Genetic solutions to climate change

Dr Grant Walling, research and genetics director

Regardless of your political or personal views, it is now inevitable that the issues of climate change and sustainable living will dominate the agenda for all governments and industries during the 21st century. Terms such as 'carbon footprint' and 'one planet living' are now becoming ever more common in the business vocabulary.

The scale of how much many countries and industries will have to change was highlighted in a report by Mathis Wacker-nagel of the Global Footprint Network.

The only country with a sustainable level of development was Cuba and that was only achieved due to a US oil embargo (see New Scientist, Issue 2624, page 10 for more details).

The question in the pig production sector is whether genetics can provide a solution to these climate change challenges? The answer is not simple.

Governments cannot simply export the problem overseas as this just adds food miles and fails to recognise this as a global problem.

Also scientists cannot become too entrenched in their individual disciplines, as the solution needs to benefit the entire system.

Reducing nitrogen excretion is not a benefit if arable operators need to purchase greater amounts of artificial nitrogen fertiliser (itself requiring a high energy production process) to compensate.

Some recent work in Edin-burgh suggests that not only can genetics improve the carbon footprint of pig production but has been doing so for at least the last 20 years. The key is the improvement of efficiency.

Breeding companies for the last 25 years have selected animals based on higher output (pigs/sow/year) and higher levels of efficiency (high growth rate and lean meat % and low FCR).

This means that the level of output (kilos of pigmeat) per unit input (kilos of feed) has significantly improved over time.

Based on pig breeding company rates of genetic improvement, Eric Audsley, Huw Jones and Adrian Williams estimated the effect of genetic improvement on enteric and nitrogenous emissions using LCA modelling.

They presented their results at a workshop recently held in Edinburgh on the potential of livestock genetics, genomics and breeding to reduce methane and nitrogen emissions from livestock systems.

The results from 1988 to date showed a 1.5% per annum reduction in methane emissions, a 1.7% per annum reduction in nitrogen excretion, a 1.2% per annum reduction in C02 emissions and a 1.3% reduction in MJ of energy used per unit output.

More importantly, the paper also predicted a 1% per annum improvement in all these traits for the next 15 years.

Such reductions meant that pig producers using modern genetics had already achieved Kyoto greenhouse gas emissions targets by the time the treaty was signed in 1997 (the treaty agreed a 5.2% reduction based on 1990 emission levels).

If the same achievements were realised in all other industries not only would Kyoto environmental protocols be met but so too would more ambitious targets such as the UK Climate Change Bill (60% cut by 2050) and the European Union Energy Policy (a unilateral 20% reduction in green house gas emissions by 2020).

Based on this research, policy makers and legislators should therefore not ask how pig genetics can provide climate change solutions but recognise the achievement that is already being made available to pig producers globally.

Indeed, other sectors would be well advised to mirror the business models of genetics companies with their effective selection for efficiency rapidly disseminated into their products.

Based on this evidence, pig genetics can truly be considered a green industry. ■

Disease resistance or disease tolerance?

Dr Grant Walling, research and genetics director

Producing a pig resistant to endemic pig diseases sounds a very attractive proposition and if it were possible such pig lines would be very much in demand. There is a twofold benefit to the pig population of having resistant animals. One comes from the reduced level of infection and the other from the reduced level of challenge, as fewer infected animals are contributing to the pathogenic reservoir that exists in the population. There are, therefore, multiple benefits to the producer due to the reduction in the cost of production from reduced veterinary and medicine costs, better phenotypic performance and lower mortality.

So, why haven't genetic companies produced such animals? One reason is that genetic variation in the host is not seen for all diseases. In pig populations, scientists have found evidence of genetic variation to diseases such as PRRS, but not EP.

To further complicate the issue, anecdotal evidence for genetic variation in susceptibility to other diseases is inconsistent, for example the Danish stopped using Hampshire sires to reduce the incidence of PMWS, whilst many British pig producers switched to Hampshire sires as a solution to PMWS problems.

