

Improving Livestock



Selective breeding has long been used by farmers to improve the quality of livestock. Over the past 10-15 years breeders have worked on developing broader breeding goals that incorporate animal health and welfare traits, as well as productivity. This note describes current technologies used in livestock breeding, research into future technologies and how the improvement of livestock can contribute towards future food security.

Food Security

The world's population is projected to rise from the current 7 billion to between 7.8 and 10 billion by 2050¹. This, coupled with increasing income, is likely to stimulate demand for higher quality food. To meet this demand, the livestock industry will have to produce more meat, fish, eggs and dairy products, using fewer resources, while protecting animal welfare and reducing the impact on the environment². The importance of this issue is illustrated by the recent announcement of an inquiry into sustainable food by The House of Commons Environmental Audit Committee.

Selective Breeding

Traits

Selective breeding is the process of breeding animals for particular physical characteristics, known as *phenotypic traits*, such as high quality meat, disease resistance or increased milk yield. These traits have a genetic component but are also influenced by environmental factors. The larger the genetic component of a trait, the higher the chance that desirable characteristics will be passed on from parent to offspring.

Overview

- An increasing worldwide population will see an increase in demand for more animal products between now and 2050.
- Animal breeding has already been successful across livestock sectors, increasing food production worldwide.
- New genetic techniques allow potentially valuable animals to be identified at a young age. However, details of an animal's physical characteristics will still be required to assess an animal's actual performance.
- Key challenges for improving livestock include improving production, efficiency and welfare, while decreasing the use of resources and impact on the environment.
- Some new technologies may raise regulatory challenges with regards to public acceptance and animal welfare.

The aim of selective breeding is to improve groups of animals so that the results are maintained within the population in future generations.

Traits considered beneficial are similar across livestock sectors, although the most valuable traits vary depending on the intended use of the animal and the species in question. Figure 1 summarises some common groups of beneficial traits used in selective breeding.

Figure 1. Traits for Livestock Improvement

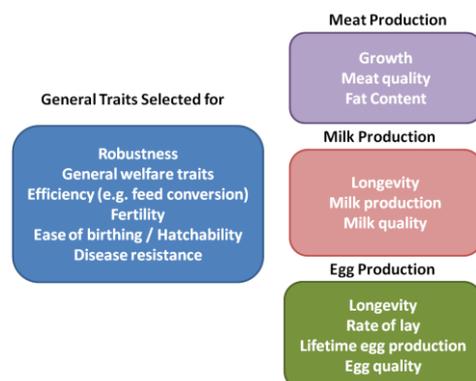
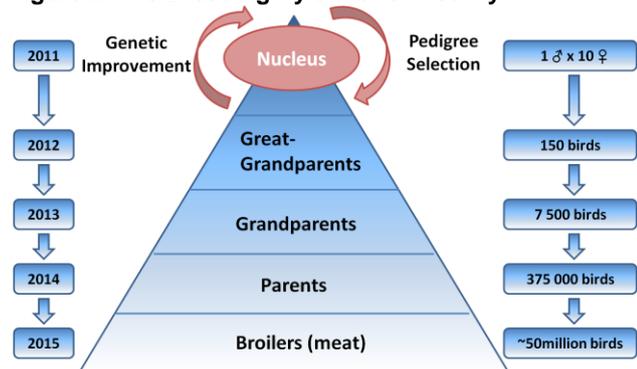


Figure 2. The Breeding Pyramid for Poultry⁴



Traditional Selective Breeding

Accurate measurement of desirable phenotypic traits such as those depicted in Figure 1 is the basis for most selective breeding programmes. Animals with desirable phenotypic traits are used for breeding, producing offspring with improved characteristics, which may in turn be selected for further breeding, or used for commercial production.

Some livestock sectors breed animals in the general pattern of the traditional breeding pyramid shown in Figure 2. Genetic improvements are made in a comparatively small number of animals at the top (nucleus) of the pyramid. In the poultry and pig sectors these improvements are being developed by a small number of global breeding companies, whereas in other sectors individual breeders and companies are independently improving their stock. As many fish and shellfish species produce hundreds of eggs, the pyramid structure of breeding is not required and improvements can be seen in commercial animals within one generation. Some general differences between livestock sectors are summarised in Table 1.

