OPINION ON THE WELFARE IMPLICATIONS OF BREEDING AND BREEDING TECHNOLOGIES IN COMMERCIAL LIVESTOCK AGRICULTURE

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FAWC Opinions

FAWC Opinions are short reports to Government[1] on contemporary topics relating to farm animal welfare. They are based on evidence and consultation with interested parties. They may highlight particular concerns and indicate issues for further consideration.

The Farm Animal Welfare Committee is an expert committee of the Department for Environment, Food and Rural Affairs in England and the Devolved Administrations in Scotland and Wales. It was established on 1 April 2011 following a review of public bodies. The Committee and its predecessor Council both use the acronym FAWC.

Opinions published by the Farm Animal Welfare Committee

Contingency planning for farm animal welfare in disasters and emergencies, 2012

Opinions published by the Farm Animal Welfare Council

Lameness in sheep, 2011
Mutilations and environmental enrichment in piglets and growing pigs, 2011
Osteoporosis and bone fractures in laying hens, 2010
Welfare of the dairy cow, 2009
Policy instruments for protecting and improving farm animal welfare, 2008
The welfare of farmed gamebirds, 2008
Enriched cages for laying hens, 2007
Beak trimming of laying hens, 2007

[1]Where we refer to Government, we are addressing ourselves to the Department for Environment, Food and Rural Affairs in England, the Scottish Government and the Welsh Government, and other responsible Government Departments and Agencies.

Opinion on the welfare implications of breeding and breeding technologies in commercial livestock agriculture

Scope

1. To provide an overview of the animal welfare implications of selective breeding strategies and breeding technologies in commercial livestock agriculture.

2. Livestock sectors considered in this Opinion include dairy cattle, beef cattle, sheep, pigs, broiler (meat) chickens, laying hens, turkeys and salmon. Other livestock sectors may share some of the issues but are not covered in detail.

Background

3. Responding to the Farm Animal Welfare Council's 2004 Report on the Welfare Implications of Animal Breeding and Breeding Technologies in Commercial Agriculture, the Government recognised the need for independent advice on the impact of conventional and novel breeding technologies on farm animal welfare and commissioned FAWC to prepare this.

4. Farm animals have been selected by their keepers for various traits since domestication. All are still subject, to a greater or lesser extent, to active selective breeding and/or the use of breeding technologies.

5. Some species of farm animals have been domesticated for up to 8,000 years but others have been farmed for far less time and may not yet really be domesticated, e.g. gamebirds and salmon. Selected traits started with docility and productivity. Since the 1970s-1980s other traits have been actively selected, e.g. robustness, health and bone strength. The rate of change has accelerated in some species, aided both by management improvements and also by breeding technologies.

Welfare concerns or contentious issues and/or opportunities to improve welfare

6. There are approximately one billion farm animals (i.e. birds and mammals; fish are additional to this) reared in the United Kingdom (UK) each year and many more elsewhere. Animal breeding can have beneficial or adverse consequences for their welfare. Detailed arguments have been presented in the following reports:

- FAWC's advice on broiler chickens (1992), sheep (1994), outdoor pigs (1996), laying hens (1997, 2007, 2010), dairy cattle (1997, 2009), broiler breeders (1998), cloning (1998, 2007, 2012), animal breeding and breeding technologies (2004).
- The Banner Committee report on the ethical implications of emerging technologies in the breeding of farm animals (1995).
- The Agriculture and Environment Biotechnology Commission (AEBC) report on animals and biotechnology (2002).

7. Our major concerns were summarised in 2004. Then, we were concerned about general trends in breeding, given the commercial pressures on breeders and farmers alike. Today matters are improving: we still have concerns but we are encouraged that many breeding goals now include aspects of animal welfare, e.g. disease resistance.

8. In the past, selective breeding for productivity was the focus. This approach was then correlated with the expression of undesirable changes in animal health and body structures (notably skeletal and metabolic diseases, lameness and mastitis). In the past decade the science which underpins animal breeding (and associated technologies) has been used to identify the trade-offs required for more robust selection strategies. But as long ago as the 1970s some breeding companies recognised the benefits of including welfare (e.g. leg health) in tandem with production traits in their selection programmes.

9. New automated data capture technologies have increased opportunities to record traits that traditionally have been more difficult to measure, such as those relating to disease, health and welfare. Many large breeding companies have re-aligned their breeding goals to give greater prominence to traits such as health, fitness and welfare – as well as the environmental impact of livestock production.

10. The Farm Animal Breeding and Reproduction European Technology Platform, FABRE TP, brought together a wide range of interested parties to produce a vision of how livestock breeding might develop in Europe in the medium term. In 2006 it produced its vision for 2025[2]: for EU farm animal breeders to meet the global need for sustainable increases in food quality, quantity and production efficiency; promote breeding of farm animals that is biologically and economically sustainable, taking into account social responsibility and cultural and regional values; ensure transparent development of new technologies and production systems; and set a research agenda to deliver this vision.

11. Advanced genomic tools using whole genome single nucleotide polymorphism (SNP) technology are already being implemented in some sectors of the livestock industry. For example, the genetic merit of dairy cattle in the UK is now reported using genomic breeding values for some traits. Genome-wide selection (GWS) provides genomic predictions of genetic merit at a much earlier stage than traditionally, even before an animal is born. It offers considerable advantages to the livestock industry, through improved efficiency and a high rate of genetic progress, for any trait that is recorded accurately to develop reliable predictors of genomic breeding values. FAWC is concerned that the 'easy to measure' (largely production) traits are being implemented in advance of those for functional fitness, due largely to lack of good data on health and fitness traits. If a breeding programme does not include both types of trait the non-production traits will fall behind in selection and lead to poorer animal welfare.

12. For example, even though farmed salmon have undergone relatively few generations of selection, their vulnerability to endemic and exotic disease challenges can lead to very high levels of mortality which can be exacerbated in farmed fish rearing

[2] http://www.euroqualityfiles.net/vision_pdf/vision_fabre.pdf

environments. New genomic technologies to identify families resistant to infectious pancreatic necrosis (IPN) are currently being used to select elite breeding stock.

13. Planned breeding programmes are commonplace but sometimes can still result in poor welfare. For example, planned or accidental mating of inappropriately large males to females causes an increase in dystocia in species such as cattle and sheep. Some selected lines of turkeys are unable to mate naturally after selection for high productivity. The consequence is that many elite breeding turkey stock in the UK are mated using artificial insemination (AI). Female salmon have eggs removed manually; but there are welfare concerns whenever fish are handled out of water. For this reason, fish are usually anaesthetised or killed before being stripped of their eggs.

14. Importation of genetic material for use in the UK livestock industry is largely unregulated. There is evidence that introgression[3] of lethal recessive genes has occurred from the importation of germplasm outwith the EU. Some imported farm animals are more susceptible to endemic diseases than UK strains leading to avoidable, poor welfare for these animals. For example, some imported breeds of sheep are very susceptible to becoming lame and another recently imported breed has a high susceptibility to scrapie.