A major dilemma associated with this issue is that of resistance or tolerance. Would producers prefer animals that are resistant to, or tolerant of, a particular disease? Resistance is the ability of the host (in our case the pig) to moderate the life cycle of the pathogen. Tolerance is the ability of the host to withstand the impact of the infection.

An answer to the resistance or tolerance debacle may be closer thanks to some work conducted by JSR Genetics at the Roslin Institute funded by the UK government (DEFRA) and the UK levy board (MLC).

Growth rate measurements and white blood cell counts were taken on animals and their progeny across a range of farms of varying health conditions. The results showed that animals with the highest growth rates had low counts of specific white blood cells (namely NK Cells, B Cells and monocytes). This was seen across all farms regardless of disease status (no genotype x environment interaction).

This suggests that the breeding company approach of having high health nucleus farms selecting animals to sell to lower health commercial farms is scientifically sound as top nucleus performers would also be top commercial performers irrespective of health.

Interestingly, on both farms these top performers will always have lower counts of NK cells, B cells and monocytes.

It is the finding of a correlation between high performance and low white blood cell levels that suggests tolerance to be the better strategy in coping with disease. Animals with a degree of resistance to a disease can still become infected and can experience a drop in performance depending on which part of the pathogen's life cycle it is able to moderate.

In contrast, tolerant animals become infected but do not experience, or experience a lower loss in performance associated with the disease. It is these animals that concentrate their resources on production traits, rather than diverting resource to fight disease when faced with infection, that are the most profitable in a commercial pig production enterprise. It is therefore tolerance, and not resistance, that delivers the greatest benefit.

Animals with resistance to a particular disease may still become infected and experience a drop in performance depending on which part of the pathogen's life cycle it is able to moderate.

Resistance may manifest itself as reduced susceptibility to infection, increased latency period, improved recovery rate, reduced infectiousness or reduced mortality. Tolerant animals become infected but do not experience the losses in performance associated with resistant animals, as they do not divert resources in triggering a response to the infection. ■

Chewing the fat . . . . . about Omega 3

Dr Grant Walling, research and genetics director

Many western governments have become increasingly concerned about levels of obesity in the population and more specifically the cost of these people on healthcare services.

To try and mitigate such risks, national health authorities have tried to produce simple messages to improve the nation's health, a common one of these is 'eat less fat', however, this oversimplifies the underlying science.

Fats can be divided into different categories depending on their chemical structure.

One particular group, omega-3 fatty acids, have produced promising evidence that they may reduce the risk of heart disease, improve blood circulation, reduce blood pressure, help in cases of depression and anxiety and reduce violent behaviour: some research even suggests anti-cancer effects.

The biggest challenge to consumers is that these fats cannot be made in the human body from other sources and therefore must be supplied in food.

Omega-3 in pork

Over the last year this has given rise to a number of omega-3 pork products with claims of potential health benefits to the consumer. But are all these omega-3 pork options the same or are some better than others?

To answer this question we have to further subdivide the omega-3 fatty acids into smaller groups. Each fatty acid is characterised by the length of the carbon chain in the chemical structure. Alpha linolenic acid (ALA) has an 18 carbon chain and is widely found in plant oils. In contrast, fish oils contain the longer-chain omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

Although the body, to some extent, can convert linoleic acid (LA) and ALA into these longer-chain omega-3 fatty acids, the marine oil omega-3 fatty acids have wholesome properties of their own.

It is therefore the source of omega-3 fatty acid in the pig diet that determines the type of omega-3 fatty acid in the pork.

Pigs fed a diet of elevated linseed oil will have increased levels of ALA, whereas pigs fed a diet of increased fish oils will see increased levels of EPA and DHA. The scientific data suggests that the longer chain fatty acids (from marine oils) are better for human health.

