Advanced Computing Systems

Dr Grant Walling

The philosophy of 18th Century agriculturalist Robert Bakewell was to 'breed from the best', a strategy with which even modern day genetics companies will still be able to identify. During the last 200 years the biggest change has been in the tools used to identify, store and process data on the best animals. The evolution of the computing industry has occurred at a far faster pace than that of the various pig breeds.

Back in November 1971 Intel released its first microprocessor, the 4004. It ran at 108KHz, contained 2,300 transistors and could execute 0.06 million instructions per second (MIPS). In contrast, the latest Intel Xeon processors run at 3.8GHz, contain in excess of 5.5 million transistors and can handle over 300 MIPS. A several thousand fold improvement in all areas. Similar rates of progress in pig growth over the 35 years would mean that pigs would reach slaughter weight less than three hours after being born!

The real benefit of these technological advances however is in the computational and storage power of the modern computer. The academic work of Henderson in the late 1960s and early 1970s gave animal breeders statistical methodology to design advanced breeding programmes using mixed model equations for the best linear unbiased prediction (BLUP) of breeding values. Due to the complex nature of these calculations this was impossible to achieve on large populations due to the limitations of computing capacity.

Now, JSR can produce solutions for greater than 500,000 equations for more than 150,000 animals across 20 generations of breeding in a single analysis, which represents only a single population in one breeding company. Scaling this up to account for multiple populations per breeding company and then all breeding companies, starts to highlight the importance of computational power to the pig industry.

Computer systems however can only process the data and instructions that they are given. The other aspect of breeding success has been the ability to digitally store and therefore analyse data from huge numbers of animals. The move from paper records to advanced electronic databases allows selection decisions to be made on hundreds of thousands of animals rather than the simplistic approach of pedigree breeders who typically bias all decisions on the performance of the animal alone. Every event associated with an individual animal can now be logged and analysed. This may include the simple measure of growth rate through to complex measure of marbling after slaughter.

The result of the investment in technology is greater rates of genetic progress and an ability to influence a greater number of traits. The coupling of the increasingly global nature of the breeding business with information technology now allows the performance of an animal in one country to influence the selection of an animal in another.

So when will the industry have all the computational power that they need? The answer is difficult to estimate. Academics continue to develop new techniques and statistical advances to use the available technology. These advances have lead to JSR developing 'Select' a powerful future proof database to run statistical evaluations of any collected data through any analysis programme available. The lack of fixed data formatting makes the database highly adaptable to any change in the genetics industry.

Whilst the future is difficult to foretell, our knowledge of genetics does allow us to predict that those who are slowest to adapt are the most likely to become extinct. ■

Genetic solutions to boar taint

Dr Grant Walling

Pork from entire male pigs can have an unpleasant flavour or odour. This is caused primarily by two chemicals, androstenone and skatole, which are released by the pig during puberty.

The consumer's eating experience of the resultant meat is typically poor, especially in Asian populations who are anecdotally more sensitive to the abnormal smell and flavour.

Approaches to avoiding boar taint vary across the globe. The majority of countries practice surgical castration; however, elastic rubber bands (bloodless castrators) are also used. Both methods sever the vas deferens, the tubes that connect the testes to the urethra. Australia and New Zealand use immunocastration through vaccination.

The 'Improvac' vaccine stimulates an immune response in the pig preventing development of the testes.

In the UK and Ireland, both methods of castration are prohibited, so traditionally these pig producers have needed to slaughter pigs at lighter weights to avoid excessive levels of boar taint.

The current situation is likely to change in the near future. Many British and Irish producers are now slaughtering pigs at heavier weights.

Animal welfare concerns in the EU question the acceptability of routine castration and many producers outside Europe would like to benefit from the significant improvements in feed efficiency and lower fat levels that are achieved with non-castrated boars.

Significant savings in labour costs could also be achieved if the castration process was no longer necessary. Globally, the reduced nitrogen excretion from entire males could bring environmental benefits, especially in nitrate vulnerable zones.

