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Breeding and biotechnology in farm animals – ethical issues[1]

C. Gamborg & P. Sandøe

Introduction

Over the last century, and especially since the Second World War, animal production has become ever more efficient. Broiler chickens can grow to a weight of 2 kg in about five weeks, while 40 years ago it took twelve weeks to reach the same weight, and over the same period milk yields in most dairy cows have more than doubled. These achievements derive in part from improved management techniques, but to a large and still increasing extent they are the outcome of farm animal breeding, i.e. genetic improvement.

Recently, traditional selective breeding — using the best specimens of each generation as parents for the next generation — has been increasingly supplemented by various forms of biotechnology. Thus today's breeders employ techniques such as artificial insemination and embryotransplantation to control animal reproduction. In a not very distant future it seems likely that gene technology will be exploited commercially in a routine manner as well.

The tremendous growth in productivity has added to human wealth. It has also allowed farmers to make good use of the natural resources at their disposal. However, farm animal breeding has also had a negative impact — on animal health and welfare, and on genetic diversity. And these drawbacks mean that we need to ask whether some ways of using the tools delivered by animal genetics are morally unacceptable. In particular, we ought to ask: is economically motivated animal breeding that concentrates on improved

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productivity and carries costs in genetic diversity and animal health and welfare defensible? What limits to acceptable practice should we set in this area? And what other issues in breeding need to be looked at in the future? Greater control in this area is accompanied by a heavier burden of ethical responsibility.

These ethical questions must be faced by breeders, farmers, and ultimately the rest of us. To answer them we need to understand both the science and current practice of animal breeding. This understanding will ensure that the worries on which we focus are factually grounded and not based on erroneous assertions. But this is not enough. We also need to reflect on the values that lie behind attitudes to animal breeding — those, that is, that drive the search for improved productivity, and those that cause people to have misgivings about that search. For we need to resolve the ethical conflicts to which these values often give rise, and these conflicts will never be resolved while the parties to them lack mutual understanding of one another's perspectives and values.

Animal breeding and biotechnology

In prehistoric times wild beasts were tamed, and through generations of selection domesticated animals evolved. The domestication of animals has played a very important role in the development of our culture.

Ideally animal breeding allows us to design future generations of domestic animals. This can, for example, be done with particular regard for production, reproduction, health and functional traits. Breeding goals vary with species, local conditions and time. Thus ancient peoples were primarily concerned to obtain meat and skin, and to develop working animals, from cattle. The cows they kept produced little milk. Today in Western Europe, by contrast, specialised cattle are bred to produce either milk or beef. In many parts of Asia and Africa oxen are still bred for characteristics that improve their quality as transport animals. Pigs, which are always bred for meat, are subjected to breeding techniques that produce high quality pork or bacon at the lowest possible cost. Poultry have also followed this pattern of specialisation, and many breeds are now designed either to produce eggs (laying hens) or to produce meat (broilers). In laying hens, genetic selection has been for traits ensuring that more eggs are produced. In broilers the main breeding goal has been to improve juvenile growth rates and to encourage the efficient conversion of feed to meat.

Breeding techniques have developed dramatically over the last century. Systematic recording of the productivity of dairy cows started in the late nineteenth century. Other species, such as pigs and sheep, had to wait until the early twentieth century. It was at the beginning of the twentieth century, when Mendelian genetics was rediscovered, that breeding began to evolve towards more advanced breeding practices. Since then several changes have occurred that are worth noting. First, there has been a growing focus on production rather than the physical appearance of the selected parent animals. Secondly, the genetic potential of animals has come to be measured by looking at the performance of ancestors, sibs and offspring rather than looking at the performance of parent-animals. Thirdly, advanced biometrical models have been put to use to estimate the genetic potential of possible parent animals. Finally, modern biotechnologies, including molecular genetics, have been exploited by breeders.

In biotechnology a distinction can be made between reproductive technology and gene technology. The former aims to control (and often accelerate) the process of breeding. The first technology of this kind to be developed was artificial insemination, which allowed reproduction to take place without natural mating. In the 1950s a technique for freezing semen enhanced the potential of artificial insemination. Semen storage made it possible to pass on valuable traits from male breeding animals to a greater number of individuals, and to transfer genes over time and across local and global geographic boundaries. Contemporary breeders are, therefore, no longer restricted by the locally available gene pool. Worldwide, 110 million artificial inseminations are carried out in cattle each year (Thibier & Wagner, 2002).