Get the correct ratio

Consumers should also be aware that it is the ratio of omega-3 to omega-6 fats (especially ALA versus LA) that are important to human health, simply eating a greater quantity of fat does not provide health benefits and would lead to a deterioration in coronary health.

Taking things further one American group in 2006 created a transgenic pig with a gene (fat-1) that creates an enzyme to convert omega-6 fatty acids to omega-3 fatty acids.

The resultant offspring would not need to be fed an omega-3 diet to produce the desired fatty acids in its meat as it would be able to do so naturally. Sadly current levels of public caution over transgenic animals mean such pigs are unlikely to enter the supply chain in the foreseeable future.

Using the more conventional nutritional approaches, DHA levels in a standard 200g pork chop can be improved 553% from 15mg to 83mg.

This represents over 40% of the recommended daily amount. DHA levels in 120g of cooked ham can also be improved by 526% from 6mg to 37.6mg.

The raw material prices for the feed mean that such enhanced pigmeat can be 5% more expensive to produce; the true test will be determining how much consumers value their health?

Those wanting to find out more information about omega-3 enhanced pigmeat should visit http://www.jsrgenetics.com/vitapork.php ■

Genome wide selection: science fiction becomes fact

Dr Grant Walling, research and genetics director

After many false dawns and wayward forecasts it is now rare for scientists to stand up and predict the future.

However, Mike Goddard's keynote address at the recent British Society of Animal Science meeting did just that.

His bold assertion advocated a change from collecting pedigree data and measuring traits to selection based wholly on an animal's genome sequence.

Whilst this is not going to happen overnight, Mike seems confident that the next two decades may make this a reality; but just how likely is this to happen in the global pig industry?

Genome sequence

Firstly, we will need the pig genome sequence and, thanks to the efforts – and financial input – of North America, this is likely to be available within the next two years.

Secondly, we will need the development of a sufficiently dense marker chip.

Given that the length of the pig genome is 3.15 billion base pairs, it is likely that 315,000 markers will be needed to provide adequate coverage.

The cost per animal of analysing these chips also needs to reduce from the current levels of US$2,000.

Even if all these criteria are met, how would the industry use the information?

Meat eating quality

One innovative suggestion from Mike Goddard related to how the technology could be used to improve one area that is difficult to achieve using conventional breeding – that of meat eating quality.

It may be as simple as buying a few hundred packs of meat from conventional retail outlets and studying similarities in the genome sequence from the best tasting packs.

Source populations could then be screened to identify those animals with the same sequence. Such animals would then comprise the supply base of a scheme designed to produce products of higher meat eating quality.

Whilst this application is very appealing, the technology is less likely to find successful application in pigs compared to other species. This is because many of the economically important traits in pigs can be measured before sexual maturity and slaughter.

In contrast, the dairy industry has to wait for up to six years for bull proofs before selecting the animals for further breeding; hence, much larger generation intervals are incurred.

It is by eradicating this specific problem that this technology is likely to be of greatest benefit to livestock breeding programmes.

In pigs, it will be difficult to measure traits such as fertility, post slaughter traits and disease resistance that are likely to be most affected, as is often the case with new genomic technologies.

Future premonition

In the meantime, a colleague recently reminded me that the genome wide selection concept is not as novel as we may think.

The 1997 Andrew Niccol film 'Gattaca' describes a world where society analyses DNA and determines where its members belong in life.

The lead character, played by Ethan Hawke, is born with a congenital heart condition which would prevent him from achieving his career ambition of space travel.

So he assumes the identity of an athlete whose genes would allow him to fulfil his dream.

Despite being made over ten years ago, it is interesting that the only concept that Andrew Niccol got wrong was the species.

Had he picked a domestic livestock species, it may well have been that for once, science fiction had provided a real glimpse into the foreseeable future! ■

A spoonful of Darwin helps disease go down?

Dr Grant Walling, research and genetics director

Are veterinary prescriptions causing pig producers more harm than good? Are high price drugs perpetuating disease problems on pig units? And could Charles Darwin's work provide a better solution?

