that can be derived from those animals. Will the animals be destroyed after lactation or when the organs are taken out? Or will the wool and meat get on the market? And if so, shall those products be labelled then? Is destruction ethically and morally acceptable to citizens and consumers, let alone animal welfare organisations? The same questions apply to all genetically modified animals to come, be it for medical, pharmaceutical or plain production purposes.

The hypothesis with regard to the future of farm animal breeding is that the genetic modification of farm animals will trigger the same type of broad discussion on animal production at large, as is the case with gmo crops. The additional ethical aspects with regard to animals will increase the complexity of the debate (see also the article of Stine Christiansen and Peter Sandøe).
This leads to the following questions:
How to define 'consumers';
is genetic modification of (farm) animals an issue that concerns consumers;
is it possible to distinguish between different purposes (plain production or medicines) of the modification;
is it possible to influence the direction farm animal breeding is taking through dialogue between the sector on the one hand and consumers on the other hand.

3. Methods

Assuming there may be a parallel with developments in crop production, it is interesting to take a closer look at the market introductions and the reactions these triggered.
Several years ago, Monsanto took the world by surprise with the Roundup Ready Soya Beans. All of a sudden the product was on the market, without any preliminary discussion or introduction. Moreover, it entailed a commodity product and the gmo-soy was not segregated from the non-gmo products, thus limiting consumer choice, to be used in a whole range of consumer products and without any adherent consumer benefit. At first the US government tried to block any discussion on segregation and labelling products that contained gmo-soy. A fight they lost. The perceived environmental benefit (using less herbicides) was not confirmed by an independent source. Finally, at the moment consumer and environmental organisations started to mobilise public opinion, the soy sector was very reluctant in starting a dialogue and supplying the Non Governmental Organisations (NGO's) with independent information. By the time it became clear that openness and dialogue was probably the best strategy, it was too late. The NGO's have lost

all confidence in companies like Monsanto and other biotech companies. Which makes it hard to have an open, frank and reasonable dialogue on new applications and products.

On the other hand, having such a dialogue between the industry and the NGO's does not mean that all applications are to be accepted. Dialogue should be a two-sided sword and just trying to pursuade the NGO's to accept all gm-products and applications, as is the case, will not work. The interesting point in this case is that even Greenpeace, one of the fiercest opponents of the soy, hardly ever speaks out on genetic modification of plants as such. Which does not mean that they have no eye for the inherent risks that genetic modification of plants could pose. What they do say in their campaigns is that the soy may pose health risks to the consumer (especially allergenicity), that the use of herbicides should be banned and that consumers should have a choice, which means segregation of the crops, labelling of the products and a clear supply of gmo-free products. Those are the discussion topics, or in other words 'the consumer concerns'.

In the next chapters an attempt will be made to get the right picture of the consumer, the consumer concerns and consumer demands (Chapter 4). The results of a number of consumer surveys were collected, studied and framed together. The most important surveys are mentioned in the References. They form the basis of this article.

In addition a written survey was conducted among 50 European consumer organisations and 10 animal welfare organisations. The results are presented in Chapter 5. Chapter 6 contains the general conclusions.

4. A mosaic of surveys

In this Chapter the results of various consumer surveys that were conducted on genetic modification of plants and several surveys which (partly) have genetic modification of animals as subject, will be discussed.

Consumer attitudes towards genetic engineering and breeding technologies are complex, often ambiguous and diverse. First of all, different applications can trigger a wide range of reactions. Secondly, variations in social and cultural background may also lead to adverse reactions. This means that talking about "the consumer" is not very fruitful. It is necessary to clarify how consumer groups can be distinguished and in addition try to find out how those different groups react to genetic engineering in general and genetic engineering of farm animals in particular.

4.1. Consumer typology

There have been many attempts to classify or categorise consumers. In this article we look at two different classifications. The Dutch professor Meulenberg from Wageningen Agricultural

University. made the first one (Meulenberg, 1996). The second one was reported by Leslie Gofton et al in the "Studies on the socio-economic impact of Biotechnology (Gofton *et al.*, 1998). In his report 'Market and Consumer', Dr. M.T.G. Meulenberg developed the following 'seven pure consumer types':

1. *The environmental friendly consumer:* has a preference for fresh products, from biological (organic) agriculture and has an ambivalent attitude towards technology;
2. *The nature and animal friendly consumer:* is interested in animal welfare, nature conservation and ethics;
3. *The health consumer:* is primarily interested in his personal health, goes for products with specific traits like low calories, rich in …, and health protecting or health improving agents;
4. *The convenience consumer:* chooses for snacks, ready to eat meals (microwave), easy and fast to prepare meals at home, take away meals or eating out;
5. *The hedonistic consumer:* prefers (exotic) specialities, delicacies, refined products with added value, eating out in the better restaurants;
6. *The variation seeker:* chooses for diversification in meals and ingredients, takes ready to eat meals as well as spends long hours in the kitchen to prepare a special dinner;
7. *The price conscious consumer:* does his own cooking, chooses ingredients with the best price quality ratio (in relation to his income).

If all consumers could be categorised like this, life would be easy for marketers and policy makers. In the practice there may only be a limited number of consumers that fully fit the description, whereas large numbers move between the categories at will. An additional complication is that incidents (BSE, swine fever, etc.) may create panic reactions amongst all categories and cause (often temporary) switches in categories.
Still, the categorisation can be helpful when assessing the possible impact of new products or technologies. At least one can more or less predict what the reaction could be from one or several of the groups. For example, genetic modification of pigs aimed at creating very docile, fast growing animals with extremely lean and very cheap meat, might appeal to the groups 4, 6 and 7, but definitely not to 1, 2 and 5. If the meat was also extremely low in cholesterol it might also appeal to 3.

For breeders, farmers and retailers it is important to know how big (in numbers) the various groups are and how big their influence is in the media and in society as a whole.
To assess that in detail is outside the scope of this article, but should be tackled when making decisions for future developments.

A different classification, used in the survey 'Studies on the socio-economic impact of Biotechnology' (Gofton *et al*., 1996) is the triplet 'Triers', 'Refusers' and 'Undecided'. This study focuses on the acceptability of biotechnology in relation to food products, with special reference to farmed fish.

The smallest group they identified is those of the *refusers*. They will refuse any product made with genetechnology.

Slightly larger was the group of *triers.* Within this categorisation the authors found two noticeable typologies. The first is the 'enthusiastic' trier who is more predisposed to the perceived benefits of technology in general, and the belief that it has a role in economic and personal progress.

The second type of triers was typified as those with low incomes and traditional dependence on price. They have a rather fatalistic view of the world around them. But if the price is right they will try hightech products anyway.

The third and by far largest group is those of the *undecided*. Within this group, many influences will impinge upon the process of product acceptance. They assess the perceived benefits and risks of hightech products and compare them with alternatives on the market. But then, even when a technology or product is accepted, it does not guarantee purchase.

Combining the two systems is a bit tricky and should be read with some predisposition. The refusers are to be found in the groups 1 and 2 of Meulenbergs categorisation. And the groups 4, 6 and 7 could be the undecided. Groups 3 and 5 might try gmo products.

