Future global sustainability and responsibility – What role for pig genetics?

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Background

Over the last decade there has been increasing human interest and debate over environmental issues such as climate change, sustainability and global responsibility. A key player has been the Inter-governmental Panel on Climate Change (IPCC), which was set up by the United Nations (UN Environmental Programme) and the World Meteorological Organisation (WMO) to assess technical, scientific and sociological impacts. The IPCC was awarded the Nobel Peace Prize in 2007, together with Al Gore, the ex US Vice-President. One aspect that the IPCC has researched is the role of agriculture in global warming. To date, agriculture has been mostly successful in feeding the world but the global population is growing fast. The Food and Agricultural Organisation of the UN (FAO) has estimated that to meet the demand growth fron 2000 to 2030, cereal production must increase by 50% and livestock production by 85% (FAO, 2006).

The global debate on sustainability and responsibility was galvanised by the publication of the Stern Review on 'The Economics of Climate Change' in 2006. This indicated that agriculture was responsible for 14% of global greenhouse gas emissions (GHG's) in 2000. The recently published Australian Garnaut study (The Garnaut Climate Change Review, 2008) has reported that this had increased to 15% by 2008. The Review also suggests that the per capita GHG's for Australia are four times the world average and significantly more than for the USA. There are complex reasons for this but two of the keys are the large land area and that agriculture (plus forestry and fisheries) accounts for 29.3% of GHG's. It is interesting to note that pigs account for just 1.6% of Australia's agricultural emissions, compared with 69.7% for cattle and 22.0% for sheep. Despite a mass of well-researched statistics from Garnault, it is perhaps unfortunate that the world's press main take-home message from the review has been an endorsement for kangaroo meat! This also follows the September report from the chairman of the IPCC (BBC News, 7 September, 2008) who stated 'People should consider eating less meat as a way of combating global warming'. This comment stems from the major FAO study 'Livestock's Long Shadow (FAO, 2006) which reported that the global livestock impact on GHG's was:

9% of Carbon dioxide
35-40% of Methane
64% of Ammonia
65% of Nitrous Oxide

Overall it was estimated that the direct emissions from meat accounted for 18% of the world's GHG's. Although ruminants are the major 'culprit', pressure for accountability also applies to pigs and poultry. As meat demand from these species is growing fastest it is clear that there must be plans to reduce the amount of GHG per unit of product.

Pig environmental studies

There are several recent studies on the detailed role of pigs on the environment. For example, Danske slagterier (2008) reported on 'Danish pig producers and the environment' and showed that for the 23 years from 1985 to 2008 there had been highly significant reductions in chemical discharges:

39% less nitrogen
42% less phosphorus
50% less ammonia

In addition, there had been a 50% reduction in the use of artificial fertiliser on arable land because of increased use of pig slurry. Overall it was estimated that GHG emissions per kg of pig meat had fallen by 17% in the sixteen years since 1992.

In another Danish report (Dalgaard, Halberg and Hermansen, 2007), a detailed study was made of changes in eutrophication (nitrate and phosphate from slurry), acidification (from ammonia and suphur dioxide) as well as global warming/GHG. They showed highly significant projected falls from 1995 to 2015 of 74% in eutrophication, 50% in acidification and 25% in GHG's.

The effect of different farming systems on the environment has been reported in detail by van der Sluis and ter Beek (2008) using data from Cranfield University in the UK. Using Global Warming Potential (GWP), a measure of how much a given mass of GHG is estimated to contribute to global warming, it was reported that organic production was 22% 'better' than non-organic production while outdoor breeding systems were 12% 'better' than indoor breeding systems.