Similarly, technologies have been developed to enable female animals to produce many more progeny than they would naturally. These include superovulation, which allows several embryos/eggs to be produced per selected donor, and embryo transfer, which enables the breeder to shuttle embryos to recipients that act as surrogate mothers. A technique has also been developed that makes it possible to remove immature eggs from female animals, mature and fertilise these *in vitro*, and then transfer the fertilised eggs to recipients which serve as surrogate mothers. These technologies have been of particular interest to cattle breeders, because in cattle there are long generation intervals and each cow normally produces only one calf per year.

Let us turn now to the other type of biotechnology used in animal breeding: gene technology. Gene technology makes it possible to 'map' genes. That is, it identifies the precise location of genes on chromosomes. Such mapping — which either uses direct selection of major genes or makes use of so-called genetic markers, i.e. a segment of DNA with an identifiable physical location on a chromosome whose inheritance can be followed — promises to be a very valuable aid in selective breeding. For it will allow selections to be made on the basis of genes rather than on the basis of properties of the animals to which the genes give rise.

Largely as a result of widely reported disputes over GM crops, the use of gene technology with the highest public profile is genetic engineering, i.e. the direct manipulation of an organism's genetic make-up to create genetically modified animals. Here genes from the same or another species can be introduced into a fertilised egg so that the organism that subsequently develops inherits genes of mixed origin. The mature organism might, for example, be an animal with disease-resistance genes originating in another species. It is worth emphasising at once that, until now, animals have been genetically engineered mainly for the purpose of biomedical research. At present there are no commercially available genetically engineered farm animals. And fish breeding is the only area in which genetically modified animals appear to be in the pipeline.

As we mentioned in the introduction to this chapter, the main objective of farm animal breeding was until recently to improve production and efficiency. Among other things, the pursuit of this objective has enabled farmers to become more cost effective and maintain an income in spite of the falling prices of farm products. Quite often farmers have not really had any choice here. They have had to rely on modern breeding if they are to survive economically. However, at the same time the technological developments we have described have caused varying degrees of concern among breeders, consumers and special interest groups.

The concerns in question relate to the negative impact of breeding on the health and well-being of farmed animals. Consider two examples. First, over the last hundred years milk yield in dairy cattle has increased substantially, from approximately 2000 kg to nearly 8000 kg per cow per annum, thanks partly to improved management and partly to intensive breeding. This development is welcome, both from the point of view of human standards of living and from a resource perspective. However, it has become evident that excessive breeding for high milk yields leads to animal health problems, including increases in digestive disorders and the incidence of mastitis, and reduced fertility and calving performance. Secondly, as we indicated above, a huge acceleration in the growth rate of broilers has been secured by modern selection techniques. The time required for broilers to attain commercially desirable weight has, as a result, been cut substantially. But as an unintended side-effect the birds now suffer from severe leg problems. Over recent decades companies involved in broiler breeding have invested considerable resources in breeding for leg-health. The problems persist, however. Some conditions have become less common, but at the same others have become more prevalent. In a recent Danish study it was reported that nearly one third of the birds had a significantly reduced ability to walk normally. There is every reason to believe that this impairment is painful to the animals. And a number of other problems seem to be connected directly or indirectly with accelerated growth. For example, the parent animals used to produce eggs from which the broiler chicken are hatched endure strict food restrictions under which they are permitted to eat about half of what their appetite motivates them to eat. In the absence of this restriction the animals become obese with dramatic negative effects on both animal welfare and production.

The genetic correlations between production and health traits appear in some cases, then, to be unfavourable in the sense that the genes that bring increases in productivity introduce dispositions to disease and other health problems. Even so, carefully designed breeding programmes might allow breeders to improve health and increase production at the same time — although the increases in production generated by programmes of the latter kind may be smaller than they would have been if the animal health issues had been ignored. But just how important is it to breed animals in a way that ensures good health? Are we morally obliged to do this? Or are those who worry about the plight of animals on modern intensive farms misguided sentimentalists? To answer questions of this kind it is necessary to look at the ethical principles that underpin concern about modern breeding practices directly. We shall do this in the next section. In practical terms we also need to examine alternative development paths for the future. We shall do this in the section after next.