4.2. Some results of the survey 'Studies on the socio-economic.....(Gofton et al, 1996)'

In this study surveys were made (by telephone) in 6 European countries and in the pre-stage of the project focus discussion groups were set up in every country.

The outcome of the quantitative part, the telephone survey, corresponds largely with comparative surveys like the Eurobarometer (1997), see paragraph 4.6., and will not be discussed in this article.

In the discussion groups 'Method of Production' was one of the focus points. The outcome of the discussion showed that methods of food production are an important attribute for many of the discussants. However, despite the perceived importance of the production method to the discussant, it was not necessarily salient in the purchase decision. The production method often takes a secondary role to higher-level product attributes such as price and quality. For example, gene technology was generally perceived as the antithesis of organic farming. However, if organic produce does not meet expectations, the purchaser will look to non-organic products to meet their demands.

Nevertheless, many discussants expressed concerns that the existing foods they consumed were perhaps not as natural as they would like to think.

When it comes to the 'acceptance of genetically modified farmed salmon' the outcome of the discussions lead to the following percentages of 'willing' or 'not willing to try'.

Definitely will try	9
Probably will try	16
Might try	30
Probably will not try	25
Definitely will not try	20

Easily identifiable are the consumers who refuse outright any suggestion of buying any GM product (20%). These consumers reject the technology for reasons of perceived dangers to the environment or their own or societies health. They are the typical 'refusers'.

The other group, the triers (9%), represents a typical pioneer's characteristic. Although their choice could be based on insufficient information, they perceive the new technology or product as extending choice and thus are willing to give it a try. The third group, the undecided (71%) forms a majority. In general, they have a weak understanding of the (gm) technology and uncrystallised attitudes towards it. According to the authors their attitudes are likely to be influenced by the nature of the modification and the nature of the product being modified and of course the price. But they could also be influenced by the refusers or the triers. For a small group the flavour is a very decisive argument. In their perception the flavour of wild salmon is superior and whenever available this will be their first choice (this corresponds with the 'hedonistic' consumer from Meulenberg).

The author's conclusion of this part of the study: there is a need for product by product research to identify the factors affecting consumer acceptability of gm foods.

A more general conclusion to the studies as a whole reads as follows:

1. There appears to be a well-defined group of straightforward 'refusers' in regard to genetically modified food products, including fish. This corresponds to a large extend with consumer types 1, 2 and 5 of Meulenberg.
2. A relatively small group of 'triers' may have a positive attitude towards genetically modified food products in general. Meulenberg types partly 4 and perhaps 7.
3. The majority is 'undecided'. Their attitudes and purchasing behaviour may easily be influenced by: other groups, price quality ratio, media attention, incidents, etc.. Meulenberg types 4, 6 and 7

4.3. A small selection of other surveys

In 1995, Prof. Steenkamp of the Wageningen Agricultural University did a survey amongst Dutch consumers on the animal welfare issue (N=500). The question was: which aspects are decisive when buying meat.

From this survey he distilled the following graph:

Quality	%
Sensory quality	35.9
Easy to prepare	28.4
Speciality	21.6
Natural production (includes animal welfare)	14.1

He compared the outcome of his findings with surveys from Belgium, Spain and Greece. In this comparison animal welfare was down to place thirteen on a 17-point scale. Good quality, fresh, healthy and tasty were on top of the list.

Italy

In 1995 the RSPCA (UK) did a survey (N=1000) in Italy on the consumption of veal (European Brief, 1995). The main question of this survey was: *what the public in Italy thinks about veal production and consumption.* The answers read as follows:

- What are the main reasons for consumption: taste 32%, healthy 21%.
- Are you aware of the veal crate system: heard of it 22%, people concerned after getting the story 70%.
- General attitude towards animal welfare issues: acceptance of veal produced in more animal friendly manner 70%, prepared to pay a higher price 71%

France

The same survey (N=950), with the same questions, was conducted in France. The French answered as follows:

- Reasons for consumption: taste 51%, variety diet 33%, healthy 11%.
- Awareness of the veal crate system: heard of it 70%; concerned about it 35% (percentage did not alter after extra information).
- General attitude towards animal welfare issues: colour of the meat is important, under 50% are likely to change their eating habit.

Eurogroup for animal welfare

“Public attitudes in France, Great Britain, Spain, Italy, Germany on egg purchasing and labelling” (MORI poll, June 1998, N=1000). Below, some parts from the survey (Eurogroup for Animal Welfare, 1998).

One of the main questions was whether the labels stood for battery eggs or free-range eggs. In fact they were all battery eggs. Whereas the majority of the respondents thought they were free-range eggs:

Confusion about labelling

Country	Label	Wrong answer/ Don't know %
Britain	Farm Fresh	81
	Good Country Eggs	88
France	Oeufs Fermiers	97
Germany	Eier Frisch vom Bauernhof	96
	Bauerneier	96
Spain	Heuvos Fresco	75
Italy	Fresche	76
	Extra	84

Willingness to pay more for free range eggs
(up to 35% more, except Spain, not more than 1-20%)

Country	Willing to pay more %
Spain	78
Germany	79
Great Britain	77
France	60
Italy	57

<u>Survey summary:</u>

- The public is prepared to pay more for free-range eggs.
- The labelling of eggs is unclear and causes confusion about the way in which the eggs have been produced.
- A majority in each country feels that eggs from battery cages should be labelled as "battery eggs".

The Eurogroup concludes that there is serious evidence that the public awareness regarding the welfare of animals in food production is increasing and that people are willing to pay more for free range, welfare-friendly produced eggs. The figures seem to support this conclusion, but it is likely that a fair number of respondents gave the political correct answers.

The Consumentenbond survey (Van Genderen, 1997) shows the following results: 47% of the respondents always buys free-range eggs, 19% regularly and 16% sometimes. The Dutch egg wholesalers claim that the market for free-range eggs is about 30-35% of the total sales. So the conclusion is that a large majority of the consumers is potentially interested in free-range eggs, but only a relatively small percentage is actually buying them.

4.4. Consumer attitudes

In the survey “Consumer Behaviour Towards Meat” (Becker, 1998), the topic of attitudes was viewed in the light of the question whether it is possible to identify a correlation between consumer attitudes towards the origin of meat, animal welfare, the status of meat and so forth, on the one hand, and the intensity of meat consumption on the other.

In the interviews, conducted in six European countries, respondents were confronted with a series of general statements concerning food and meat, which they had to rate separately according to their choice. Below you will find a small selection of those statements and the answers.

The first statement was *“I would never serve a meal without meat for visitors”.* With the exception of the Irish (big meat eaters) and to some extend the Italians, the respondents disagreed fairly strongly. The Swedish disagreed most strongly, which corresponds with low average meat consumption in Sweden. At the same time, the majority of the respondents in Sweden, Spain and Ireland agree with the second statement *“meat is an essential part of a meal”.*

This is partial contradictory to the above mentioned outcome, but it shows that, although most consumers can imagine serving a meal without meat, many feel that meat is essential food.