Nutritionists have tried various supplements to decrease levels of boar taint with varying success. The addition of dietary carbohydrates to the feed, such as potatoes, can reduce levels of skatole but have failed to have similar effects on androstenone. Such 'hit and miss' techniques are unlikely to provide a long term workable solution.

Newer genetic technology may have a better answer. Recently a consortium of British pig breeding companies, backed by the UK Meat and Livestock Comm-ission, successfully patented two regions on chromosomes 6 and 14 associated with levels of skatole and androstenone. The patent is also under examination in Canada and Europe.

Jim Squire's group at the University of Guelph are studying several genes associated with the pathway of androstenone and skatole synthesis. They have demonstrated that the levels of these chemicals can be reduced through selection based on an animal's genotype at these loci.

In addition, the 23 million pan-European 'SABRE - Cutting Edge Genomics for Sustainable Animal Breeding' project, involving almost 200 scientists in 14 countries, has one of its aims as 'eliminating boar taint in pigmeat'. This will also be using a genomic approach to the problem, with the aim of providing a solution that will allow the selection of animals that are free from boar taint. ■

CT scans used to spot pigs with the X factor

Dr Grant Walling

Selection by pig geneticists has traditionally focused on traits relatively easy to measure on the live animal, for example growth rate.

Such improvements have benefited producers as the breeding stock they purchased has been selected on such traits.

However, with the industry becoming more focused towards packers and retailers, they too want to see improvements in qualities affecting the economics of their businesses.

X-ray Computer Tomography (CT) is a technology many will be familiar with from hospitals. It allows cross-sectional images to be produced from a living animal (see above). The image is produced using information gained from the absorption of a low dosage X-ray beam that passes through the pig from all angles around the body. This allows the identification of different types of tissue, as dense tissue (such as bone) appears light and less dense tissue (such as air in the lungs) appears darker.

A series of scans on a pig provides a very accurate prediction of the carcase composition. The improvement in prediction of carcase muscle, fat and bone is 6.4, 5.6 and 15.0% respectively when compared with more conventional ultrasonic techniques. Of greater benefit to the processing and retail sector is the ability to be able to differentiate muscle yield within the different primal cuts (loin, ham, belly and shoulder).

The heritability of the CT muscling traits is moderate-high (typically around 40%) and so suited to genetic improvement. More recent work with CT scanning in the sheep sector has suggested a methodology for the selection of meat quality using measures of muscle density.

Without this technology, breeding companies have previously had to use carcase dissection data. The downside of such techniques is the necessity to slaughter animals prior to data collection. CT scanning is able to collect the valuable information on live animals (under anaesthetic), which can then be used for further breeding.

Conventional selection schemes ensure that JSR boars meet the high criteria required by producers. This new technology is allowing JSR to scan all AI boars prior to entry into the AI studs, providing the processing and retail sectors with information that ensures only the most suitable boars are used in their supply chains.

Although originally developed to benefit human medicine, CT scanning is now a useful tool for a healthy pig industry. ■

Meat eating quality

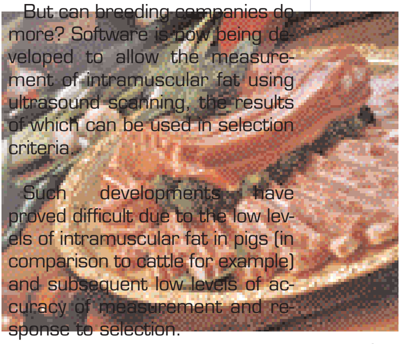
Dr Grant Walling

With the de-commoditisation of pork in many established markets, emphasis has changed from simplistic production output to more complex measures of the product.

Indeed many producers rather than solely focusing on output per sow, place greater emphasis on achieving a greater reward for their product.

One trait that can significantly benefit the value of the product is meat eating quality and packers and retailers are increasingly offering greater rewards to those who are able to achieve significant improvement in these areas.

Improving meat eating quality is not easy. Despite many claims of the minority breeds only the Duroc and homozygous RN- Hampshire animals have consistently demonstrated meat eating quality benefits in peer reviewed scientific trials.



But can breeding companies do more? Software is now being developed to allow the measurement of intramuscular fat using ultrasound scanning, the results of which can be used in selection criteria.