15. Genetic modification (GM) of commercial farm animals is not permitted in the UK. GM has the potential to improve animal welfare in some cases, for example it would be beneficial to insert the specific DNA coding for polledness (absence of horns) into horned populations of cattle, e.g. Holstein, to avoid routine disbudding or de-horning of calves.

16. Higher-producing, biologically efficient livestock are likely to have the least impact on the environment. Whilst a renewed drive for production could benefit the environment, FAWC is concerned that it should not detract from further broadening breeding goals that could improve animal welfare. This concern has been addressed by some breeding companies that have invested considerable research effort into the best way to combine aspects of welfare, fitness and environmental impact.

Number of animals involved, duration and extent of poor welfare or suffering

17. Annually, nearly a billion farm animals (and fish in addition) are reared in the UK, the majority of which are broiler chickens kept for meat. The number of breeding animals is significantly fewer (the proportions varying between species). For adult breeding animals there are about 2 million dairy cows, 15 million ewes and half a million sows[4].

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[3] Introgression means mating animals with a specific (desired) characteristic into another population that does not have it. 'Lethal recessive genes' are a major problem when an animal inherits two copies of a gene that codes for an undesirable characteristic such as malformation or greater susceptibility to disease. If only one copy of the gene is inherited then, normally, it is not expressed. Depending on the mode of inheritance, the inadvertent use of animals carrying such genes in an uncontrolled breeding situation (e.g. not paying attention to the levels of inbreeding) can lead to a high number of affected animals.

[4] Agriculture in the UK 2011 - http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-crosscutting-auk-auk2011-120709.pdf

18. Welfare problems can occur in elite breeding stock as well as their offspring, where such issues are multiplied. For instance, the use of a bull selected for extreme muscularity that is mated with 40 cows can lead to a high incidence of dystocia (complications at birth) when its offspring are used for breeding across many herds. This has resulted in some farmers relying on elective caesarean sections for all cows to avoid dystocia.

19. The issue of whether a shorter or longer productive lifespan is desirable from an animal's point of view is often debated. However, it is clear that addressing key health issues through careful selection of breeding animals leads to longer (and healthier) life expectancy in their offspring; although life expectancy in some breeding stock is still lower than is desirable, e.g. dairy cattle[5].

20. Some pig breeding programmes that focussed on increasing litter size led to larger litter sizes with high levels of perinatal mortality in piglets. Mortality itself is not a welfare issue if the death is humane, but it is an indicator of the extent of suffering and waste of life that occurs. Concurrent selection for survival characteristics is now being introduced by some breeding companies.

Legal context

21. EU law on animal breeding procedures is contained in EU Directive 98/58/EC (transposed into the Welfare of Farmed Animals (England) Regulations 2007 in England with similar legislation in Scotland and Wales); its Annex states:

"*Natural or artificial breeding or breeding procedures which cause or are likely to cause suffering or injury to any of the animals concerned must not be practised. This provision shall not preclude the use of certain procedures likely to cause minimal or momentary suffering or injury, or which might necessitate interventions which would not cause lasting injury, where these are allowed by national provisions."*

"No animal shall be kept for farming purposes unless it can reasonably be expected, on the basis of its genotype or phenotype, that it can be kept without detrimental effect on its health or welfare."

22. FAWC is quite clear that genotypes must be matched with the relevant environment. For example, most highly selected animals require excellent management and careful nutrition. Failure to provide these leads to an inability to meet the needs of the animals; poor welfare is expressed as poor body condition, high levels of disease and chronic lameness in mammals. Selection schemes incorporating 'Genotype by Environment' (G x E) as an integral component of breeding programmes lead to increased robustness of selected animals such that appropriate genotypes can be selected for specific environments (e.g. different farm types).

[5] Farm Animal Welfare Council, Opinion on the welfare of the dairy cow, 2009

23. Primary legislation relating to animal breeding and breeding technologies in the UK comprise the Animal Welfare Act 2006 and the Animal Health and Welfare (Scotland) Act 2006; the Veterinary Surgeons Act 1966; and the Animals (Scientific Procedures) Act 1986.

24. Legislation also exists to govern specific breeding techniques. Exemptions to the general ban on mutilations are listed in the Mutilations (Permitted Procedures) (England) Regulations 2007 (as amended) (and similar legislation in Scotland and Wales). Embryo transfer in cattle is covered by the Bovine (Collection, Production and Transfer) Regulations 1995, under which a veterinary surgeon must be satisfied that a cow receiving an embryo is suitable to bring it to term and calve naturally before the technique can be used, and the Veterinary Surgery (Epidural Anaesthesia of Bovines) Order 2010. Artificial insemination is covered by the Artificial Insemination of Cattle (Animal Health) (Amendment) (England) Regulations 2002 (as amended) (and similar legislation in Scotland and Wales).

25. Welfare codes describe many requirements and good practice that apply to the welfare of breeding animals in various livestock sectors[6]. In addition, the code for laying hens states that "*When considering the establishment or replacement of a flock, the choice of hybrid should be made with the aim of reducing the risk of welfare and health problems.*"

26. The European Forum of Farm Animal Breeders (EFFAB) has developed a 'Code of Good Practice for Farm Animal Breeding and Reproduction Organisations', (Code-EFABAR) which addresses the issues of food safety and public health, product quality, genetic diversity, efficiency, environmental impact, animal health, animal welfare, and breeding and reproduction technologies[7].

International considerations

27. Some breeding companies are large multinationals, which sell germplasm in the form of semen, embryos or live animals. Decisions about traits and their weighting can be made by companies with headquarters outwith the UK. In some cases, the UK may have little or no control over the type of animal that is being marketed and there are no guidelines or regulations that cover the importation of such material.

28. The UK hosts large international breeding companies for broiler chickens, turkeys, ducks, pigs, fish and cattle. The UK is in a good position to profit from, and initiate, interactions with these companies. Historically, FAWC has often interacted with UK-based breeding companies; these links are important and valued greatly.

29. Company breeding programmes have to cater for shareholders' interests; some programmes appear to focus on the profitability of a few breeding traits. Companies should consider long term trends in demand and legislation and react appropriately,

[6] http://www.defra.gov.uk/foodfarm/farmanimal/welfare/onfarm/index.htm
[7] http://www.effab.org/CODEEFABAR.aspx

taking into account that it can take 10-20 years to adapt to new circumstances in some species.

30. Despite strict biosecurity measures to minimise disease risks from imported stock (e.g. quarantine), these requirements do not cover the risk associated with susceptibility to endemic diseases – in particular to those usually expressed later in life. Importers also may not screen for known congenital defects such as lethal recessive genes (e.g. congenital pseudomyotonia), that in some instances go 'hand-in-hand' with desirable characteristics of an imported strain. Bovine leucocyte adhesion deficiency (BLAD) became widespread in the USA due to artificial insemination from affected bulls.