II prefer to buy meat from animals which I know have been treated well”, was the third statement. Nearly 90% of the respondents agreed strongly or slightly with this statement. Ireland and Sweden ranked highest (92%). Next came Germany and Italy (88%), Spain (87%) and finally United Kingdom (84%).

More or less the same figures can be found for the statement, *“We should have more respect for animals”.*

This brings the researchers to the conclusion that, since in each country, information on animal welfare is seldom available for a specific meat product, the respondents seemed to refer more to a general vague interest in animal welfare rather than to their actual purchasing behaviour.

4.5. The consumer and genetic modification of animals

Most of the surveys come to the same two conclusions: the general public is poorly informed about genetic modification (plants and animals) and tends to be very sceptical about the application. But, as Sandøe and Holtug (1998) write in their article on ethical aspects: “it would be a mistake to believe that the scepticism of ordinary people arises simply from a lack of factual knowledge”. The Eurobarometer (1997) on Biotechnology underlines this statement with a simple graph which shows that in countries where the factual knowledge is low (e.g. Portugal), people are less concerned than in countries with a reasonable informed population (e.g. Denmark).

The survey “Publiek en genetische manipulatie (*Consumer attitudes towards genetic manipulation)* (Koopman *et al.*, 1998), contains two chapters that are of interest to this article. One chapter deals with the question which groups in society have a lot of influence regarding decisions about genetic engineering. First the respondents were asked which group had the most influence and secondly they were asked which group should have more influence. The results are as follows (first the percentage what people expect and between brackets what seems more desirable): scientists 90% (65%); companies 75 (25); government 70 (90); media 40 (21); NGO's 28 (61); general public 20 (70).

It is quite clear that people think that scientist, the media and the companies have too much influence on the decisions. Government, the general public and the NGO's should have more influnce.

The chapter deals with the genetic modification of animals. In general, a mere 50% is against genetic modification. When it comes to the more detailed questions there is a slight shift. In favour of higher milk production is 17%, whereas 77% is against it. Production of medicines through the milk of genetically modified animals is acceptable to 41% and exactly the same percentage is against it (the rest don't know). The production of donor organs for xenotransplantation is favoured by 46% and only 37% are against. But, if animal welfare is at stake 82% is against.

People tend to 'vote' different when the benefit of the modification is adherent. Like the modification of animals for the production of humane medicines or in the future perhaps tissues and organs for xenotransplantations. Another Dutch survey (Smink, 1998) shows that a small majority (52%) would approve the modification of cows for the production of lactoferrins (medicine) through the milk. But the same trait just for the benefit of a higher milk production was rejected by over 75% of the respondents.

The Consumentenbond survey (5) amongst 2.500 members (representative selection out of 650.000), shows the following figures (N=1872, 75%):

- g.m. of animals for medicinal purposes: 9% fully acceptable, more or less acceptable 35%, more or less unacceptable 19%, unacceptable 33%, don't know 4%.
- g.m. of animals for production purposes: 3% fully acceptable, more or less acceptable 12%, more or less unacceptable 23%, fully unacceptable 60%, 2% don't know.

In this survey the members were also asked which aspects are decisive when buying meat:

Decisive	price %	Freshness %	Housing of animals %	Killing mode %	Meat exterior %	Environm. aspects %
Never	6	1	39	64	1	34
Sometimes	25	3	42	24	5	43
Regularly	40	16	15	9	28	17
Always	29	80	4	3	66	6
Average*	2.9	3.7	1.8	1.5	3.6	2.0

*4 points scale: 1=never, 4=always

Freshness (3.7), exterior (3.6) and price (2.9) are clearly the most important aspects.

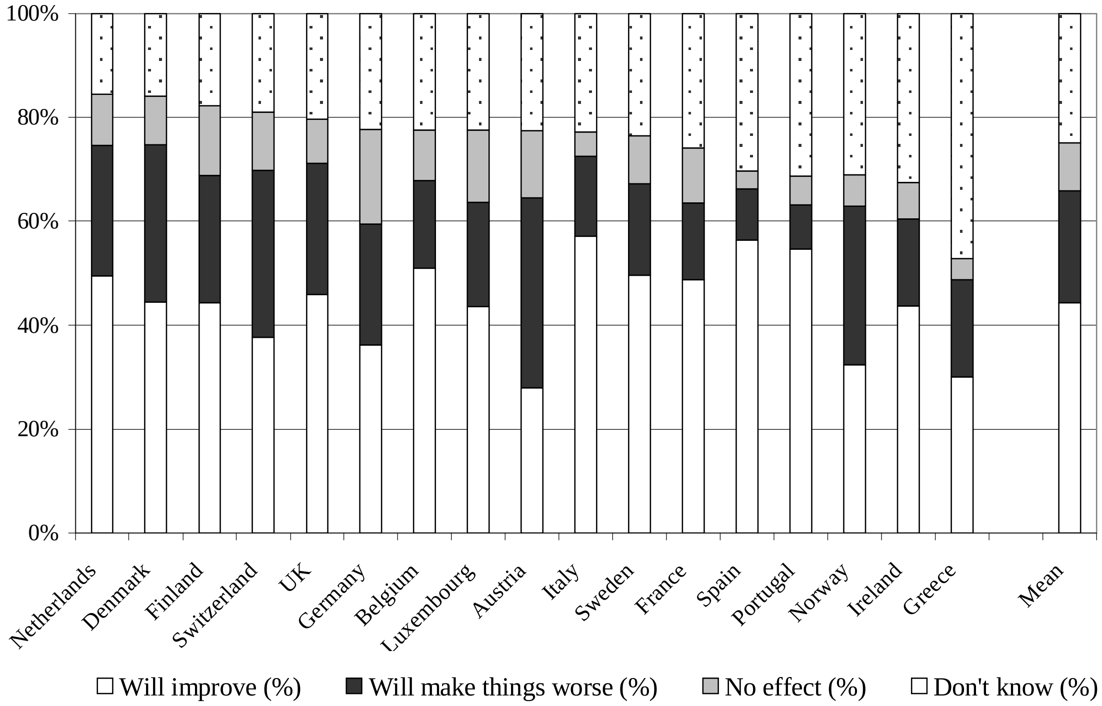
Interesting also is the question on factual knowledge:
do you know that……….

	Yes	no
Chicken feed standard contains medicines	47	53
From all chickens (free range and battery) part of the beak is cut off	48	52
Horns are cut away from all young farm animals (cows, sheep, goats)	37	63
Although forbidden, many meat animals are administered growth enhancers like hormones	91	9
Modern biotechnology is the same as genetic manipulation	64	36

4.6. The Eurobarometer (Eurobarometer, 1997; Durant et al., 1998)

The Eurobarometer on Biotechnology is probably the most cited report when it comes to assessing the impact of modern biotechnology (genetic modification) in the food production and the market. The Eurobarometer is periodically repeated, providing an opportunity to chart shifts in opinion since earlier surveys in 1991 and 1993.