Ethical limits to breeding

Ethical problems relating to breeding differ markedly from those connected with the way animals are kept by the farmer (Sandøe *et al.*, 1999). The ethical issues raised by animal husbandry concern *existing* animals. They include questions about the treatment of animals, and more specifically about housing systems, the opportunity to exercise 'normal' behaviour, the incidence of disease and so on. Here the relevant question is roughly this: bearing in mind that some husbandry practices cause pain or discomfort, what kinds of treatment are acceptable in the efficient farming of this animal?

By contrast, ethical questions concerning farm animal breeding relate to *potential* animals. The relevant question is: what sort of animals should there be? To answer this question we need to clarify the purposes for which it is acceptable to alter the genetic composition of animals (to a greater or lesser extent) in order to improve their utility to us. And we need to ask what kinds of concern should be considered in this connection. To some observers the mere thought of intentionally changing genetic composition through breeding is ethically unacceptable. Interfering with the 'natural' selection process is 'playing God'. A more widespread and moderate attitude to breeding runs as follows. We cannot undo our earlier interventions into the animal kingdom. Farm animals are in any case already domesticated and recognisably distinct from their wild relatives or ancestors. So the key ethical question is not whether we should abandon animal breeding but how we should breed. In particular we need to clarify the ethical limits of breeding.

In scientific and public debate three (as it were) auxiliary topics are repeatedly raised when modern breeding and reproductive technology are under discussion. These are: animal welfare, animal integrity and biodiversity. Let us examine these topics, and their relevance to breeding, in turn.

The precise definition of *animal welfare* is the subject of intense scientific and philosophical discussion (Appleby & Sandøe, 2002). However, it is fair to say that both physical health and the ability to exercise a range of normal behaviours are important measures of welfare (e.g. Sandøe *et al.*, 1997), and there is widespread agreement that pain and other forms of suffering impair welfare. The welfare problems encountered in animal husbandry relate in part, as already indicated, to breeding goals connected with high levels of productivity (Christiansen & Sandøe, 2000). Turkeys bred for muscular development suffer increased leg disorders and other health problems. Male birds are sometimes too heavy to mount females without damaging them, which makes artificial insemination necessary. Clearly these side-effects of laudable breeding goals may reduce the welfare of turkeys. Again, the breeding of double-muscled cattle for beef has lead to calving difficulties. In many cases Caesarean sections are required (Broom, 1998) and this increases the risk of welfare problems. Finally, reproductive technologies can also have a negative impact on welfare. Embryo transfer makes surgery necessary in sheep and pigs, and *in vitro* fertilisation has several unintended and unwelcome results: it leads to an increased number of late, spontaneous abortions and other birth problems (McEvoy *et al.*, 2001).

Most people would readily acknowledge that animal welfare is an ethical concern with a direct bearing on the issues raised by livestock farming and farm animal breeding. Is it, however, the only such concern? An example involving laying hens suggests that it is not.

Modern egg production systems are notorious for animal welfare problems. Often the laying hens live in battery cages, with limited possibility to walk. Alternatively, they are kept in large groups where there is a better opportunity for exercise, but this results in feather pecking, which in turn leads to damage to plumage and ultimately flesh wounds. Cruelly, these wounds encourage additional pecking from other hens, and there is in the worst cases a real risk of cannibalism.

Several attempts have been made to alter production systems to mitigate these negative effects, but they have been largely unsuccessful. A common containment measure is to mutilate day-old chickens by removing the tips of their beaks. Another approach involves breeding: it is to breed blind hens. For according to a Canadian study (Ali & Cheng, 1985), congenitally blind chickens do not face the same problems of feather pecking, cannibalism and other associated problems as do sighted ones. Purely from an animal welfare perspective, the breeding and use of these hens appears to be quite unproblematic. Studies also show that the blind hens have no problem finding feed and water, have a lower feed intake, a body weight similar to laying hens with unimpaired vision, and produce more eggs per day. Even though they might miss out on some of the pleasures and joys of chicken life, it is perhaps reasonable to expect that they will adapt and lead a life that is unobjectionable from the point of view of welfare — at least, compared to the feather-pecking alternative.