31. For poultry, the responsibility for high biosecurity is shouldered by the industry. One of the UK's leading poultry companies is currently the first global company to hold OIE-accredited 'Compartmentalisation' (special disease-free zone) status.

Advice by FAWC and EFSA

32. In a number of its past species-specific reports, FAWC expressed concerns about the effects of breed and breeding technology on farm animal welfare. For example, in relation to turkeys we recommended that "*Artificial insemination should be undertaken only by competent, trained staff, who should take care to use only those turkeys which are in good physical condition*."[8]

33. In its submission to the Banner Committee[9], FAWC concluded that the Animals (Scientific Procedures) Act 1986 was sound, particularly because a cost-benefit analysis was applied which required assessment of the extent of animal suffering against the potential benefit to society and to other animals. The Act improved the attitude of researchers towards experimental animals by requiring them to demonstrate the integrity of research and its benefits. FAWC is disappointed that no similar legislation exists to protect animals outwith the Act in commercial farming.

34. Furthermore, we proposed that an independent body should be established to address ethical questions about developments in animal breeding. The Banner Committee also commented that, although normal selective breeding fell outwith its remit, it was not invariably neutral as regards animal welfare. Breeding could result in "*highly objectionable side effects*".

35. In 1998[10], FAWC recommended that the general principles as prescribed by the Banner Committee should be adopted as a framework within which present and future uses of animals should be assessed. The 1998 Report also made a series of recommendations specific to cloning.

[8] Farm Animal Welfare Council. 1995. Report on the Welfare of Turkeys

[9] Banner Committee – Report of the Committee to consider the ethical Implications of the emerging technologies in the breeding of farm animals. 1995

[10] Farm Animal Welfare Council. Report on the Implications of Cloning for the Welfare of Farmed Livestock 1998

36. We gave evidence to the Agriculture and Environment Biotechnology Commission (AEBC) during its work on animals and biotechnology (2002). The AEBC report made an important contribution to the debate on biotechnology, particularly since it also sought to include public opinion in the development of its conclusions.

37. In our 2004 Report on the Welfare Implications of Animal Breeding and Breeding Technologies in Commercial Agriculture, we recommended that a standing committee should be established to evaluate breeding technologies and livestock breeding programmes, echoing similar calls by the Banner Committee and the AEBC. However, the Government did not accept this recommendation and instead asked FAWC to provide such advice.

38. Other features of our 2004 report included: calls for robust surveillance of animal welfare, in particular of breeding programmes and breeding technologies, including targeted surveillance on farms where new breed types or new breeding technologies are introduced commercially; R&D and training programmes for husbandry systems to support new genotypes; and prevention of uncontrolled entry of genetically modified and cloned animals into commercial agriculture. Code-EFABAR encompasses the recommendations for robust surveillance.

39. More recently, FAWC advised on the implications of cloning for welfare[11], following strong media interest in the importation of the offspring of a cow cloned in the USA. We concluded that there are unlikely to be any specific welfare implications of the cloning procedure *per se* for the offspring of a cloned animal; however, cloning as a breeding technology may present problems for animal welfare. For example, embryos, foetuses, placentae and offspring resulting from *in vitro* production of cattle can differ significantly in morphology and developmental competence compared with those from embryos produced normally. The consequences of abnormal offspring syndrome include embryo mortality, developmental defects in offspring and adverse effects on the dam due to foetal oversize. FAWC has updated its advice on the welfare impacts of cloning in a letter in April 2012[12].

40. FAWC's Opinion on osteoporosis and bone fractures in laying hens identified that selection for bone strength could be a long term strategy for alleviating some of the problems associated with osteoporosis, alongside improvements in nutrition and production system design. Studies of the potential of genetic selection for increased bone strength also suggest that there are no adverse effects on egg production or eggshell strength: indeed there may even be benefits. The Opinion recommended that greater attention should be given by breeders to minimising osteoporosis in laying hens through breeding, e.g. by genetic selection for bone quality, but recognised the difficulties raised by the international nature of the poultry breeding industry.

[11] http://www.fawc.org.uk/pdf/250107.pdf
[12] http://www.defra.gov.uk/fawc/files/Welfare-implications-of-cloning-of-farm-animals.pdf

41. The European Food Safety Authority (EFSA) has produced several opinions[13] on the health and welfare of farm animals covering breeding and breeding technologies, either specifically or as a part of general husbandry. Some of the recommendations made are relevant to this opinion, specifically the need for better reporting and transparency of data related to animal welfare. As a result of EFSA's recommendations, one research study is appraising the breeding programmes of major EU poultry breeding companies.

42. In November 2006, the National Standing Committee on Farm Animal Genetic Resources recommended regular, formal exchanges of views between itself and FAWC. These exchanges have been initiated. The Committee has also published a statement on the use of cloning for genetic diversity[14].

Evidence

43. There is now sound scientific and commercial evidence that selective breeding and breeding technologies can both impair and improve various aspects of the health, welfare and productivity of farmed animals. The following précis of examples is not exhaustive but includes sector-level breeding programmes, antisocial behaviours, double muscling and dystocia, molecular technologies and breeding practices.

Scientific knowledge and its implementation relating to the topic

44. Breeding livestock and fish for human consumption is a global activity primarily controlled by a few multinational companies, which produce breeding stock and germplasm for a range of environments around the world. In some cases, the same genotypes are used for breeding in all environments, whereas for others, specific strains are developed which are better suited to certain climatic and environmental conditions.

45. Problems may arise when there is a mis-match between the environment and the genotype, normally with high-performing genotypes, e.g. dairy cows yielding over 11,000 litres of milk per lactation or hens laying over 300 eggs per year. These animals require very high standards of management (e.g. specialised diets, disease control measures, suitable environments and skilled keepers). If their needs are met, they can lead lives that are as good as those with lower levels of production. However, excellent management is not universal, and, without it, high performing genotypes may suffer disease and reduced functional fitness, leading to poor welfare.

46. The recent trend for extensively-managed sheep is a move towards ranching; this only works well if the correct breed is selected for the management style. This includes breeds of ewes that have strong maternal bonds with their offspring, relevant innate behaviours such as seeking shelter when required, good resistance to disease and ability to lamb unaided. Breeds having high litter sizes are inappropriate for such low intervention farming systems.

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[13] http://www.efsa.europa.eu/en/ahaw/ahawscdocs.htm
[14] http://archive.defra.gov.uk/fangr/documents/100914-cloning-statement.pdf

47. Over 100 problems associated with livestock breeding programmes in the 1990s were described by Rauw and colleagues[15]. Problems highlighted were mainly concerned with the results of rapid reproductive rates and short generation intervals in those species that had undergone more generations of selection compared with others.