Influence of genetics

Plastow (2007) reported that 40 years of genetic progress had halved the amount of manure produced on a per productive sow basis and that the amount of land needed to produce a cooked breakfast of eggs and bacon had been reduced by 70% through improved efficiency. Perhaps, of even greater importance has been the ongoing genetic progress across a wide range of performance and efficiency traits. Walters (2001) reported on national annual genetic trends in the UK which ranged between 1.3% (for feed conversion) to 2.1% (for backfat). Van der Steen, Prall and Plastow (2005) showed highly significant phenotypic changes from the 1960's, which had a sizeable genetic component:

Table 1. Typical phenotypic progress from 1960's to the present

	1960's	Today	% change	Benefit
Weaned/litter	14	21	50	7 extra pigs
Lean %	44	55	37	11.25 kg more lean
FCR	3.0	2.2	27	75.2 kg less feed
Kg lean/tonne feed	85	170	100	85 kg more lean/tonne

Walling (2008) noted that the best performing units now far exceed the average benefits so that the percentage change from the 1960's in pigs weaned per litter is over 100% and more than 200 kg of lean per tonne of feed is seen on the most efficient units of today.

Despite the positive trends in genetic progress there has been little published on the correlated benefits accruing to the environment. However, Audsley, Jones and Williams (2007) reported on modelling work at Cranfield University in the UK which looked specifically at the effect of improved genetics in livestock on GHG's using a complex input:output life cycle model. Table 2 shows the differences between livestock in emissions:

Table 2. Emissions per tonne of product in 2007

	Methan	Ammonia	Nitrous oxide	GWP
Broilers	5	23	3	3448
Layers	8	28	4	3791
Pigs	**49**	**28**	**2**	**4689**
Beef	265	71	12	14704
Sheep	301	41	11	15813

Comparing the twenty year period from 1988 to 2007 the authors reported significant percentage falls in methane, ammonia, nitrous oxide and GWP in pigs and poultry but not in beef and sheep:

Table 3. Percentage change from 1988 to 2007 through genetic improvement

	Methan	Ammonia	Nitrous oxide	GWP
Broilers	-20	+10	-23	-23
Layers	-30	-36	-29	-25
Pigs	**-17**	**-18**	**-14**	**-15**
Beef	0	0	0	0
Sheep	-1	0	0	-1

Based on these data, the authors concluded that the annual reduction in GWP in pigs through genetic improvement was 0.8% over the last twenty years. They also forecast that, if the same levels of genetic progress were achieved in the next 15 years, then there would be further reductions in methane, ammonia and GWP of 15%, 14% and 14% respectively. Hopefully, with the advent of new technologies and more accurate breeding value assessment, genetic progress will increase over the next 15 years to give even greater environmental benefits!

An interesting feature of the Cranfield model was that pigs rivalled poultry in terms of current and future improvements in feed conversion:

Table 4. Percentage gains in feed conversion

	1988 to 2007	2007 to 2022
Layers	25	20
Broilers	20	15
Pigs	25	18
Beef	0	17
Milk	18	10

Future Options

Genetics will continue to play a key role in ensuring future global sustainability. The main advantages of genetics are that gains are cumulative and permanent. Furthermore, most genetic techniques are 'sustainable' although cloning is now under huge political pressure in Europe with a ban passed in the European Parliament last month (see - http://cordis.europa.eu/search/index.cfm?fuseaction=news.document&N_RCN=29825).

Essentially there are five main routes through which genetic improvement can help to reduce GHG emissions:

1) Improved productivity and efficiency.
2) Reduced wastage.
3) Direct selection to reduce emissions.
4) Developing new indices for selection on emissions.
5) Exploiting genetic resources.

1. Improved productivity and efficiency

As shown above, selection to date has been impressive and it will be important to continue progress for the future. The message is keep up the good work!

Among the benefits from successful selection are higher gross efficiency by reducing the overall maintenance cost of production, a requirement for fewer animals for a given level of output and a reduction in the finishing period directly lowering emissions and the amount of slurry produced.