The Success of Selective Breeding

While traditional selective breeding produces small, incremental improvements in livestock, the cumulative gains over time are considerable. For example, in the past 20 years it is estimated that improvements made through selective breeding have generated £1.4billion of profitability in the UK dairy industry through increased efficiency and production.¹

There is also strong evidence that improvements in efficiency and production achieved over the last 20 years have resulted in substantial reductions in resource use and in green house gas emission per unit product for many species.³ One measure of productivity and efficiency is the feed conversion ratio - a measure of how much feed is required to produce a certain amount of meat or animal product. As shown in Figure 3, selective breeding has significantly improved the feed conversion ratio in the broiler (chicken meat) sector since the 1970s.⁴

Advances in Technology

Selective breeding depends on collecting information on physical characteristics (phenotypic traits), and using that information to select the best animals to breed from.

Figure 3. Feed Conversion Ratio in Broilers⁴

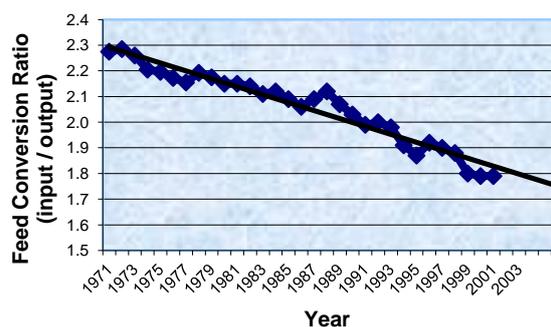


Table 1. Differences Between Sectors

Industry	Number of major Companies	Scale	Reproduction
Chicken	Layers – 2 Meat – 4	International	Natural
Turkey	2	International	All Artificial
Duck	2	International (85% China)	Natural
Pig	50:50 private companies: farmer co-ops	Domestic	Some Artificial (dependant on country)
Dairy	Internationally mainly farmer co-ops. The 2 largest UK co. are FTSE250 listed or privately owned	Mostly national, global trade in semen	Artificial: embryo transfer, sexed semen
Beef	Mainly farmer co-ops	Mostly national	Natural and artificial
Sheep	Often part of farmer co-ops	National	Mostly natural
Fish/shell fish	Developing similarly to poultry	Mainly EU, US and Chile	Artificial

Advances in technology and computing power have allowed for significant increases in the amount of data that can be used to estimate an individual’s breeding value, and the speed at which these data can be analysed.

Other technologies have also played a role in improving productivity and efficiency in the livestock sector. Examples include Artificial Insemination (AI), which has facilitated global distribution of elite semen, while sexing of semen has allowed fewer unwanted dairy bull calves to be born within the dairy industry.

Genetics and Selective Breeding

Recent advances in genetics have had a significant impact on selective breeding programmes. It is the phenotypic traits of animals that are of interest to breeders. If these can be mapped onto particular genetic features, it makes it easier for breeders to select animals with the required traits and

greatly accelerates breeding programmes. The sections below detail some of the genetic approaches used.

Estimated Breeding Values

An Estimated Breeding Value (EBV) is an approximation of an individual animal's breeding worth for a particular set of traits, and is based on the performance of the individual and its relatives. EBVs are often published with an accuracy value, which is an indication of the confidence that the EBV is the animal's true genetic value. The EBV of an animal will influence its economic worth (animals with an EBV in the top 1% of the range may fetch a considerable premium) and/or the price paid for breeding services.

Accurate EBVs are easy to obtain and test in high-turnover industries such as pigs and chickens. However, it takes longer to obtain accurate EBVs in larger animals such as cattle. For instance, calculating a bull's EBV for milk production traits requires testing the health and productivity of his daughters, which may not be possible until 5-6 years after the bull is born. This large time lag has led the dairy industry to implement genomic methods that may allow earlier prediction of higher accuracy EBVs (see below).