A comparisson of the outcomes of the three consecutive Eurobarometer surveys shows that the number of 'optimists about the technology' is dwindling (Nielsen, 1997). In 1991 the percentage of optimists was 51%. The percentage of pessimists was 11%. In 1996 the percentage of optimists



had dropped to 44% and the number of pessimists had grown to 21%.

Figure 1: Results by country of the question: 'Do you think biotechnology or genetic engineering will improve quality of life, make things worse or will make no difference? (Eurobarometer, 1997)

An analysis of the beliefs about the effects of genetic engineering in general can explain differences in attitudes between countries (Figure 1). The results seem the contradict the idea that increased knowledge will create a more rational, thus positive attitude towards genetic engineering. There is even reason to conclude the contrary: the more people know, the less they seem to like it. Especially for applications in animals, agriculture and food, high levels of knowledge correspond with low levels of acceptance (Durant *et al.*, 1998). However, John Durant thinks it is not solely the level of knowledge that defines the general attitude of the public. Public expectations of biotechnology are generally highest in those countries where the technology has been applied the least, such as Spain, Greece and Portugal – and vice versa.
Nielsen (1997) thinks the large number of “undecided” (no effect, don’t know) in all the European countries might represent realism on the part of the public, rather than ignorance (Nielsen,). An “intuitive” public understanding of “declining marginal utility” might explain the public expectations to biotechnology. The public seems to understand that the consequences of modern biotechnology are uncertain because they depend on the politics of regulation and on market attitudes to applications. It states*: “The classical argument that beneficial technological innovation will diffuse in society stand to be contradicted or falsified by a persistent and widespread mobilisation of opinion against the technology. And the antipathy may be all the more*

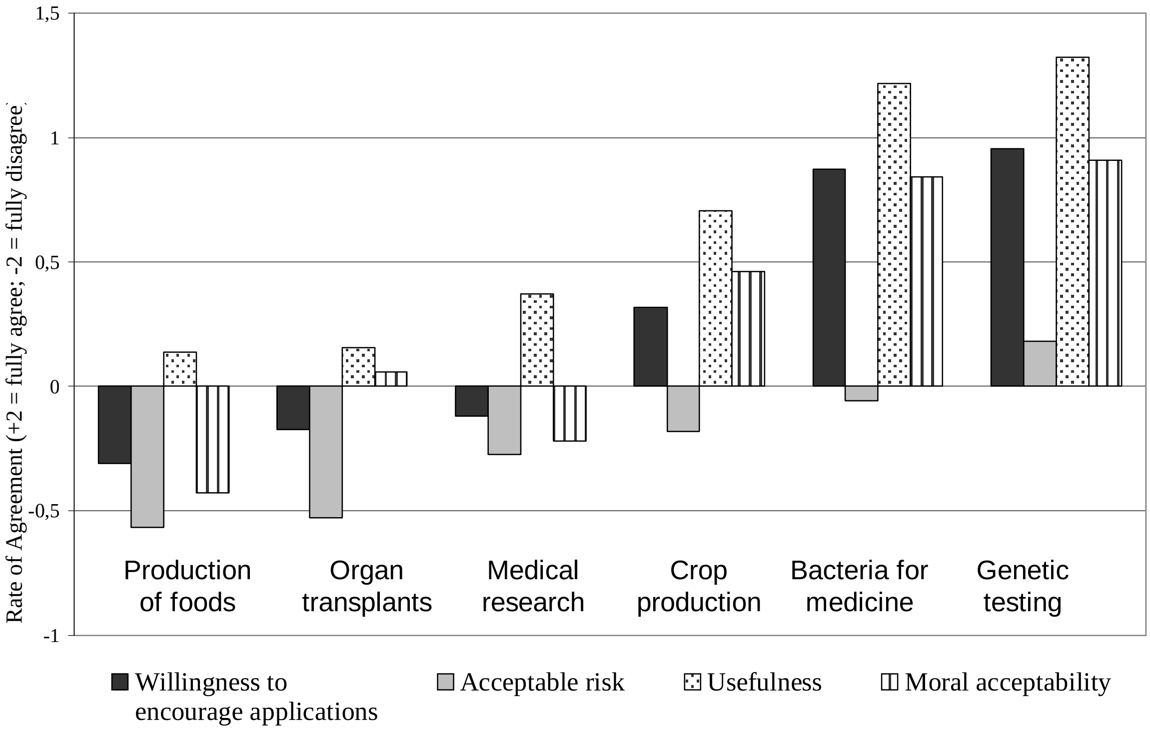


Figure 2: Responses to questions about encouragement of further development, acceptablity of risks, moral acceptability and perceived usefulness (Eurobarometer 1997, average for all countries)

effective because of its dual nature. There is a profound difference between preserving the old order, and hesitating in the face of future risks. Until those in biotechnology recognise that, changing public attitudes will continue to be a source of perplexity."

Another analyses of the Eurobarometer was made by a team of researchers working as part of a Concerted Action of the European Commission (DG XII) in 1997. They conclude that large sections of the European public seem deeply ambivalent about much of modern biotechnology. The prevailing focus of this ambivalence appears to be moral, a collection of anxieties about unforeseen dangers that may be involved in a range of technologies that are commonly perceived to be 'unnatural'. Their conclusions are best illustrated in Figure 2. The willingness for encouragement of further development of an application, which could be considered an indication for the level of acceptance, depends upon the nature of the application. The differences can be explained from a combination of the factors risk, moral acceptance and usefulness: Low perceived risk, moral acceptability and perceived benefits/usefulness correspond with more positive attitudes towards the applications.

A final general remark concerns the situations in which opinions tend to be quite polarised. Figure 1 shows this is the case in most countries: equal groups with outspoken positive and negative opinions and an often rather large group that has no clear opinion (yet) or does not know. The members of the most positive and negative groups are not very likely to change their minds. New developments, incidents, the media and opinion leaders can make the people that do not have an outspoken opinion shift to either the group. It is practically impossible to forecast the moment, the direction and extent of such shifts.
One question in the Eurobarometer survey focussed specifically on plant and animal breeding: 'Only traditional breeding methods should be used, rather than changing the heriditary characteristics of plants and animals through modern biotechnology' showed the following reactions.