Such developments have proved difficult due to the low levels of intramuscular fat in pigs (in comparison to cattle for example) and subsequent low levels of accuracy of measurement and response to selection.

The success of such ultrasonic methods does however rely on a favourable correlation between intramuscular fat and meat eating quality.

Whilst the correlation is favourable, intramuscular fat is only one of many factors affecting meat eating quality and focusing on this one trait alone will mean slow progress toward improving meat eating quality.

More advanced scanning systems such as CT or MRI scanning have demonstrated in sheep populations that image density can be a good indicator of meat eating quality, however the cost of scanning large numbers of animals limits the potential impact of such technologies.

One company, however, has taken selection for meat quality further by collecting information from reject animals at the slaughter plant.

Darby Genetics in Korea, the JSR distributor with a number one market share, have a trained assessor to score marbling in reject carcases that is then included in their genetic analyses. The selection indices including marbling have resulted in their Marbler Duroc boar.

Improvements in meat eating quality do not simply rest with breeding companies. Eating quality is influenced throughout the pork supply chain. The feeding of the animal, lairage prior to slaughter and hanging of the carcase post slaughter, to name just three, all have a significant effect on meat eating quality.

It is therefore vital that any meat eating quality scheme targets the whole supply chain rather than one factor as those working in isolation are typically unable to achieve significant benefits.

Marker Assisted Selection

Dr Grant Walling

Over the last few months this column has highlighted some emerging technologies in the field of pig breeding. Many have either been novel technologies specifically applied to pigs or cross-over technologies from other industries with application to the pig industry.

It is therefore strange that, whilst genetic markers have been discussed for over a decade, marker assisted selection in the pig industry is still considered novel technology.

In order to clarify the subject, it is necessary to differentiate between individual genotyping of a specific locus (used widely by many breeding companies to eradicate the undesirable variant of the halothane gene that resulted in sudden death of animals and pale, soft exudative meat) and marker assisted selection in which many markers are genotyped and used within the analysis of breeding values.

The reason genetic markers have had such a high profile over the last decade is twofold. Firstly, the over enthusiastic short term predictions of academics working in this area and, secondly, breeding companies looking to justify their research spend to board members and shareholders.

Interestingly, it has been the statistical implementation of this data that has presented the greatest obstacle to progress in breeding companies.

The challenge facing geneticists has been how to balance the genotypic information with the phenotypic measurements taken on the animal.

This question has only relatively recently been addressed by the statisticians, allowing the analysis to combine both genotypic and phenotypic information.

Even now, traits with significant phenotypic information from the animals (such as backfat, for example) show little benefit from including genotypic information.

The main advantage is for traits with limited phenotypic data such as meat quality, boar taint and immune function. The other major change has been the number of genetic markers that can routinely be used in such analyses.

Earlier work concentrated on individual markers that may themselves be beneficial or simply linked to beneficial regions of the genome. Vast sums have been spent patenting individual genomic loci.

However, with the arrival of simpler, denser markers looking at single nucleotide polymorphisms (SNPs) newer projects at JSR now look to genotype each animal for 7,600 SNPs scattered throughout the entire genome.

Statistical models can then decide which marker information is worth using in the analysis to improve the estimation of breeding values.

Such powerful tools supersede the outdated patented single locus approach.

Despite these huge advances, breeding companies still have to deliver performance to the producer and packer. No one has ever bought breeding stock based on how many markers were genotyped in the population.

Any technology has to deliver performance in the field whether that is growth, yield or meat quality. For this reason, it is unlikely that genotypic selection will ever wholly take over from phenotypic selection in the foreseeable future.

It is therefore fair to conclude that, despite several false dawns and broken promises, marker assisted selection is only now emerging as a useful tool for breeding companies. ■

Developments in AI

Dr Grant Walling

Agricultural businesses are familiar with the concept of harnessing biological science within their working models to help maximise economic success.

Indeed, developments in biology have lead to breakthrough technologies that have revolutionised the pig breeding industry as it is today.