48. Breeding companies have addressed many of the criticisms levelled in the past. For example, breeding programmes in broiler production now embrace survival and fitness, bone quality and strength, foot and leg defects, and heart and lung capacity, as well as more traditional production traits. Commercial data from descendents of nucleus (selected) populations ('sib testing') on poultry and salmon farms will inform selection decisions within nucleus populations.

49. However, improving productivity and improving health and welfare are often genetically negatively correlated; there is a conflict between improved robustness and productivity that needs to be carefully managed. Failure to manage this conflict may lead to companies erring on the side of increased productivity.

Sector-level breeding programmes

50. Public distrust about livestock breeding is often fuelled by a lack of transparency. Details of sheep and beef breeding programmes in the UK are publicly available and much less concern is focussed on these species. Most concerns are over private breeding programmes for pigs and poultry, perhaps because the 'nuts and bolts' of core breeding programmes comprise confidential intellectual property. Guidelines from EFFAB can help companies to become more open and accountable about animal breeding and animal welfare (e.g. Kappell *et al*, 2012[16]).

Breeding out antisocial animal behaviours

51. The impact of selection for high productivity on behavioural traits is unclear although there is evidence[17] that selection for high output (eggs or lean meat) is associated with selecting for antisocial behaviours, e.g. injurious pecking in laying hens and tail biting in pigs. For example, many genes differentially expressed in feather pecking strains compared with non-feather peckers, are also involved in muscle development, muscle metabolism and memory. There are large differences between and within commercial strains of egg-laying poultry for feather pecking and mortality, implying that there is potential for the development of strains that have a reduced propensity to feather peck and thus require less severe beak trimming or no trimming at all. Similarly, in pigs, aggression at mixing and maternal aggression leading to savaging

[15] Undesirable side effects of selection for high production efficiency in farm animals: a review. Rauw, WM et al Livestock Production Science Vol. 56 Iss. 1 15-33

[16] Kappell, D.N.R.G., Hill, W.G., Neeteson, A.-M., McAdam, J., Koerhuis, A.N.M and Avendano, S. 2012. Poultry Science 91:565-574.

[17] Buitenhuis, A.J., Hedegaard, J., Janss, L., Sørensen, P., 2009. Differentially expressed genes for aggressive pecking behaviour in laying hens. In: Proc. 60th Ann. Meet. Euro. Assoc. Anim. Prod. , Barcelona, p. 280. Breuer K et al. Heritability of clinical tail-biting and its relation to performance traits Livestock Production Science. Vol 93 Iss 87-94 2005

of offspring are undesirable behaviours that can be reduced through selective breeding[18].

52. The main problems with implementation of selection against such behaviours is that including behavioural traits in breeding programmes is not straightforward and that the difficulties and costs of measuring these traits outweigh perceived economic benefits. We were informed during consultation that these two key behavioural traits (feather pecking in laying hens and tail biting in pigs) are amongst others that are already being used or are being considered for use in selection programmes. This type of research should inform the work of the Beak Trimming Action Group, since it could provide a permanent strategy to cope with the challenges arising from a ban on beak trimming. If behavioural traits are to be incorporated in breeding programmes, more research is needed on proxy traits and economic benefits.

53. One novel selection strategy proposed over 15 years ago[19] is selection at group rather than individual level, e.g. a cage of laying hens. By taking social effects into consideration, this approach can be used to pick birds that are better able to perform in group housing situations without negative impacts on their co-housed counterparts.

54. There are many examples where molecular technology has the potential to improve animal welfare. For instance, it is used to identify single genes or those which have a large effect on some disorders (see para 30 above). Also, screening all known individual gene variants (single nucleotide polymorphisms, SNPs) to control aggressiveness or other antisocial behaviours could soon become an integral part of breeding programmes for all species. Elite selection candidates are now routinely genotyped by pig and poultry breeding organisations and genomic information is increasingly being used alongside conventional breeding values as a major component in national evaluations for dairy and (soon) beef cattle.

Double muscling and resulting dystocia

55. We first highlighted concerns about double muscling in Belgian Blue cattle and the consequences for dystocia in 1989[20]; our concerns are still extant and now embrace some sheep breeds.

56. The main concern with double muscling is about assisted births and caesarean sections. If these operations are planned and conducted by a skilled veterinarian the outcome can be a live born calf. However, females born by this route might themselves not be able to deliver their own calves and males might produce calves that cannot be born naturally. If such bulls are used on commercial farms where there is no intention

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[18] Turner, S.P., Roehe, R., D'Eath, R.B., Ison, S.H., Farish, M., Jack, M.C., Lundeheim,N., Rydhmer, L., Lawrence, A.B., 2009. J. Anim. Sci 87, 3076–3082.; Turner, S.P., D'Eath, R.B., Roehe, R., Lawrence, A.B., 2010.. Anim. Welfare 19 (S),123–132.
[19] Muir, W.M., 1996. Group selection for adaptation to multiple-hen cages: selection program and direct responses. Poult. Sci. 75, 447–458.; Bergsma, R., Kanis, E., Knol, E.F., Bijma, P., 2008. The contribution of social effects to heritable variation in finishing traits of domestic pigs (Sus scrofa). Genetics 178, 1559–1570.
[20] Farm Animal Welfare Council. Press Notice – Calving in the Belgian blue. 11 January 1989.

to perform caesarean sections electively, then it is highly likely that poor welfare will occur with damaged mothers and calves. Decline in numbers of skilled stockpeople and veterinarians might exacerbate this further.

57. Caesarean sections are clearly not 'normal' and, however well undertaken, almost inevitably entail considerable pain for the animal concerned. There is therefore an argument that society should not routinely allow conceptions where it is likely that a caesarean will be required. As well as ethical concerns, there are practical welfare issues. Veterinarians differ considerably in the familiarity and expertise that they have in undertaking this procedure. A caesarean section is a major operation that needs an experienced and skilled veterinary surgeon and good stockmanship in recovery.

58. Typically, about 8% of births are assisted in extensively managed hill sheep[21], but the prevalence can be three times greater in some terminal sire breeds[22]. Genetic studies have reported antagonistic genetic relationships between muscularity and calving/lambing ease. To address this, UK-evaluated beef and some sheep breeds have implemented recording programmes; Estimated Breeding Values (EBVs) are now available for these traits combined. This is a major step forward but the rewards of muscular livestock *vs.* the financial benefits of easier lambing will determine how much emphasis breeders place on each trait in the future.

Molecular technologies

59. Genome-wide selection (GWS) is now enhancing practical breeding programmes for some species and is regularly being used in dairy cow selection and by some poultry and fish breeders. It provides genomic predictions of breeding merit based on screening DNA for particular variants that are associated with desirable animal characteristics. The process operates at the whole animal level because the animal must possess all the required characteristics to make it valuable enough to be used for breeding. Selection for sought-after qualities in this way does not modify the animal’s genetic make-up by introduction of genes. It is an enhanced version of natural selection and should not be confused with genetic modification.