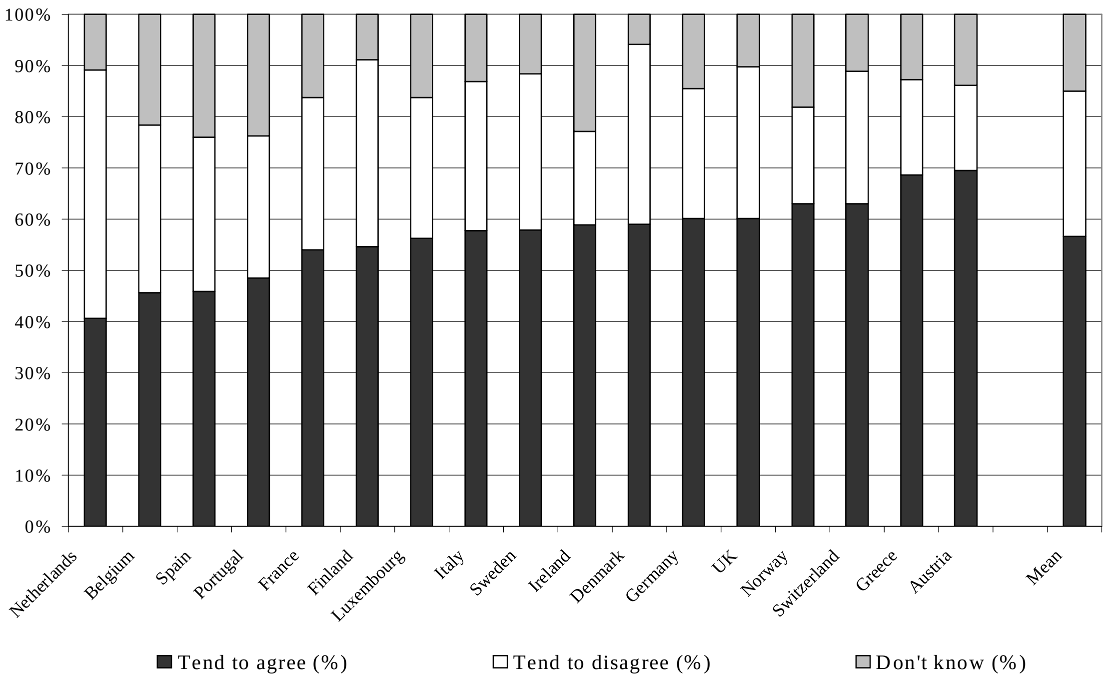


Figure 3: Responses to question: ‘Only traditional breeding methods should be used, rather than changing the heriditary characteristics of plants and animals through modern biotechnology’ (Eurobarometer 1997, by country)

5. Survey amongst consumer and animal welfare organisations

Although the influence that consumer and animal welfare organisation have on the factual purchasing habits of consumers is limited, they certainly do have influence on the public perception in regard to meat quality, meat (animal) production systems and animal welfare systems. Through their lobbyists they also influence the legislative process. This means that it is important to breeders and producers of animal products to take into consideration the demands those organisations put forward in regard to the whole production chain (from feed to food).
The Consumer and Biotechnology Foundation (C&B) did a survey that consisted of two parts. The first part was made up with questions regarding the interest (consumer) organisations have in the subject of animal breeding, keeping of animals and the quality aspects of animal food production. The second part focussed on three future scenarios which were put forward to them. On 10 December 1998 a questionnaire was sent out to 50 consumer organisations and 11 animal welfare organisations. The questions were related to a number of scenario's in regard to the future of farm animal breeding. On January the 7th 1999 a reminder was sent to the same addresses.
On the 3rd of February 1999 13 completely filled out questionnaires have been received. So the score is 21%.
The questionnaires received came from:

1. De Verbruikersunie, a Belgian consumer organisation
2. The Farm and Food Society, a British organisation of family farmers
3. Talis/Aequalis, a French animal welfare association
4. EKPIZO, a Greec consumer organisation
5. GAIA, a Belgian animal welfare organisation
6. Verein für Konsumenteninformation, Austrian consumer organisation
7. Kuluttajaliito, Finnish Consumer Association.
8. ADDA Association, Spanish animal welfare organisation.
9. OCU, Organizacion de Consumidores y Usuarios, Spain
10. CLCV, a French Consumer Organisation
11. Eurogroup for Animal Welfare, Brussels, Belgium
12. National Consumer Research Centre, Finland
13. Dutch Society for the Protection of Animals, Den Haag, the Netherlands

This ads up to the following conclusions:

- a questionnaire is perhaps not the best way to get information from this type of organisations, or
- the subject is of minor importance to those organisations.

5.1. Review of the answers Questionnaire part 1, general questions

The first question was about the involvement of the organisation in the subject of animal breeding and or the sale of animal products. Of the consumer organisations 2 are actively involved, 2 are not actively involved and 3 have some involvement. Of the animal welfare organisations 5 are actively involved and one answered with "some involvement".
One of the most important general questions was: "Do you consider animal breeding and live stock production important consumer issues?" The answer was a clear "yes" from 12 out of the 13 respondents. This needs no further discussion. Next they were asked to be more specific on the various aspects of live stock production. The ethical aspects of animal breeding are considered to be important consumer issues by 4 consumer and 6 animal welfare organisations. Two consumer organisations thought it to be of some importance and one did not answer the question.
The question about the ethical aspects of animal keeping (factory farming) resulted in almost the same score, respectively 5, 6 and 2.
The safety of animal products is an important consumer aspect according to all respondents, as is the use of growth promoters. The irradiation of meat (or other animal products) and the genetic modification of farm animals are also important consumer issues. Strikingly, one consumer organisation thought both subjects to be of minor importance to consumers as long as the safety of the products was guaranteed.

Some conclusions from this part of the questionnaire:
The two consumer organisations that said 'no' to the first question are not actively involved in the subject, but nevertheless do test animal products en publish about it. One of the two organisations also answered 'no' to question number two, which is a bit strange as later on they do agree on most of the aspects from question 3.
The overall conclusion is that consumer and animal welfare organisations are rather unanimous in their answers. They do agree on the fact that animal breeding and live stock production are definitely 'consumer' issues, including the more specific aspects of animal production.

5.2. Reviews of the answers Questionnaire part two: scenarios

In this part of the questionnaire, after a short general introduction, the organisations were confronted with three possible scenarios for the future in farm animal breeding. In brief the scenarios read as follows:
A) conventional path: more or less a continuation of the current system, with emphasis on perfect animals and products for a reasonable price.
B) welfare path: emphasis on animal welfare, moderate production levels, but resulting in higher consumer prices.

C1) high tech path: emphasis on maximum production levels and efficiency, special product traits and fairly low prices.
C2) high tech path: emphasis on maximum production levels and efficiency, special product traits and fairly low prices, including the use of biotechnology and cloning.

The organisations were questioned in detail on all possible aspects and choices in respect to the three scenarios. To start with the scenarios, C1 and C2 are definitely rejected by 10 out of the 13 organisations. Only one consumer organisation is willing to discuss it to some extend. Two organisations did not answer this question. The Scenarios A and B are more or less acceptable. For Scenario A the score was acceptable 6, not acceptable 2, to some extend 4. Scenario B scored respectively 7, 1 and 4.

Which of the following breeding technologies are acceptable to your organisation?
1= no problem; 2 = acceptable; 3 = acceptable for product quality and healthy products; 4 = only acceptable for welfare and disease resistance; 5 = not acceptable; 6 = don't know.