A previous generation would not recognise a pig industry using AI, genetic marker testing, growth modelling, nutrient partitioning or various meat eating quality traits.

Unfortunately, however, biology also works against us. Evolution has delivered an animal with an effective immune system – one that actually hinders the pig producer during mating.

The importance of this reaction is apparent when considering the number and propensity of sexually transmitted diseases.

When semen is therefore deposited into the reproductive tract, a number of molecular and cellular changes occur that are very similar to a standard immune response.

Within hours after mating, leukocyte infiltration occurs in the endometrium of the sow. Such a response can have a negative effect on semen and embryonic survival rates, but reduces disease risk to the sow.

Thankfully, biology also provides an answer to this problem. In conventional mating, co-evolution has delivered the presence of seminal plasma – an essential component in regulating uterine immune reactions post-mating.

It is the dilution and changes made to semen through AI processing that has changed the levels of seminal plasma away from its optimised norm.

Knowing which of the components of the seminal plasma is operational is the key to being able to replicate this effect.

Rhodes et al. in 2005 tried using TGF-ß but failed to improve live foetuses per litter, implantation rate, foetal survival or percentage of corpora lutea.

There is also compelling evidence that seminal fluid has a major change on the pH of the vaginal environment changing it from 3.5-4.0 before intromission rising to a more semen friendly ~7 due to the buffering effect of the fluid after ejaculation (Hodgson & Hosken, 2007).

Seminal fluid is also implicated in the role of inducing contractions in the female reproductive tract, facilitating semen transport toward the site of fertilisation (Prins, 1998).

Given the role of seminal fluid in improving the environment of the sow reproductive tract, strategies such as a boar service followed by an AI service are successful.

In this way, the AI dose benefits from improved sperm survival due to the site improvements provided by the boar's seminal fluids.

Various products are now being developed using different components of this seminal plasma to try to replicate the suppression of the sow immune response and the induction of contractions in the reproductive tract.

Earlier trial work at JSR has been promising but still creates a number of logistical issues about how such a product should be delivered to the sow using the AI process.

A successful immunosuppressant product is unlikely to be of use to the pig industry if the increased complications of delivery deliver a greater inefficiency than benefit.

It is likely that this area will deliver a number of new products to the pig industry in the near future with diluents and catheters that will be designed to replicate the very same biology that we dismantled in the name of progress through AI. ■

References

Hodgson, D.J. & Hosken, D.J. 2007. Journal of Theoretical Biology (In Press).

Prins, G.S. 1998. In: Knobil, E., Neill, J.D. (Eds.), Encyclopedia of Reproduction, vol. 4. Academic Press, New York, pp. 610–615.

Rhodes et al. 2006. American Journal of Reproductive Immunology 56 (3), 153–156.

A role for cloning in pig breeding?

Dr Grant Walling, research and genetics director

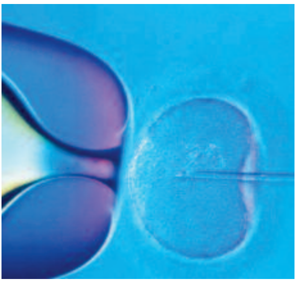
Keith Campbell, one of the creators of Dolly the sheep and more importantly the technology that allows the cloning of animals from an adult cell, had recently expressed surprise in the press at the lack of uptake of the technology in the agricultural sector. Are breeding companies missing out on a worthwhile technology or is this an application of the technology too far?

The subject of cloning came up at the 'Animal Breeding to Meet Global Challenges' meeting in Cambridge recently and an interesting discussion ensued about how breeding companies may use such technology.

Cloning cannot be used at the nucleus level, this would make all animals genetically identical and future genetic progress would be impossible.

Cloning could however have an application at the multiplication tier. A breeding company could produce a large number of F1 parents and select an exceptional sow. An animal that produced 16 pigs born alive for six litters and weaned at least 15 pigs in every one of those six litters, whilst maintaining condition and always holding to first service.

This animal could potentially be cloned ensuring all F1 parents to be of both high and uniform quality. Meanwhile the geneticists would be working in the nucleus population to deliver genetic improvement to ultimately produce an even better F1 parent that would replace the current product once proven.