60. Potentially, GWS offers great potential in livestock breeding to influence traits that are important for animal welfare. Unfortunately, high initial costs, and the population structures associated with the process required to validate and implement GWS, means that the production traits that are already recorded on large numbers of animals may be selected first. For industries with definitive and clear pathways from elite breeding populations through to commercial application, this method has as many benefits as it does pitfalls.

61. Our main concern is that, because it offers accelerated responses to selection, unless the complete set of broader, non-production breeding goal traits are included,

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[21] Ilska et al., 2009

[22] MacFarlane et al. Genetic parameters for birth difficulty, lamb vigour and lamb sucking ability in Suffolk sheep. Animal Welfare Vol 19 S99-105 May 2010

these will be left behind and are likely to deteriorate, due to their known (often antagonistic) genetic relationships with production.

62. The second concern is that candidates for breeding are identified at (or even before) birth. Thus, some diseases or congenital defects that do not manifest until later on in the animal's life could be overlooked. On the other hand, known mutations causing deleterious effects (e.g. bovine leucocyte adhesion deficiency (BLAD) in dairy cattle) can be detected and removed from the population. New opportunities for screening for other single or major gene defects in livestock have opened up with use of genome-wide methods which do offer beneficial outcomes for animal health and welfare.

Breeding practices

63. Trans-cervical insemination (AI) is widely accepted and practised for most livestock species and can simplify management; it reduces the inefficiencies associated with keeping males only for use in a short breeding season. It also allows for more widespread use of elite breeding males that have proven beneficial characteristics for health and productivity. This method should be promoted both to avoid the biosecurity risk of buying in breeding stock and also to promote the use of semen from animals with good breeding values for desirable characteristics. Most AI is undertaken because of these benefits. However, sometimes the rationale for its use in beef cattle and turkeys is to avoid the physical problems associated with mating high bodyweight males with smaller females. Calving problems that can result are discussed in paragraph 56.

64. FAWC has more than once raised concerns about breeding technologies used with dairy cattle such as ovum pick-up, repeated epidural injections for oocyte collection, the effects of repeated administration of superovulatory drugs, and the problems regarding oversized calves, and hence calving difficulties, resulting from *in vitro* fertilised embryos[23] [24]. Embryo recovery should be limited to one collection per animal in a given breeding season in particular as this is frequently undertaken using a general anaesthetic. The veterinary profession should not perform any reproductive practice if there is prior knowledge that the resultant pregnancy will require a caesarean to give birth. Using proven bulls and rams with good breeding values for calving / lambing ease figures is recommended.

65. The high cost of Embryo Transfer (ET), and relative reproductive inefficiency compared with natural mating, means that it is used only with elite herds and flocks. Our previous concern that juvenile *in vitro* embryo transfer (JIVET) would become commonplace has not been realised[25].

66. The costs associated with other reproductive technologies such as laparascopic AI also precludes them from becoming mainstream in the sheep industry. There is still

[23] Farm Animal Welfare Council. Report on the Welfare of Dairy Cattle. 1997
[24] Farm Animal Welfare Council. Report on the Welfare Implications of Breeding and Breeding Technologies in Commercial Livestock Agriculture. 2004
[25] Op.cit. 24

some concern expressed by the veterinary profession that the laparascopic AI method used by sheep breeders does not adequately address the pain associated with the procedure. There has been a lack of research in this area in the UK over the past 2 decades, but studies abroad have shown no difference in visual expression of pain in sheep with and without pain relief although more information is needed including physiological aspects of pain. The lack of effective licensed pain relief drugs for sheep is not an adequate excuse to omit the use of pain relief for laparascopic AI with the Cascade system in place.

67. Cloning refers to somatic cell nuclear transfer (SCNT). Cloning is not practised commercially in the UK; breeding companies reported that they were not engaged in any cloning practices and, for commercial reasons, would not be doing so in the future. Cloning is an inefficient, costly way to produce food. As breeding companies rely heavily on public trust, it is important to them that they are not associated with cloning or other 'unnatural' breeding practices.

68. Unless further restrictions on the use of products from cloned animals are enforced by the EU, it is likely that UK consumers may at some point consume milk or meat products from animals that were derived from cloned animals born/reared in another country. EU legislation regards foods and food ingredients derived from clones as novel foods which must be assessed and approved at EU level before they can be placed on the market. However, commercial cloning is now taking place on a regular basis in the USA, and also in other major exporters including Argentina and Brazil. In these countries there are no regulations restricting lawful export of clones, their offspring, semen or embryos, or products derived from clones or their offspring, and there is no labelling requirement to allow additional controls in importing countries. There is no restriction on trade in cloned animals or semen, ova, embryos or offspring from clones and no way of distinguishing animals or animal products that are derived from a clone or its offspring. As there are no requirements for labelling such imported products, UK consumers would not have a choice on whether or not to consume a product derived from a cloned animal.

69. Genetic Modification (GM) refers to when animals are modified either via transgenesis (when individual genes from the same or a different species are inserted into another individual), or by the targeting of specific changes in individual genes or chromosomes within a single species. The use of GM animals in the UK has been undertaken commercially in the past for the production of 'farmed' pharmaceuticals in sheep's milk, to help human sufferers overcome key aspects of disease. Very few other successful examples exist despite potential benefits to use GM to benefit human health as well as animal welfare directly. For example, (paragraph 15) using GM to make dairy and beef cattle polled (hornless) would bring great welfare benefits by alleviating the need to de-horn cattle in commercial farming situations.

Evidence from farming and allied industries

70. In the UK, selective breeding using computer-generated 'Estimated Breeding Values' (EBVs) for key traits of economic importance is undertaken both by private companies and collectives. EBVs provide unbiased estimates of genetic worth for a range of traits that are often combined by an economic weighting factor into total merit indices. These are then used to guide breeders on selection of replacement males and females. EBVs are a powerful tool to improve component breeding traits by between 1% and 3% per annum each.

The salmon industry

71. Breeding practices in the salmon industry range from phenotypic selection to complex software and genomic technologies for selection against key diseases, such as infectious pancreatic necrosis (IPN). Careful and detailed protocols for fish selection are apparent and typical breeding goals are:

Health and Welfare	Production	Quality
Robustness	Early maturation	Shape
Disease resistance	Growth	Flesh colour
Sea lice resistance	Feed conversion efficiency	Fillet weight
Skeletal integrity	Vegetarian diet	Fat content
		Flesh quality

72. The mixture of traits needed by the salmon industry and for fish health and welfare should be relatively easy to achieve because resistance to disease and robustness is aligned closely with profitability and good welfare. It is also common practice in aquaculture to use sib testing in commercial environments and against specific challenges.

73. Most farmed salmon are about a dozen generations removed from their wild ancestors; concerns relating to selective breeding have not arisen. Salmon breeders generally have a balanced approach to breeding and produce fish that are well adapted to production environments. Most concerns centre on biosecurity of imported eggs and other disease issues.