Genomic Profiling

Recent advances in genome sequencing have allowed the emergence of new genomics-based technologies, such as Single Nucleotide Polymorphism (SNP)-chip analysis. SNPs are single-point variations in DNA sequence that occur naturally throughout an animal's genome (its total genetic sequence). Some SNPs may be linked to desirable traits, while others may be indicative of less desirable characteristics. An SNP-chip is a commercially available tool that can contain tens or hundreds of thousands of probes to test for SNPs spanning the entire genome. It essentially provides a snapshot of an individual animal's genetic characteristics. The aim is to build up a database that links genetic information from SNP-chip analysis with phenotypic information on physical characteristics. This technology is being developed across several livestock sectors as a cheap, efficient and reliable method of predicting the genetic value of an animal at a young age, to maximise its breeding potential.

Genetic evaluations for dairy cattle, sheep and the majority of beef animals are funded and controlled by the Agriculture and Horticulture Development Board (AHDB) and performed by Edinburgh Genetic Evaluation Services. AHDB is funded by statutory levies, and aims to improve the efficiency and competitiveness of UK livestock industries. Genetic evaluations for poultry and pigs are carried out by individual breeding companies.

Regulation of Selective Breeding

CODE-EFABAR⁵ is a voluntary EU code of good practise for farm animal breeding and reproduction organisations that sets out guidelines for food safety, public health, animal welfare, breeding technologies and sustainable breeding.

In addition, the Welfare of Farmed Animals (England) Regulations 2000⁶ states that:

- "Natural or artificial breeding procedures which cause, or are likely to cause, suffering or injury to any of the animals concerned shall not be practised";
- "No animal shall be kept for farming purposes unless it can reasonably be expected, on the basis of their genotype or phenotype, that they can be kept without detrimental effect on their health and welfare."

Future Challenges

Key challenges for improving livestock include improving production and efficiency while decreasing the use of resources and impact on the environment. Immediate goals for livestock are similar across sectors, and include:

- skewing the sex ratio of newborn animals (this has already been achieved in many fish species);
- reducing and reusing animal waste;
- improving feed efficiency;
- improving animal health and welfare;
- decreasing the environmental impact of livestock.

Selective breeding, together with other new technologies, may help to address some of these challenges.

Other Methods of Improving Livestock

Genetic Modification

Genetic modification (GM) is the direct manipulation of an organism's genome. It can be used to introduce new characteristics into a species not possible by traditional breeding methods. For example, GM can be used to cross species barriers by transferring genes from one species into another. There are no GM animals currently in the food chain worldwide; however, there is ongoing research in this area. Some examples of GM research are shown in Box 1.

Box 1. GM Animals with a Potential Role in Agriculture

- The Roslin Institute in Edinburgh and Cambridge University have produced GM chickens that can become infected by H5N1 bird flu, but do not pass on the flu to other chickens. The ultimate aim is to produce completely flu-resistant animals.
- The *Enviropig* is the trademark for a GM line of Yorkshire pigs being developed in Canada. They contain genes from a bacterium and a mouse that allows them to break down phytates, a source of phosphate in feed that is usually indigestible. The pigs get more phosphate from their feed and produce waste that is less polluting.
- *AquAdvantage* is the trademark for a GM line of salmon developed in the US that grow twice as quickly as wild salmon, due to the addition of genes from two different species of fish. However, there are arguments that similar improvements have already been achieved through traditional selective breeding methods. On 15th June 2011 the US House of Representatives passed an amendment to prohibit further Food and Drug Administration funding for approval of this salmon.

Regulation of Genetically Modified Organisms

The EU has an established legal framework regulating research into GM animals, GM food and feed and the release of Genetically Modified Organisms (GMOs) into the environment. The role of the European Food Safety Authority (EFSA) is to assess and provide scientific advice

to risk managers on any possible risks from GMOs for human and animal health or the environment. As of May 2011, no applications on GM animals have been submitted to the EFSA. The EFSA has been asked by the European Commission to develop guidelines for the risk assessment of GM animals,⁷ looking at the:

- safety of food and feed derived from GM animals;
- safety of releasing GM animals into the environment;
- possible health and welfare implications on animals related to their genetic modification.