Proponents of Darwinian medicine would argue that a longer term strategy may be to accept short term pain in return for animals better evolved to thrive on a commercial farm.

The theory traces back to Darwin's original concepts of natural selection but evidence that it works surround us in the world today.

Negative impact

Wherever a significant disease challenge is being exerted on a population, and the disease decreases the ability of the infected animal to contribute offspring to future generations, Darwin's influence can still be seen.

Nowhere is this starker than in sub-Saharan African populations where the incidence of the HIV virus and mortality from the disease is high.

Yet within these populations, and among the sex workers within these countries, are individuals who have experienced very high disease challenges but not succumbed to the virus.

These people, in turn, must confer some genetic resistance to the disease.

Given the huge impact the HIV virus has on survival once it has been contracted in such countries without widespread access to antiretroviral drugs, those with greater resistance are likely to make the greatest contribution (genetically) to future generations.

Furthermore, the benefits of resistance will be passed to future generations through genetic inheritance.

So what lessons can be learnt by pig producers? If all sow medication were to be removed from a farm, the mortality at parities one and two would increase on units with higher disease challenges, but these animals would contribute comparatively fewer animals into the system. More resistant surviving sows would, therefore, make a greater contribution to the population and transmit any genetic resistance to the endemic disease to their progeny.

Businesses that would benefit greatly would be those currently producing their own replacements but using high levels of medication which may be masking any inherent resistance to the endemic disease on the unit.

Breeding populations of GGPs and GPs, to contribute to subsequent generations of the breeding herd, with the innate ability to resist disease is economically more sustainable.

Furthermore, the effect would be permanent and cumulative upon previous generations of selection.

Darwinian medicine also explains the spikes in mortality that are experienced when a particularly virulent or destructive pathogen is first seen in a previously naïve environment.

The most susceptible individuals quickly succumb to the disease and are rapidly removed from the population.

Survival of the fittest

Over time animals with a greater tolerance or resistance to the disease remain and their progeny make up the majority of the farm, therefore the impact of the disease diminishes in these more immuno-competent animals.

Vaccinating populations prior to a disease outbreak protects the most susceptible animals creating the necessity for further vaccination in subsequent sus- ceptible generations and the pig unit becoming reliant on the vaccine.

So why don't veterinarians prescribe more Darwinian medicine? The reason is often that the short term impact of disease on pig businesses is too great a financial burden to simply suffer.

Whilst natural processes are capable of delivering the perfect solution, sadly they can be too slow for a world devoted to cash flows and three year business plans. ■

Putting the customer first

Dr Grant Walling, research and genetics director

Once again the JSR Technical Conference provided stimulating and challenging ideas for the influence of science and technology on the future of the industry.

Whilst much of the conference will be covered in the pig press one concept from Rob Cumine may have been missed by some of the audience.

Using his retail background Rob highlighted the agricultural issues that are most important from a consumer perspective.

Perhaps, not surprisingly growth rate and carcase yield did not appear on the list of 39 issues. In fact such traits would have only influenced the 'production cost' topic.

Time for a change?

Throughout the world pig genetics are primarily still sold on their farm performance characteristics despite bearing little relevance to consumer demands. But could things be different?

Rob Cumine highlighted projects in the Australian sheep industry where extensive work has been done on the shelf life of lamb. Shelf life is primarily influenced by various features of muscle biochemistry such as oxidation of myoglobin.

Scientific studies have highlighted such traits to have a genetic component and hence populations can include shelf life within a selection index.

Through genetic selection the consumer then gains an improvement in a trait with specific importance to their sector of the food chain.

Of the 39 issues highlighted approximately 14 could potentially be addressed using conventional genetic selection but why are such priorities so low on the scale of pig producers around the world?

The answer (and hence the problem) is the structure of payments to the industry. Pig producers select efficient, fast growing, high yielding animals because they are cheaper to produce.