Egg laying hens

74. Breeding of poultry for egg production (‘layers’) is mostly undertaken by breeding companies based in Europe and North America, which supply breeding stock for UK-based egg production and maintain several hundred separate strains that are tested for use around the world. In the past 30 years, egg production per hen has increased annually from 230 in the 1960s to over 300 eggs over the laying cycle; around 60 weeks of lay (see Appendix 3). Breeding programmes mostly focus on feed conversion

efficiency, body weight, egg and shell production and quality, and on hatchability of fertile eggs.

Broiler chickens

75. Broiler breeding in the UK uses more than 30 different strains. Health, welfare, fertility and fitness traits now account for about two thirds of the breeding emphasis in contrast to the production traits in the 1960s. It has been possible to improve health, welfare and robustness, while at the same time hastening growth rate, and decreasing the carbon footprint. Some breeding companies offer breeding stock that are free from salmonella, mycoplasma and leucosis. Broiler chickens now take just 35 days to reach market weight compared with 60 days in the 1970s, without consequent increases in mortality.

76. Since the 1970s, animal welfare-orientated breeding goals have been included in selection regimes, e.g. leg weakness and sudden death syndrome in fast-growing chickens[26] [27]. Techniques to measure bone quality (e.g. a lixiscope) have been used since the 1980s. Measurements of oxidative capacity are used to improve robustness by preventing physiological problems arising from selection for breast meat yield and feed efficiency. Selection for survival in a range of different environments to improve robustness is a welcome initiative to minimise mismatches of genotype with environments. We would like to encourage the widespread uptake of the practice.

77. The Food Standards Agency (FSA) and the Animal Health Veterinary Laboratories Agency (AHVLA) are now using welfare outcomes identified at slaughter for a 'trigger' system to address some of the issues raised in the Meat Chicken Directive. This alerts those responsible when lesions or other abnormalities are observed in birds at the point of slaughter. The prevalence of conditions including ascites, emaciation, dermatitis and cellulitis, joint lesions and respiratory disease, amongst others, and of death on arrival is recorded. These data are valuable to producers which can then be linked back to breeding stock to aid selection of better genotypes.

Pigs

78. There is a similar system for pigs of reporting welfare outcomes identified at the abattoir (BPEX Pig Health Scheme[28]).

79. As with other livestock species, the breeding focus forty years ago was performance characteristics such as growth, feed efficiency and reduced back-fat thickness. Since then, many more traits have been added, some of which are non-production characteristics to meet societal concerns and therefore market requirements. An attitude shift has also been apparent in some companies, in that former protectionist

[26] Farm Animal Welfare Council. Report on the Welfare of Broilers, 1992
[27] Farm Animal Welfare Council. Report on the Welfare of Broiler Breeders, 1998
[28] http://www.pighealth.org.uk/health/home.eb

policies to prevent competition have given way to a preferred and welcome engagement, and exchange of information.

80. The breeding focus nowadays covers a wide spectrum of traits in three main areas, i.e. growth and carcass traits, reproduction and fitness. The latter incorporate survival at all stages of production; the international breeding companies use data on these traits from many commercial farms. This helps to minimise any mismatch of genotype with environment.

81. Genetic resistance to disease has also been the focus of research for pig breeding companies over the past 20 years, who now prefer a 'whole animal' approach and general immunity, rather than specific markers for individual diseases.

82. For the last decade or so the breeding goal has shifted from maximising litter size *per se*, to rearing capability (in terms of teat number and survival rate of offspring). This is because of a strong, antagonistic genetic relationship between litter size and piglet survival.

83. The shift in emphasis of breeding goals from 'high output' to 'greater efficiency' means that only those animals which are better able to be productive and healthy, survive and rear offspring successfully, are selected as parents of the next generation. These new goals are more profitable, giving all-round benefits for both welfare and shareholders. However, it is more difficult to implement new breeding programmes where the link between good animal welfare and profit is less clear. In these circumstances, the use of new technologies to lower the costs of recording, and tailored genomic solutions for a wider set of functional fitness traits, should be beneficial.

Sheep, beef and dairy cattle

84. The national breeding programmes for ruminants are largely not in the hands of privately-owned companies, but led by Signet sheep and beef breeding programmes and DairyCo. For this reason, open access to the knowledge of the breeding goals and weightings can be obtained from these companies. A more detailed analysis on dairy cattle breeding objectives is reported in FAWC's 2009 Opinion on the welfare of the dairy cow[29].

85. The breeding goals for sheep and beef are more or less split between traits for maternal aspects of livestock production (e.g. milking/maternal ability and number of offspring) and carcass attributes. Some breeding programmes combine the two, to produce indices of overall genetic merit as lessons learnt from other livestock sectors on the benefits of broader breeding goals have been taken on board.

[29] Farm Animal Welfare Council, Opinion on the welfare of the dairy cow, 2009

Statement of the critical issues and questions

86. Current regulations regarding genetic material in the UK, and provision of information to the public about animal breeding have not kept up with recent advances in applied biology and biotechnology over the past decade. A new way to inform the public and encourage societal debate is required.

87. Code-EFABAR has been implemented since our last report on animal breeding in 2004. This code of practice has been developed with European funding and involves ethical input; its aims are to improve transparency and its analysis is comparable across countries and species. It is endorsed wholeheartedly by animal breeders.

88. Reliable data that reflect the state of endemic disease in farmed livestock and fish are needed so that the impact of subtle changes over time can be monitored routinely in a standardised way. As these data are usually more difficult and expensive to measure compared with production data, breeding companies should invest more in technological solutions to monitor animal health and welfare. Over time, this should reduce the costs associated with recording these traits.

89. New genomic technologies, particularly GWS, currently offer many opportunities to identify strains of livestock that are more or less susceptible to some diseases. More investment or ‘kick-start’ funding is needed to support the development and implementation of these technologies for the farming industry with a greater focus on functional fitness, disease and other traits that are important for animal welfare.

90. Despite welcome initiatives to broaden breeding goals, it is still the case that selection for heavier, more muscular carcasses in all livestock species can lead to associated leg problems and dystocia: an animal’s mass must be supported appropriately throughout its life.

91. Our previous Opinion[30] highlights that osteoporosis, leading to bone breakages in laying hens, is still an issue that arises partly as a direct result of selection for greater egg output. Another breeding goal is egg shell quality, which needs to be maintained throughout lay and which is fuelled by the depletion of calcium reserves from bones. This means that bone strength is unlikely to improve until specific aspects of bone quality are included in the breeding programme. If combined in a broader breeding programme then it is possible that, given appropriate weighting, osteoporosis can be reduced.

92. The restriction of feed for broilers at some stages of their growth is practised to prevent problems later on; parent stock need lifelong restriction with the consequence that they are often hungry. More research is needed on the level of feed intake control before firm conclusions about the significance of feed restriction programmes for bird welfare will be possible.