Cloning

Cloning is the process of producing a genetically identical copy of an organism. While cloning in fish can be achieved relatively easily, the cloning of livestock is more difficult and costly. The routine cloning of livestock is thus not economically viable and it is currently used only to reproduce high-quality pedigree animals for breeding. Outside the UK, small numbers of high-quality bulls have been cloned to increase their breeding potential, and descendants of these clones are present on farms in the UK. From the perspective of genetic improvement, cloning is of limited use as it prolongs 'old' genetic traits when the industry is constantly looking for new genetic variety to improve a species as a whole.

Regulation of Cloning

The sale of meat and milk from cloned animals in the EU is currently regulated by the EU Novel Foods Regulations. These require food from non-traditionally bred animals to be authorised before it is placed on the market. However, there are no regulations on the sale or distribution of products from the immediate offspring or further descendants of cloned animals. The Council of the European Parliament failed to agree on amendments to the Novel Foods Regulations in March 2011. The UK Food Standards Agency (FSA) states that products from the progeny of clones should *not* be classified as novel foods.⁸

In November 2010, the Advisory Committee on Novel Foods and Processes (ACNFP) concluded that meat and milk from cloned cattle and their progeny were unlikely to present any food safety risk, but that consumers may wish to see clear labelling of such products. In December 2010, the FSA concluded that mandatory labelling would provide no significant food safety benefit. Defra suggested that mandatory labelling for consumer choice would be unenforceable and impractical.⁹ Campaign groups such as GM Freeze disagree with this, and believe labelling could be enforced.¹⁰

Animal Welfare Considerations

Selective Breeding

In the past, selective breeding has tended to involve intensive selection for easy-to-measure traits, such as high growth rate in chickens or high milk production in dairy cattle. When a single trait is intensively bred for, there can be increases in undesirable characteristics, especially when those characteristics are not specifically monitored. One

example has been intensive selection for growth rate in chickens bred for meat, where the development of the heart, lungs and legs could not keep up with the accelerated body growth rate, leading to serious welfare issues.

In the past 10-15 years (30 years for meat chickens) all livestock sectors have come to recognise the issues associated with intensive selective breeding, and have altered their breeding strategy to tackle this. All livestock industries now select for health and welfare traits such as fertility, general robustness and absence of specific defects, alongside production and efficiency traits. Schemes such as the RSPCA's Freedom Foods label products with an assurance that certain standards of welfare are kept.

Another potential problem is inbreeding, which occurs when closely related animals are bred together. Breeding companies now have a better understanding of this issue, and monitor the amount of inbreeding occurring within their populations to help to prevent adverse side effects.

Genetic Modification and Cloning

Groups such as GeneWatch and the RSPCA are concerned about animal welfare in the production of GM animals and the effects of the modification on the animal and the environment.¹¹ Concerns have also been expressed about the welfare of cloned animals. Groups such as the RSPCA view products from the progeny of cloned animals as novel foods, and oppose any cloning for food purposes.

Public Attitudes

Selective breeding may be viewed in a negative light by the public, due to the intensive selection for productivity used in the past.⁴ The breeding industry is keen for the general public to understand how breeding programmes have been developed and now include the health and welfare of livestock as an important part of their aim.

Experience with GM crops suggests that the public are wary of genetic modification. However, research by organisations such as the Roslin Institute suggest that consumers may be more accepting of GM animals if the first such products show a clear benefit to the animal and consumer, rather than purely economic benefits to the producer.

Endnotes

- 1 Foresight: The Future of Food and Farming (2011)
- 2 H. Charles, J. Godfray, et al. Food Security: The challenge of feeding 9 billion people. *Science* 327, 812 (2010)
- 3 <http://goo.gl/fDdni>
- 4 The Evolution of Genetics, Breeding and Production, Ken Laughlin (2007)
- 5 <http://www.ffmpeg.org/>
- 6 <http://www.rspca.org.uk/allaboutanimals/laboratory/biotechnology>
- 7 <http://www.efsa.europa.eu/en/topics/topic/gmanimals.htm>
- 8 <http://www.food.gov.uk/gmfoods/novel/cloned/>
- 9 <http://www.defra.gov.uk/food-farm/animals/cloning/>
- 10 <http://www.gmfreeze.org/news-releases/23/>
- 11 <http://www.legislation.gov.uk/uk/si/2000/1870/contents/made>