Technique	1*	2	3	4	5	6
Reproduction:						
Artificial insemination	2**	4		1	3	1
Freezing of semen	2	4			3	2
Heat induction		1			5	4
Embryo Transplantation	1	1			6	3
Ovum Pick-up		1			6	4
In Vitro Fertilisation	1	1		1	5	3
Cloning: embryo splitting	1				9	1
Cloning: nuclear transfer	1				9	1
Sperm sexing	1			1	4	5
Embryo sexing	1				6	4
Monosexing (fish)			1		6	4
Inter specific hybridisation (fish)	1				7	3
Triploidisation (fish)	1				8	2
Cytogenetics (fish)				1	6	3
Selection:						
Gene mapping	1	3		1	3	2
Marker assisted selection	1	2		1	2	4
Genetic. Modified animals						
With DNA introduced from the own species	1			1	8	2
Transgene animals (DNA From other organism)					10	2
Transgene animals for Xenotransplantation			1		8	3

* = rating, ** = number of respondents

6. Discussion and conclusions

6.1. Discussion

In 'Agrarisch Dagblad' of 24 December 1998, an article was published under the heading '*Ballot paper or cashier ticket'* (Vullings, 1998). The major statement of author Jan Vullings reads*: "The public goes shopping with two hats on. As good citizens they like to follow the lamentations of the animal protection organisations about the so-called abuses in animal keeping. But as soon as this good citizen enters the supermarket, he no longer acts as critical consumer. He looks at the cashier ticket instead of the ballot paper. A double standard. And it is just this double standard that wreaks havoc on the farmer'.*

This article describes the problems the farmers have with the demands for safe, healthy, welfare friendly and environmentally sound products: *"Demands aired mainly by the consumer and animal welfare organisations. It is no problem to the farmers to deliver those products, but it has a price. And as long as the consumer is not willing to pay a fair price and keeps looking for cheap foods nothing will change".*

Apart from this 'double standard' amongst consumers it is obvious that the whole situation in regard to animal production systems is highly polarised, with a fairly large segment of the population 'undecided'. The latter may, depending on incidents and media attention for the subjects, develop a more polarised attitude. This development will depend on a great number of factors. One factor is the influence groups with more extreme attitudes in the field of animal production systems may have on the debates and the legislative system. Another factor is the type of application and the perceived benefits to the consumer. Also the media could play an important role in the process. Highlighting incidents, the headings of articles and the general 'tone' could create a very negative image to new developments like genetic modification and cloning. On the other hand, a more positive attitude from well trusted sources like consumer and animal welfare organisations could create a more positive attitude amongst the 'undecided'.

In Chapter 2 it was presumed that the genetic modification of animals will trigger a discussion on animal products at large (breeding, housing, product segregation, labelling) as an analogy with the introduction of gmo-crops.

The question is: does the studied literature support this hypothesis? To be honest, a clear yes or no is not possible because of lack of clear data. The reason for this is that most of the material was on the genetic modification of plants and the material on animals focussed primarily on animal products and not on the breeding of animals.

On the other hand, some surveys give at least some indication that there is reason for a cautious approach of the matter. The SWOKA survey (Smink, 1998) indicates that, at least in the

Netherlands, a large portion of the respondents is weary about the genetic modification of animals for improved production traits. Only a small majority would accept the genetic modification if the benefit was clear, i.e. the production of life saving medicines for example. A result close to the outcome of the (also Dutch) Consumentenbond survey (Van Genderen, 1995). And in the case of the gm-farmed-salmon (Becker *et al*, 1998) a mere 55% of the respondents said that they would or might try the fish. Which leaves 45% saying no.
The weariness of large numbers of consumers will undoubtedly lead to a debate on the genetic modification of animals. But what shape this debate will get remains to be seen.
By parity of reasoning the question whether genetic modification of animals is an issue that concerns consumers (Question 2) is more or less answered. In addition, the results of the questionnaire amongst the consumer and animal welfare organisations show clearly that the genetic modification of animals is definitely an aspect that concerns them. And they are the organisations that may set the stage for a debate.
The question whether it is possible to distinguish between different purposes of the modification, can only partly be answered. Again the SWOKA and Consumentenbond surveys (Smink, 1998, Van Genderen, 1995) give an answer: yes, consumers do look at the type of modification and the purpose. If the benefit to society is seen as important, less opposition can be expected as is the case when this benefit is not so obvious or absent. And on basis of the Eurobarometer there is little reason to expect really fundamental differences in this aspect between the EU member states.

Question number 4, is it possible to have a fruitful dialogue between breeders and the public, is most difficult to answer. The soy-case has taught us that the introduction of gm-products, without any consumer benefit and no communication and dialogue, will backlash on the sector. On the other hand, no one can guarantee a smooth introduction of genetic modification of animals, for whatever purpose, by having such a dialogue.

From the questionnaire, how limited the response may be, we can learn a few things. First of all, as said before, genetic modification of animals does concern the consumer and animal welfare organisations. Which means that the average consumer will hear about it. Also, the animal welfare organisation, and to a lesser extend the consumer organisations, opt for scenario number two. This is the scenario in which the breeding is focussing on animal welfare and health aspects. Some consumer organisations are in favour of reasonable priced, good quality and safe end products and do not have such clear-cut ideas of how to reach this goal. Although, the genetic modification of farm animals does not have their preference. Remains the question whether the average consumer is prepared to pay the price for welfare friendly products.

6.2. Conclusion and recommendations

When introducing new, sophisticated techniques like genetic modification of animals, the following should be taken into account:

- the benefits of new product(s) or techniques should be evident and clearly demonstrated to the general public.
- there seems to be little public support for the genetic modification of farm animals.
- the genetic modification of farm animals for medical purposes seems to be more acceptable to the general public than for production purposes. However, a large scale destruction of gm-farm animals, or the use of carcasses from gm-animals for feed and/or food purposes may easily trigger a discussion on the sector as a whole.
- segregation of the products derived form gm-animals and labelling of the end product will give the consumer the opportunity to choose.
- general consumer concerns are to be taken serious and tackled with openness and, whenever possible the will to comply with those concerns (demands) in terms of R&D.
- in order to become familiar with those consumer concerns and to create a future scenario, which has support in society, an open pro-active discussion should be started at an early stage. The breeders should preferably base their policy on the outcome of a dialogue with the consumer and animal welfare organisations

References

Becker, Tilman; Benner, Eckhard; Glitsch, Kristina (1998) - “Consumer behaviour towards meat in Germany, Ireland, Italy, Spain, Sweden and the United Kingdom”- Dept. of Agr. Policy and Agr. Economics; Universities of Hohenheim and Göttingen.

Durant, J. et al (1998) - Biotechnology in the public sphere, Appendix 2: Eurobarometer 1996, survey results, Science Museum, London.

Eurobarometer (1997) – The Europeans and modern biotechnology. Eurobarometer 46.1. October and November 1996. EU Study EC DGXII. 87pp.

European Brief (1995) - “Veal and Animal Welfare – what the Public Think in Italy and France” RSPCA (UK).

Eurogroup For Animal Welfare (1998) - MORI Survey. Public Attitudes in France, Great Brittain, Spain, Italy, Germany on Egg Purchasing and Labelling.

Gofton, Leslie; Kuznesof, Sharron; Ritson, Christofer (1996) - “Consumer acceptability of Biotechnology in Relation to Food Products, with Special Reference to Farmed Fish” - EU Study EC DGXII, University of Newcastle Upon Tyne.