Whether it really is better, for the birds' welfare, to create congenitally blind hens, depends on how animal welfare is defined. Welfare may be, and often is, defined with an emphasis on the absence of disease and pain. But it may also be defined so that it involves 'good functioning' — that is, so that an essential element of it is the ability to exercise 'normal' biological capacities (normality being relative to the species). Plainly, the second of these definitions would have the implication that blindness in hens *is* a welfare problem.

But the objection to breeding congenitally blind chickens may be of a very different nature altogether. To many people the objection to breeding blind hens to ensure that they can be accommodated within an intensive production system is not about welfare. It is about *animal integrity* and its violation (Sandøe *et al.*, 1999). How powerful is this second kind of objection?

The concept of animal integrity is difficult to define (Christiansen & Sandøe, 2000). A notion of roughly the following kind captures a widely felt worry: "We can define the genetic integrity of the animal as the genome being left intact. This seems to be a meaningful notion in view of the fact that we can clearly point out some factors or actions by which the genome would not be left intact" (Vorstenbosch, 1993). What does leaving the genome intact mean? One obvious way to understand this is that we should abstain from technical interference with the genome. Then this definition only covers cases in which genetic change has been brought about through gene technology, and in the case of the blind hens technology of this kind was not involved. It therefore seems that the idea that animals have a certain nature, or range of natural features (e.g. sight), is essential to the notion of animal integrity. To violate an animal's integrity, on this expanded definition, is to breed an animal in which this nature, or range of natural features, is no longer intact.

It remains to be seen whether the notion that an animal possesses an essential nature can be sustained outside a religious context — that is, without defining what is natural by reference to the intention of a creator. But the concept of integrity is not without other problems (Sandøe & Holtug, 1998). A scientific objection to the concept is that it fails to take into account the fact that genomes exhibit a high degree of plasticity within changing environments. A more philosophical objection asks whether the concern for animal integrity is about what we do to individual animals or about what we do to entire species/races. In any case the 'conservatism' involved in the whole idea of preserving existing genotypes can be questioned. What is so special about these genotypes? Returning to animal welfare for a moment, it might be asked how respect for integrity benefits the animals. Currently, broilers experience leg problems as a result of over-rapid juvenile growth, as mentioned earlier. What would justify a refusal to initiate selective breeding programmes to eliminate this problem and improve animal welfare? Would the desire to maintain the integrity of existing breeds be enough? Is it not plausible to hold that breeding for improved health and a reduction in susceptibility to naturally occurring diseases is an unconditionally good thing?

If animal integrity and animal welfare are both considered relevant, a balancing of the two concerns against each other will often be necessary. This raises further questions. Are the two concerns equally important? Is one more important than the other — or should one, ultimately, be regarded as ethically irrelevant and abandoned?

Let us now turn to the third thing that people worry about when they have misgivings about the modern breeding industry: *biodiversity*. Concerns about biodiversity are not about the welfare of individual animals. Nor can they be adequately captured by talk about the integrity of individual species. They focus instead on the existence and value of whole populations. And more particularly, they focus on the variation and variability of life forms, functions, structures and processes that populations embody at the species and genetic level.

The importance of biodiversity to breeders can be hard to gauge. To many in the industry, breeding is all about retaining genetic information and resources for future use. However, there are signs that the diversity of the gene pool within breeds and species is being threatened by intensive selection pressures. For example, variation within breeds has decreased following widespread use of artificial insemination in Holstein dairy cattle, where the overriding purpose has been to make a healthy breed available to farmers.

The number of extinct or endangered cattle breeds has indeed increased dramatically over recent decades. In several European countries three breeds or fewer make up more than 90% of dairy herds. Advanced breeding programmes typically focus on a limited number of breeds, discarding other, more traditional breeds. From 1970 onwards a breeding programme in Norway focusing on the Norwegian Red Cattle ensured that more than twenty-five indigenous breeds went out of production within just two decades — leaving the Norwegian Red Cattle as the only commercially viable dairy cattle breed (Christensen, 1998).