Assuming a fixed market price, a lower cost of production equates to improved profitability but the assumption of a fixed market price is the very cause of the problem.

Producers who produce consumer focused pork are in most instances paid the same as those who base their business on the lowest cost of production.

Despite producing a superior product for the consumer the fixed price means lower profitability ultimately leading to a less competitive business.

If those producing enhanced pork were given additional reward funded by a modest price increase from the happy consumers this would balance the inequality.

Equally, the converse could also apply where those ignoring customer needs could be penalised due to the lower value of the poorer quality meat.

The additional rewards being passed back up the supply chain would cover the research and development costs of the new traits to be included in the selection indices.

The lack of current integration in the supply chain is stifling such research and prevents progress in these areas.

Quality pork

Although there has been some moves in the UK to differentiate 'quality' pork, this has been almost entirely restricted to the bacon segment, of which much is dominated by overseas suppliers and much more needs to be done in the UK before a sustainable position is found.

Some countries have however evolved significantly further than others. South Korea has a system that influences the payment to pig producers based on a marbling score of the meat.

Marbling is caused by intramuscular fat and has been shown to be correlated with improved meat eating quality.

It is an excellent example of rewarding producers for meeting the demand of the consumer rather than purely their own farming system. ■

Precision pork production

Dr Grant Walling, research and genetics director

Recent dissection work undertaken by JSR at Harper Adams Univer-sity College and also at the University of Bristol has further demonstrated the value of using Duroc sires to improve meat eating quality.

Duroc sired progeny had 35% more intra-muscular fat, 13% lower shear force values and 16% lower drip loss in comparison to progeny from conventional white sire lines.

Ultimate pH was higher and the colour of the meat darker – confirming the superiority of the Duroc breed for meat eating quality.

The x factor

Meat eating quality however does not simply stop at the breed and those that think that all Duroc sired pork will contain the magical 'x' factor for pork quality need to reassess their production system.

Meat quality can even be influenced before the piglet is born by enhancing sow nutrition 85 days into gestation to increase the number of muscle fibres in the unborn piglet.

Post parturition muscle fibre number is fixed and can only be increased in diameter. Growth actually plays an important role in determining meat eating quality.

Tougher meat

Recent work by BPEX has demonstrated animals with a slower or interrupted growth rate produce tougher meat, with increased levels of drip loss, hence such animals should be removed from quality meat initiatives.

Perhaps some of the greatest influences on meat eating quality are determined during that last 24 hours of an animal's life.

Initiatives aimed at increasing meat eating quality during an animal's life can be quickly eliminated through inappropriate treatment of animals during this period. Animals should have feed withdrawn 12-18 hours prior to transportation to slaughter to reduce motion sickness and gut fill.

Increasing stocking density in transportation, from 0.5m^2 to 0.37m^2 per 100kg, reduces stress and hence the incidence of dark, firm, dry meat (DFD) by 11% (EU legislators and animal welfare groups please take note).

Reduce acute stress

Upon arrival at the slaughter plant animals should not be fed (but should have access to water) and should not be slaughtered immediately – this reduces acute stress and the incidence of higher levels of pale, soft exudative meat (PSE). Instead animals should be rested for one to three hours.

After three hours DFD incidence start to rise again (11.6%), after nine hours this rises further (18.6%) and those leaving animals in lairage overnight exhibit very high levels of DFD meat (24.9%) with nearly one in four animals producing inferior meat eating quality.

Those claiming that overnight lairage is somehow beneficial for animals, or leads to a better quality product, are therefore wrong. DFD is an indicator of an animal that has suffered long term stress.

Good meat eating quality is therefore delivered by a successful set of processes rather than by a singular factor.

Global schemes

Meat eating quality supply chains are, therefore, created through the involvement of the whole chain and not by an innovator working alone.

It is for this reason that JSR successfully participates in various global schemes aimed at delivering enhanced quality eating products to pork consumers. ■