Koopman, B.; de Jong, J.M.; Gutteling, J.M.; Seydel, E.r. (1998) - Publiek en genetische manipulatie 1998: meningsvorming en informatievoorziening, Twente University (Enschede, The Netherlands).

Meulenberg, M.T.G. (1996) - "Market and Consumer" -, Wageningen Agricultural University (in Dutch)

Moses, V. (1998) - "Looking at the Biotechnology Consumer"; EU Study EC DGXII, King's College, London 1998.

Nielsen, Torben Hviid (1997) - Nature Biotechnology, Vol. 15 December 1997; "Behind the color code of "no". Based on Eurobarometer on Biotechnology, 46.1.

Sandøe, P.; Holtug, N. (1998) – Ethical Aspects of Biotechnology in Farm Animal Production. Acta Agric. Scand. Suppl. 29

Smink, C. (1998) - Maatschappelijke Acceptatie van genetische modificatie bij dieren – SWOKA (in Dutch).

Van Genderen, Arie W. (1995) - "Animal Welfare and the Environment"; study on behalf of the Consumentenbond. Consumer & Biotechnology Foundation (in Dutch).

Vullings, Jan (1998) - Stemkaart of kassabon? - Agrarisch Dagblad, December 24,1998.

[1] Arie van Genderen. Huib de Vriend. Consumer & Biotechnology Foundation, P.O. Box 1000, 2500 BA The Hague, The Netherlands

Appendix 1

Breeding technologies

The selection and reproduction of animals are the key actions in improving animal performance for a defined characteristic. The art of choosing and reproducing animals has been enormously improved in the last fifty years. Techniques like artificial insemination have spread widely in cattle because of the possibility of using frozen bull semen. Nowadays, advances in reproductive and genome technologies allow the implementation of more and more efficient breeding schemes. Besides the reproductive technology of cloning an adult sheep and producing the world famous Dolly, other possibilities of managing the reproduction of farm animals exist. Some are already routinely used, others are available but still not cost effective or still under improvement. Genome technologies showed a great progress with the introduction of Polymerase Chain Reaction (PCR) and application in selection programmes. Marker Assisted Selection (MAS) is already a reality in plant breeding and in some cases in animal breeding. In principle, it can be applied in all farm animal species.

We will briefly describe which reproductive and genome technologies are available in farm animal breeding. As said before some of the reproductive techniques are used routinely, like Artificial Insemination (AI) or Embryo Transplantation (ET).

<u>Artificial Insemination</u> was used first by an Italian physiologist Lazzaro Spallanzani in 1780, who obtained pups from his dog. Nowadays, AI is used in different species and breeds, including humans. This technique combined with the use of frozen semen has revolutionised cattle breeding throughout the world. Other livestock species have had a slower development, due to difficulties of collecting and freezing semen, and inseminating females. Sheep artificial insemination, for example, is not so routinely used in animal breeding. Unfortunately, the anatomical structure of the cervix prevents intrauterine deposition of semen by insemination syringe (Cappai *et al.*, 1998). Consequently, cervical artificial insemination with frozen semen results in low fertility (Maxwell & Watson, 1996), due to impaired sperm transport through the cervix and the short survival of frozen-thawed spermatozoa in the female reproductive tract (Lighfoot & Salamon, 1970). In pigs, mainly fresh semen is used, because of the lower fertility rate of frozen and thawed semen. In poultry, salmonids, catfish and turbot the females are inseminated artificially. Semen can be frozen in all fish species, but in practice the use of frozen semen is limited for conservation purposes and the preservation of genetic resources (Maisse, 1996). Anyway, in all farm animal species where it is used, the AI technique offers several advantages, such as control of animal disease (only healthy animals are used. AI has been important in limiting the dissemination of venereal diseases), genetic improvement (excellent animals can be used more often and more efficiently), and moreover the exchange of valuable genetic material, for species where frozen semen can be used easily (Salisbury *et al.*, 1978;

Foote, 1980; Colenbrander *et al.*, 1993; Perret *et al.*, 1997; Cunningham, 1999).
Embryotechnology, the production and the transfer of embryos, has become well established in modern livestock breeding programmes. The recovery of embryos includes the induction of multiple ovulation by hormonal treatment, a technique known as Multiple Ovulation and Embryo Transfer (MOET). This technique has now been used for over 20 years, mainly in cattle but also possible or under development in horses, sheep, goats, and pigs. In the 1950s MOET was appreciated because it enabled the production, storage, and transfer of embryos. Main benefit of ET is the increased number of offspring per female, thus increasing the reproductive rate of females and their contribution to the breeding programme. Furthermore ET, for all mammals, permits an easier and more rapid exchange of high genetic material between countries, and reduces the cost of international transport by flying embryos rather then shipping animals. ET can limit the need to transport live animals between farms, thus decreasing the risk of infectious diseases. The technique consists in the recovery of embryos from elite female (donors) and the transfer of them to recipient females. This technique is really important because from this technique all the new technologies have started. The only disadvantage of the technique is the high cost, varying from one country to another, but costs are always high. Therefore it is usually used for breeding animals only (Ruane, 1988; Woolliams & Wilmut, 1989; Polge, 1995; Nicholas, 1996; Wilmut, 1996; Cunningham, 1999). The importance of the technique depends on the ability to recover, store and transfer embryos on recipient females. The *in vitro* production of embryos (IVEP) is a technique which involves three steps: recovery and maturation of oöcytes (IVM), fertilisation (IVF) and the culturing of the resulting embryo to a stage at which it can be transferred into the uterine horn of a recipient female. Oöcytes can be collected from the ovaries of slaughtered females by aspiration, or by the recently introduced *ex vivo* ovum pick up (OPU - Pieterse *et al.*, 1988; Brackett, 1992; Besenfelder *et al.*, 1998). With OPU oöcytes are recovered directly from live animals. This technology can fundamentally increase the number of offspring produced per donor animal without having to subject the female to any hormone treatment. Due to this technology limitations in female reproduction may be overcome (Leitch et al., 1995; Galli & Lazzari, 1996). The commercial application of IVEP depends on the type of embryos produced. In cows, for example, only 30% of cultured oöcytes develop into embryos to be transferred (Cunningham, 1999). The disadvantage of this technique is that it can be done only in the laboratory. Moreover it is a really costly technique.
Another technique, sex determination (sperm or embryo sexing), is not used routinely. Sperm determination consists of the identification of a minimal difference in DNA contents (about 3%) between X and Y spermatozoa using a flow cytometer (Pinkel *et al.*, 1982; Cran, 1992). In embryo sexing the presence or absence of the Y-chromosome, specific to the male, inside some cells of the embryo, is determined (Nibart, 1992; Powell & Wilmut, 1995). These latter techniques are or will be important in farm animals, because they can reduce costs. For example it will be

possible to obtain heifer calves for dairy replacements and bulls for beef production. Supernumerary male embryos in particular in export programmes could be eliminated and fewer female recipients could be used, resulting in a big economic advantage. In livestock the production of identical twins (monozygotes) by means of a micro-surgical division (splitting) has also become an acceptable practice. In poultry, the sex determining gamete is carried by the female. As cell division takes place before the shell is laid down on the egg and the egg laid, it will technically be very difficult to determine the sex of poultry embryos. In fish farming, the phenotypic sex of the males or females can be managed by external factors (e.g. temperature, density). Males often mature before they achieve the commercial size desired by the consumer. This is used to produce monosexed fry (mostly females) without hormonal treatment. Like 99% of the animals and all plants, polyploïds occur in wild fish or mollusc populations. These fish and molluscs are sterile. Triploïdy can be induced by managing the thermal or hydrostatic conditions after fertilisation (Chevassus, 1987). The triploïd fish and molluscs could be introduced in farming in order to prevent the mixture of selected with wild animals in nature.