[30] Farm Animal Welfare Council. Opinion on osteoporosis and bone fractures in laying hens. 2010

93. There is some evidence that selection for high growth rates in broilers has resulted, in some strains, in animals that spend much of their time lying down when they are not feeding. If the housing conditions for these broilers are poor, this can exacerbate problems, e.g. causing increases in hockburn or pododermatitis.

94. The expansion of the use of EBVs and GEBVs to include aspects of health and welfare necessitates recording of health and welfare traits that are typically difficult or expensive to measure. The commitment by some companies to ensure that key aspects of health and fitness are not overlooked has gained significant momentum, especially over the past decade. This has occurred against a background of long-term decline in the value of primary products compared with the costs of disease.

Ethical analysis

95. Elite breeding animals are particularly valuable and, in some cases, no expense is spared to ensure that they are free from disease or any other problem that may compromise reproduction. This high level of care could be viewed as either 'masking' the true expression of selection outcomes or provision of the most suitable rearing environment that expresses an animal's genetic potential. An example would be a bull born by elective caesarean section, kept on deep straw and fed a high quality diet. Such an animal might appear to be of high genetic merit but might not thrive in standard conditions.

96. Breeding programmes that encompass both production and functional fitness traits lead to long-term improvements in animal health and welfare. There are considerable economic benefits through the use of bulls with breeding values for good locomotion and low somatic cell counts in their daughters, for example.

97. Having more robust livestock that are able to thrive in a range of different environments benefits both animals and farmers and will lead to fewer problems associated with any mis-match between the genotype and its rearing environment. For example, from a welfare point of view it is preferable that sheep repeatedly lame with footrot should not be used for breeding replacement animals.

98. The international nature of some breeding companies means that decisions about weighting breeding goals and the inclusion of certain traits are subject to influences which may not be suited to UK conditions or values.

99. Introducing more legislation or ethical review to manage breeding practices better or to control the importation of germplasm into the UK may lead to some companies deciding that the UK’s regulatory burden is too complex or restrictive, in which case the welfare problem may be exported, and any ability to influence these companies lost. Corporate responsibility, e.g. adoption of a Code of Good Practice for breeding companies that includes consideration of sustainability and is aimed at transparency across borders, offers a good way to deal with this.

100. The drive to feed the increasing world population – and to do this while limiting environmental and other impacts – will inevitably see the use of genetic selection in a major role. Most analyses of the impact of genetic selection on greenhouse gas emissions conclude that in general, faster growing, more efficient animals emit lower levels of greenhouse gas per unit of output (milk, meat, eggs) than their slower-growing or less efficient counterparts. However, more information is needed on whether environmental impact is reduced when whole life course analyses are undertaken (which include, for example, the carbon costs of producing concentrates for feed). How we reconcile these world-wide drivers with maintaining animals' integrity and good welfare is a major challenge to be met, at least in part, by the continued expansion of breeding programmes to include aspects of health, fitness and climate change. FAWC has published its advice on sustainable intensification in a recent letter to government in 2012[31]. It argues that in pursuit of sustainable intensification, production should not be promoted 'at any cost'. The concept of sustainability must include the welfare of farm animals. Indeed, livestock agriculture cannot be considered sustainable if an animal's life is not worth living.

101. Very often there is a trade-off between high meat yields and assisted births. The long-term consequences of difficult births in terms of production and survival prospects are not immediately apparent whereas the reward of receiving higher prices for more highly-muscled animals is.

102. If many laying hens have osteoporosis after one laying season due to the production of more than 300 eggs and, as a result, suffer bone fractures during lay or from catching and transportation to the abattoir, the question arises whether we have pushed these birds beyond their biological capacity to cope with such high production levels? Similarly, if broiler chickens only grow fast because they spend much of the day lying down and not moving, then do such animals deviate too far from our perceptions of how they *should* behave? FAWC's view is that practices have gone beyond what is acceptable. Similarly, we need to question whether it is acceptable that male elite breeding turkeys have been selected for size to the point that they cannot be allowed to breed naturally for fertility and fear of injury to females.

103. The breeding of pigs and other species for docility also prompts the question: How far should the breeding process be permitted to go before *telos* is inappropriately compromised? Farm animals have been domesticated but as yet have not been bred for reduced sentience. Where is the borderline of acceptability to be drawn, at docility, reduced aggression, reduced capability to feel pain, etc.? Production levels that will inevitably lead to animal welfare issues have been bred for in the past, e.g. milk production and mastitis in dairy cows, additional offspring in pigs without sufficient teats, egg numbers and osteoporosis in laying hens, growth rate in broilers and skeletal integrity, but controls intended to safeguard welfare are being actively included into breeding programmes now. It is difficult to provide clear-cut answers to all of these questions but FAWC's overall position is that too many breeding practices have resulted

[31] http://www.defra.gov.uk/fawc/files/sustainable-intensification.pdf

in farm animal morphologies and behaviours that are far from ideal. We should use established and new breeding technologies in such a way that the essence of each farm animal species is not compromised.

104. FAWC increasingly adheres to a precautionary principle where the animal should be given the benefit of any scientific or moral doubt. It also recognises the crucial role of the stockman in the rearing of all livestock.

Conclusions

105. Farm animal breeding companies should be congratulated for the progress made on breeding goals aimed at improving robustness and health and welfare traits. However, there are still some issues associated with high production levels resulting in poor animal welfare.

106. FAWC is concerned that genomic selection for easy to measure (largely production) traits is being implemented in advance of traits for functional fitness, due largely to a lack of data on health and fitness traits. The risk is that non-production traits will fall further behind and may lead to poor animal welfare in the long term.

107. FAWC is equally concerned that a renewed drive for production efficiency in an effort to reduce the impact of livestock production on the environment through higher-producing, biologically efficient livestock could detract from inclusion of broader breeding goals into breeding programmes, and lead to a deterioration in animal welfare.

108. New genomic technologies offer scope to determine likely future health status of animals. There has been lack of investment in the use of GWS in the UK compared with other countries. Some breeding companies have invested heavily in this technology for production traits, even though the greatest value is in predicting traits at an early stage of life that cannot easily be seen or measured or that are expressed late in life.

109. If an offspring's or parent's welfare is compromised by a breeding decision or technology then it should be a negative measure affecting the assessment of whether the animal has had – or will have - a life worth living. Breeding programmes or technologies should support the concept of a life worth living.

110. Failure to label products that have been created as a result of cloning means that purchasers have no knowledge of their provenance. As cloning is still an inefficient and expensive way to produce livestock, and as the current UK public opinion is similarly negative to that for GM foods, it is unlikely in the short term that cloning will i) become routine, or ii) be acceptable to the public as a way to produce the food they eat.

Recommendations

111. FAWC should maintain oversight of animal breeding and breeding technologies and Government should seek to raise the profile of its role in this regard.

112. Breeding companies for farmed animals and fish should incorporate a broad range of breeding goals into their breeding programmes, including fitness and functionality in tandem with productivity.