The structure of the breeding programme would therefore remain the same at the nucleus level but one multiplier would produce F1 parents using the conventional method, with the product being tested on a commercial unit. Other multipliers would simply produce the clones of the most successful F1 from the commercial unit.

So why isn't this happening? On paper the strategy appears to be a possibility. The largest current barrier is efficiency. The cloning process produces many unsuccessful attempts at creating an animal.

Each unsuccessful clone adds significant cost to the programme. A producer purchasing a cloned animal may have to cover the cost of hundreds of unsuccessful attempts. This may make his F1 parent prohibitively expensive, despite its' excellent performance guarantee.

The other area is the acceptance of the product by the consumer. Previous applications of the cloning technology have been in the pharmaceutical industry where very valuable animals have been cloned because of their abilities to produce high quantities of specific animal proteins. This time we are asking the consumer to accept the progeny of cloned animals into the food chain, a much further step than they have accepted previously.

So is Keith correct in claiming the livestock sector is missing out on a technology? Perhaps there are still a number of barriers to progress before it becomes a genuine opportunity but ultimately it will be the consumer that decides whether such products are desirable in the human food chain. ■

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The cost of GM technology

Dr Grant Walling, research and genetics director

The news that the French president has decided to stop planting any genetically modified (GM) crops from next year will no doubt be popular with some groups but increases the risk of Europe becoming an agricultural backwater.

Sir Ben Gill recently argued that if wheat prices from the 1960s had kept up with inflation we would now be paying over US$1200 per tonne. The reason prices have remained significantly lower is due to science and genetic advances providing higher yielding varieties and increased mechanisation and engineering advances allowing cropping on a significantly larger scale.

At a time of high global demand several regions in the world have experienced poor harvests. The poorer supply and high demand has led to escalating prices. If certain varieties of GM crops, for example drought resistant strains had been used in these regions yields would be higher and ultimately prices would be lower. By excluding GM technology the agricultural sector is being prevented from using science to provide the solutions to current challenges. The costs for which will ultimately be paid for by the consumer.

There is now a clear split developing between countries prepared to licence, grow and utilise GM crops and those that are not. As a result a two tier pig production industry is emerging with the GM users able to maintain lower costs of production and ultimately be able to achieve a competitive advantage in the global market. It is therefore likely that many consumers will choose to consume pigmeat produced from raw materials that are not available to their home market producers.

But what of GM technology in livestock genetics; is there a conceivable role that could be fulfilled by the application of GM?

As with any technology, there must be a benefit for the consumer if it is to be accepted. This may be improved product quality, lower product cost, reduced environmental impact or, in some markets, improved animal welfare. Clearly some of these categories may overlap as the inclusion of a gene for disease resistance would improve both animal welfare and production efficiency leading to lower production costs.

The benefits of the technology must also be significant. It is unlikely that consumers would be prepared to accept the technology for a 1% reduction in price, however a 50% reduction may persuade more consumers of the merit of the technology.

The best traits to target with GM technologies would be those which currently present geneticists with the greatest difficulty in overcoming with current techniques or for traits with the largest economic impact. These are likely to be traits such as resistance to endemic disease or significant reduction in FCR and subsequent lower levels of nitrogen excretion. Policy makers and the agricultural industry should therefore not be asking whether GM livestock would be acceptable to consumers but instead under what circumstances would such technology be accepted?

Even if consumers were to accept the technology, considerable challenges still exist for the scientific community to bring it to fruition. As the process of introducing the gene into the animal genome is very inefficient, the pharmaceutical industry for example has relied upon cloning as the most cost effective way to multiply any GM success.

Therefore, GM technology cannot be developed in isolation but needs the cloning technology to partner any success.

Suffice to say, science has the capability of addressing the problems faced by society however there needs to be a clear understanding of the trade-offs that inevitably occur.

A full appreciation of this position will never be reached unless there is willingness for a clear debate in an environment of co-operation for the good of society. One thing is clear, strong leadership is required to push forward GM technology in those countries that have not adopted it, otherwise the world will lose its ability to feed itself. ■