The embryo splitting technology is now used commercially to increase the number of lambs or calves born following routine embryo transfer or *in vitro* embryo production.

Cloning, the production of multiple, genetically identical animals by means of nucleus transfer into enucleated oöcytes is basically possible (Wilmut *et al.*, 1997). Anyway, it is a technology, which requires improvements in terms of efficiency and repeatability until becoming a rountine livestock application. Analysis of the genome has become feasible, thanks to the molecular technologies developed in the last decade that have permitted the location of several genes of some interest in different species.

The purpose of the gene mapping in livestock is to identify and locate the genes along the genome (pigs, cattle, sheep, goats, poultry, fish), in order to identify genes controlling traits of economic interest. Once the gene has been identified, it is important to combine all genetic information at markers and quantitative trait loci (QTL) with the phenotypic information to improve genetic evaluation and selection (MAS= marked assisted selection). The advantage is that the effect of genes on production is directly measured in the genetic make up of the animal and not estimated from the phenotype of the animal or its relatives as before. Theoretically M.A.S. offers the possibility of a rapid selection because of the direct detection of the genetic merit of an individual. Traditional selection methods will not be replaced by molecular genetics but an integration of the two selection methods could be beneficial to the selection response.

With the transgene technology a gene or genes of a species are transferred into the DNA of another animal of a different species (Cunningham, 1999), or part of the gene is ‘knocked out’ . The technique offers several possibilities such as improvement of animal production (milk, meat, wool), product quality and disease resistance (Mcclintock, 1998), or the possibility of fish to consume plants to limit the use of wild fish in fish feed.

References

Besenfelder U., Müller M., Brem G. (1998) –Transgenics and Modern technologies- In “ The genetic of the pig” Edited by Rothshild M.F & Ruvinsky A.

Brackett B.G. (1992) -In vitro fertilization in farm animals- In” Embryonic development and Manipulation in Animal Production”. Symposium on Embryonic Technology in Domestic Species, Milan 1992, edited by Lauria & Gandolfi, 282pp.

Cappai P., Sanna S.R., Branca A., Fraghì A. and Bomboi G. (1998) -Comparison of Laparoscopic and Transcervical insemination with frozen semen in Sarda dairy ewes- Animal Science, 66-369, 373.

Chevassus B. (1987) – Charactéristiques et performances des lignnées uniparentales et des polyploïdes chez les poissons d’eau froide. In: “Selection, Hybridization and Genetic Engineering in Aquaculture” Ed. Tiews, Vol2.: 145-162.

Colenbrander B., Feitsma H., Grooten H.J. (1993) -Optimising semen production for artificial insemination in swine- In ”Control of Pig Reproduction IV” Eds. Fox Croft G.R., Hunter M.G., Doberska C. 297pp.

Cran, D.G. (1992) -Gender preselection in mammals- In: “Embryonic development and Manipulation in Animal Production” Symposium on Embryonic Technology in Domestic Species, Milan 1992, edited by Lauria & Gandolfi, 282 pp.

Cunningham E.P. (1999) -The application of biotechnologies to enhance animal production in different farming systems. Livestock Production Science, 58: 1-24.

Galli C & Lazzari G. (1996) -Practical aspects of IVM/IVF in cattle- Animal Reproduction Science, 42: 371-379.

Leitch H.W., Smith C., Burnside E.B., Quinton M. (1995) -Effect of female reproductive rate and mating design on genetic response and inbreeding in closed nucleus dairy herds- Animal Science, 60: 389-400.

Lighfoot R. J, Salamon S. (1970) -Fertility of ram spermatozoa frozen by pellet method. I. Transport and viability of spermatozoa within the genital tract of the ewe- Journal of Reproduction and Fertility, 22: 385-398.

Maisse G. (1996) Cryopreservation of fish semen: a review. In: “Science et Technique du Froid “ Ed.: International Institute of Refrigeration. Bordeaux Aquaculture’96, 443-466.

Maxwell W.M.C., Watson P.F. (1996) -Recent Progress in the preservation of ram semen- Animal Reproduction Science, 42: 55,65.

Mcclintock E. (1998) -Possible impact of New Technologies on dairy cattle breeding- Proceedings of New Zealand Society of Animal Production, Vol. 58.

Nibart M. (1992) -Practical application of two advanced biotechnologies to bovine embryo transfer: splitting and sexing - In “Embryonic development and Manipulation in Animal Production”. Symposium on Embryonic Technology in Domestic Species, Milan 1992, edited by Lauria & Gandolfi, 282 pp.

Nicholas F.W. (1996) -Genetic improvement through reproductive technology- Animal

Reproduction Science, 42: 205-214.

Perret G., Brice G., Folch J. (1997) -Review of AI use and limiting factor in small ruminants in Europe-48th Annual Meeting of the EAAP, Vienna, Austria, 25-28 August 1997.

Pieterse M.C., Kappen K.A., Kruip Th.A.M. ,Taverne M.A.M. (1988) -Aspiration of bovine oocytes during transvaginal ultrasound scanning of the ovaries- Theriogenolog*y*, 30: 751-762.

Pinkel D., Gledhill B.L., Lake S., Stephenson D., Van Dilla M.A. (1982) -Sex preselection in mammals? Separation of sperm bearing Y and 'O' chromosomes in the vole Microtus oregoni- Science 218, 904-906.

Polge C. (1995) -Forthcoming strategies in animal reproduction and breeding- In" 30th Simposio Internazionale". Milano Settembre 1995, 3-11.

Powell D., Wilmut I. (1995) -Biotechnology in animal breeding - In: "Animal breeding and infertility" Ed. M.J. Meredith. 508 pp.

Ruane J. (1988) -Review of the use of embryo transfer in the genetic improvement of dairy cattle- Animal Breeding Abstract, 56: 6.

Salisbury G.W., Van Demark N.L., Lodge J.R. (1978) -Physiology of reproduction and artificial insemination of cattle- W.H. Freeman and Company, San Francisco, 798 pp.

Wilmut I., (1996) -New developments in embryo transfer- In" Roslin Institute Edinburgh Annual Report 95-96", 97pp.

Wilmut I., Schnieke A.E., McWhir J., Kind A.J., Campbell K.H.S. (1997) -Viable offspring derived from fetal and adult mammalian cells- Nature, 385: 810-813.

Wooliams J.A., Wilmut I. (1989) -Embryo manipulation in cattle breeding and production- Animal Production, 48: 3-30.