Among particular challenges that may become more important for the future are:

a) Reduced feed intake – reducing intake is a feature of many breeding programmes. The result is that the genetic potential in lean growth is increasingly restricted (Walters, 2003).

b) Heat stress – increasing levels of heat stress are likely to occur as global temperatures increase. As a result, appetite will be further reduced in order to reduce heat production. There is some evidence that heat stress related problems are emphasised in 'modern' lines with high levels of lean growth and reproductive potential, so that genetic selection might be used to improve resistance to heat stress (Gourdine, Mandonnet, Naves, Bidanel and Renaudeau. 2006). Bloemhof, Van der Waaij and Knol (2007) have indicated that animals selected for high reproductive performance in the tropics have been indirectly selected for heat stress tolerance and they have proposed that future studies should focus on estimating the genetic variation in heat stress susceptibility in commercial sow lines.

c) Daily maintenance yields – selection for lean growth has led to animals of larger mature size and with higher maintenance needs (Knap, 2000). This has implications for breeding programmes faced with the need for increased efficiency and minimization of GHG's.

d) Exploiting nutritional differences between genotypes – several studies have shown that there is genetic and individual variation in digestibility and post absorption for energy, fibre and protein. Carre, Juin, Mignon-Grasteau and Seve (2007) have reviewed ways in which these differences might be exploited in future genetic programmes.

Finally, one of the largest problems that is faced by the commercial sector is the failure to achieve the full advantage of improved genetics because of the 'genotype-phenotype gap'. Every attempt must be made to understand the reasons for this and to alleviate the problem.

2. Reduced wastage

Selection for fitness traits (such as longevity, disease resistance and fertility) will reduce wastage levels. Most of the traits are complex but the underlying genetic components/genes are slowly being unravelled. This is an area that should reap real benefits for genetic gains in the next decade.

One aspect of climate change is that higher global temperatures will result in increased (and new?) disease burdens. Already the costs of disease are huge – some 5 to 15% in developed countries and 15 to 30% in developing countries. The result is an increase in resource requirements, higher emissions per unit of product and higher maintenance requirements (typically up to x1.40). There are many examples of genetic variability (E.coli, Atrophic rhinitis, FMD, PRRS, etc.) so it is hoped that technologies will develop that allow disease resistance to be exploited in the future. The recent review of Bishop and Kyriazarkis (2007) highlights possible areas for real progress.

3. Direct selection to reduce emissions

In the ruminant it is known that there is variation between animals, between breeds and across time for the production of GHG's. However, direct measurement in live animals is currently difficult so selection for decreased GHG's is a goal for the future. However, in the pig there is the example of the 'Enviro Pigs' (Trade marked) developed at Guelph in Canada which have been genetically-modified to excrete 60% less phosphorus. The pigs cost less to feed and produce their own phytase to digest phytate, the naturally occurring form of phosphorus in feed. A review can be found at http://www.uoguelph.ca/enviropig/.

4. Developing new indices for selection on emissions

As the environment changes, it is possible to invest in broader breeding goals. These breeding goals can be built in a number of ways but the 'valuation' of traits may be complex as there are several different scientific approaches. These include the use of restricted or desired gains, the use of relative economic values, the adaptation of economic values based on 'conjoint' analyses and total farm modelling, where trait changes are related to environmental impact. Wall, Bell and Simm (20070 reviewed these in the context of ruminant production but little has been reported on the development of porcine indices to 'save the planet'.

5. Exploiting genetic resources

There is a growing awareness about the potential long-term importance of domestic animal genetic resources. One of the key reasons for maintaining these resources is that a 'pool' of genes and gene combinations will be available for the future, acting as an insurance policy if 'modern' genotypes fail in a particular environment or have low gene frequencies in a desired trait. To date, there are several examples of favourable gene frequencies in 'traditional' breeds – for example the K88 *E.coli* resistant gene was found at high frequencies in several non-commercial genotypes. In the global assessment of genetic resources (FAO, 2007) the report has called for greater characterisation, evaluation and preservation of unique genotypes to ensure that a 'genetic' reserve is available for future production demands.

Finale

Many of the genetic techniques discussed in this paper will require high levels of expenditure to allow their successful development. At a time of global uncertainty about future funding levels for research it is important that the case for genetics funding is made forcibly. The Moran Report (2007) to the UK government showed the very high value of genetics R and D in helping to deliver on policy priorities. The accepted UK treasury delivery rate of return is 3.5% while plant and animal genetic improvement ranged from 11 to 61%. Quod erat demonstrandum!

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