Losses of biodiversity provoke anxiety for a variety of reasons. First, and most simply, many people look upon biological diversity in itself as something that has intrinsic, or fundamental, value. Secondly, in countries that possess a wide variety of, say, cattle breeds, such as Norway, the loss of breeds is often regarded as destructive of the local cultural heritage. Thirdly, some observers have speculated that if there is insufficient genetic variation within or between breeds, it will become more difficult to go back and remedy existing trait-related problems with, for example, animal welfare; and that it will be difficult to adapt breeds to new production systems and management techniques.

One way to meet these concerns would be to conserve all breeds, or at least breeds of special importance, perhaps using cryopreservation techniques. However, this is not very likely to happen at the moment: it is expensive and in any case it is unclear who (breeders? the food industry? society as a whole?) should bear the costs involved. In reality, then, priorities will have to be identified in anticipation of future needs. We will, for example, need to predict whether certain genes will become important for quality characteristics and performance at some point in the future — something easier said than done, of course.

The way forward

The mains goals of twentieth century animal breeding were to produce highly productive and feed-conversion efficient livestock and to develop animals which in other ways meet market demand, such as leaner pigs. However, these aims are likely to be supplemented by others in the twenty-first century. A number of changes have been apparent over the last few decades. The values we examined in the last section — animal welfare, animal integrity and biodiversity — are one of the drivers of change here. So in looking towards future trends it makes sense to ask what initiatives are being taken to deal with the ethical problems we have identified in real life.

To begin with it is important to realise that, where most species are concerned, the breeding sector is no longer very attached to the local farming community in Western Europe and North America. Animal breeding is an industry operating under unforgiving market forces, and in some areas, such as poultry, breeding is entirely in the hands of a very small number of multinational companies. At the same time, however, legislation governing animal protection and welfare is not international — at least, if we put aside European Union initiatives. These conditions, together with the difficulty of finding objective measures of animal welfare and exercising effective regulatory control, make it difficult to ensure that breeders address welfare-related problems.

In the Nordic countries efforts have been made over the past twenty-five years, in framing the breeding goals of dairy cattle, to bring in traits other than those enhancing productivity: health and welfare have been included among the parameters of successful breeding. This has been financially feasible because health problems in dairy cattle give rise to economic losses stemming from treatment costs and lowered production. Thus an essentially economic motive has made it possible to combine health-related and income-related breeding aims. However, in other branches of farm animal breeding it may turn out to be much more difficult to find ways to breed for increased health and welfare that are economically attractive. This would appear to be the situation in the case of poultry, for example, where any economic losses to poulterers generated by reduced health and welfare are stubbornly offset by corresponding gains.

Breeders operate in an environment in which it is absolutely necessary to cater for ethical concerns without compromising economic competitiveness. This need is recognised in a recent, ongoing EU project (2000-2003) on sustainable farm animal breeding and reproduction (Liinamo & Neeteson, 2001). In this project an attempt is being made to map the concerns and priorities of various stakeholders, such as citizens in various countries around the world, animal welfare organisations, retailers, farmers and the breeding industry itself.

The notion of *sustainable* farm animal breeding cannot be defined with just one specific set of values or one specific list of moral concerns, because ethical dilemmas lie at the core of sustainable development. However, if they are pursued sensibly, discussions of sustainability that refer to animal ethics and biotechnology will open up the discussion of ethical issues and help to set an agenda. If these discussions are to be fruitful, and if sustainability is to be more than a marketing ploy or an empty rallying cry of interest groups, it will be necessary for all parties to be aware of their own priorities and the values on which these priorities are based. Equally, a meaningful discussion among stakeholders in animal breeding will require those stakeholders to state their values in a transparent manner. And obviously, an open-minded attitude to other stakeholders’ views will be very important in any dialogue that takes place.

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Keywords: Adult mammalian cloning, biotechnology, gene mapping, GMOS, MAS, QTL, transgenics. Abbreviations: ES: embryonic stem cells ESR: estrogen receptor locus IGF-I: insulin-like growth factor I MAS: Marker-assisted selection QTL: quantitative trait loci.
Abstract. This paper discusses the use of genetic engineering applications in animal breeding, including a description of the methods, their potential and current uses and ethical issues. Genetic engineering is the name of a group of techniques used to identify, replicate, modify and transfer the genetic material of cells, tissues or compl...Â Current research in genetic engineering of animals is oriented toward a variety of possible medical, pharmaceutical and agricultural applications.