113. Breeding companies should include ‘commercial’ farm data into genetic evaluations from descendents of nucleus breeding stock, and thereby match the genotype to the rearing environments.

114. Breeding companies should work together with farmers to ensure that health traits are recorded well on farm to facilitate and maximise their value in breeding programmes for fitness.

115. Farmers have a responsibility to ensure that appropriate animals are sourced for their situation.

116. Government and industry should support research to quantify the short- and long-term consequences of dystocia in farmed livestock so that better decisions can be made by farmers on the choice of genotypes to be used in extensive livestock farming. Elective caesarean operations are not acceptable and the industry’s aim should be that all females should give birth naturally and with minimum assistance.

117. Government and industry should support research and development into genome-wide selection for welfare-enhancing breeding goal traits.

118. Publicly funded GM researchers should engage closely with the livestock-breeding industries to target research effort better towards traits that are likely to have the greatest impact on animal welfare.

119. Government should consider anew how to assess the creation and introduction of new genetic material for animals, which should include rigorous scientific and ethical evaluation.

120. More research is needed to assess the welfare impact of using laparascopic AI in sheep and specifically to assess the effectiveness of pain relief.

APPENDIX 1

Those who gave evidence and assistance

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Aquagen
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Landcatch Natural Selection
Lithgow's Ltd
National Standing Committee on Farm Animal Genetic Resources
Pig Improvement Company (PIC) Ltd
Tom Barron Independent Hatcheries
Sustainable Farm Animal Breeding and Reproduction Technology Platform

APPENDIX 2

GLOSSARY

antagonistic genetic correlations – the same genes are implicated in a positive outcome for one aspect of animal production (e.g. milk yield) and a negative outcome for another (e.g. mastitis)

artificial insemination (AI) – the impregnation of a female by artificially injecting semen into the vagina, uterus, etc. rather than by sexual intercourse

bovine leucocyte adhesion deficiency – a disease in cattle with immunodeficiency whereby recurrent bacterial infections persist

breeding goals – individual aspects of an animal's performance that are desirable to improve, e.g. growth rate in calves or resistance to mastitis

caesarean section – surgical intervention to deliver offspring

cloning – the technique of making an identical copy of an organism's DNA and genetic makeup

congenital defect – defect existing at or before birth usually through heredity or environment

differentially expressed genes – different variants of the same gene (often leading to different outcomes)

dystocia – a slow or difficult labour or delivery

easy-care – a system of production relying on the ability of animals to be less reliant on humans in terms of management and husbandry

elite breeding stock – typically high genetic merit animals from which a larger number of animals are generated

embryo transfer (ET) – the process by which the fertilized ovum is transferred at the blastocyst stage to the recipient's uterus

estimated breeding values (EBVs) – unbiased estimates of genetic worth for a range of traits that are often combined with an economic weighting factor into total merit indices; used to guide breeders on selection of replacement males and females.

genetic merit – an estimation of the superiority or inferiority of an animal for a trait such as growth rate, compared to other animals that are evaluated together in the same genetic analysis. Estimated breeding values (EBVs) are normally the 'unit of currency' to compare the genetic merit of animals, although genomic breeding values (GBVs) are now also available for some livestock species.

genetic modification (GM) – insertion of genes directly into the animal's genome through manipulation in the laboratory

genetic selection –making decisions about which animals become parents of the next generation, sometimes using EBVs to help

genome – the total genetic information present in a somatic cell and unique to any specific organism

genomic breeding values (GBVs) – breeding values derived from using genome-wide association studies to link data from SNP analyses (see below) to phenotypic information

genomic prediction of breeding merit – as above, with units of currency being genomic breeding values genotype - the fundamental constitution of an organism in terms of its hereditary factors

Genotype by Environment (G x E) – the relationship between the genotype and the environment (usually farm environment). A ‘G x E interaction’ is said to exist when the same or related animals perform differently in different environments.

genome-wide selection (GWS) – using genomic breeding values to aid selection decisions

germplasm – embryos, oocytes, semen

heritability – the proportion of total variation in an individual characteristic that can be explained by genetic association of the population in which it is measured. Expressed on a scale of 0 to 1 and used to classify the degree to which traits are easy or more difficult to alter through selective breeding, with higher values being more readily influenced through the use of selective breeding.

hockburn – lesions of upper joints of broiler chickens caused by the ammonia from urine and waste in the litter

infectious pancreatic necrosis (IPN) – viral disease of fish

introgression – mating animals with a specific (desired) characteristic into another population that does not have it

in vitro – outside or isolated from the living organism and in a test tube or other artificial environment

juvenile *in vitro* embryo transfer – Eggs recovered from ovaries from slaughtered animals are fertilised *in vitro* and transferred to recipient dams

lethal recessive genes – genes having deleterious consequences for animal health or welfare that are ‘dormant’ in a population until an animal inherits two copies of the gene

lixiscope – portable x-ray inspection equipment

marker assisted selection (MAS) – using a known gene variant that has a statistical association with a desired phenotype to assist selection of breeding stock

ovum pickup – collection of eggs (ova) from ovaries

perinatal mortality – mortality of late foetuses or new-born animals

phenotype – the physical and psychological characteristics of an organism resulting from both genetics and environment

polled - lacking horns

recessive genes – genes that are not expressed until two copies are inherited

selection index – an overall score of genetic merit usually expressed in monetary terms, which combines several different desirable breeding goals (e.g. growth rate, disease resistance, litter size)

selective breeding – picking the best animals to be parents of the next generation

sib-testing – comparison of related animals of the same generation single nucleotide polymorphism (SNP) – a DNA sequence variation occurring when a single nucleotide (C, A, T or G) in the genome differs between members of the same species.

somatic cell nuclear transfer (SCNT) – a laboratory technique to produce a clone or cells for tissue culture that involves the insertion of a donor's somatic cell nucleus into a host's egg cell that has first been emptied of its own nucleus

strain – usually refers to a different phenotype of the same breed

sudden death syndrome – a category of illness in which animals under frequent observation die either with no obvious illness or after a period of illness lasting only a few hours

telos – what it is to be a particular animal

trait – an inherited characteristic

transgenesis – individual genes from the same or a different species inserted into the genome of another individual

APPENDIX 3

Change in Livestock Performance

Species	Trait	Indicative performance		
		1960s	**2005**	**% Change**
Pigs	**Pigs weaned/sow/year**	**14**	**21**	**50**
	Lean %	**40**	**55**	**37**
	Kg lean meat/tonne feed	**85**	**170**	**100**
Broiler chickens	**Days to 2 Kg**	**100**	**40**	**60**
	Feed conversion ratio	**3.0**	**1.7**	**43**
Layer hens	**Eggs per year**	**230**	**300**	**30**
	Eggs/tonne feed	**5000**	**9000**	**80**
Dairy cows	**Milk/cow/lactation (Kg)**	**6000**	**10,000**	**67**

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