Outline of R&D directions for Australian pig genetics

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Pig genetics in Australia – the last 5 years

Staff at the Animal Genetics and Breeding Unit (AGBU) have contributed to better use of genetically superior pigs in the Australian pig industry through R&D projects conducted in cooperation with breeders, the development of genetic evaluations tools (PIGBLUP, National Pig Improvement Program (NPIP), PBSELECT), training of industry personnel in genetic principles and provision of fee-based consultancy services to breeders. Often these activities are inter-linked and a wide range of expertise is required to be able to respond effectively to the needs of the industry in regard to genetic services.

Profitability of pig production is influenced by a number of traits. Mean annual genetic gains (28 populations) achieved over the last 5 years in growth rate, backfat, feed conversion ratio, muscle depth and litter size were estimated to be worth $ 1.06 per slaughter pig (Walters, 2006). There was considerable variation in genetic gains between populations and the top 25% of populations had on average an annual genetic improvement of $1.92 per slaughter pig. The populations with superior genetic gains have a number of characteristics in common. An experienced person is in charge of the breeding program, who ensures that high selection intensities are achieved. Breeders in this group have participated in R&D projects and have often received technical advice on a fee-based consultancy. Finally, a larger number of traits are recorded on farm. This highlights the potential for higher genetic improvement in the Australian pig industry if a wider a wider range of economically important traits are considered in pig breeding programs.

Infra-structure has been put in place to facilitate the uptake of PIGBLUP, NPIP and PBSELECT and to provide extension material to the industry. Overall, the awareness of Estimated Breeding Values (EBVs) has increased in the industry as a whole and communication with breeders, producers and industry extension personnel has improved over the last 5 years.

These achievements enable the development of a number of new projects that are proposed to accelerate genetic gain and adoption of improved genetics in the Australian pig industry. Each project has a R&D component which will be conducted in cooperation with breeders who are expected to provide in-kind contributions. This cooperation fosters adoption of new technologies by breeders. The relevant modules in AGBU's genetic evaluation systems (PIGBLUP, NPIP, PBSELECT) will be modified to accommodate R&D results. In addition, information about these projects and genetic principles in general will be disseminated to industry.

Pig genetics in Australia – the next 5 years

1. Priorities for research topics as indicated by breeders

Breeders are encouraged to express their view on future research priorities at each AGBU pig genetics workshop. Following discussions at the 2004 workshop, a questionnaire was developed to explore the research priorities of Australian pig breeders. Background information was provided for each topic. This survey was sent to 20 breeders and ten seedstock suppliers returned the questionnaire.

Breeders were asked to rank eight individual topics from 1 (highest priority) to 8 (lowest priority) and two breeders specified further topics. The average score was lowest (score: 3.00) for EBVs for feed intake and EBVs for carcase traits followed by EBVs for meat quality and import protocols (score: 4.11) (Table 1).

Five of the ten respondents ranked EBVs for feed intake in the growing pig and lactating sow as highly important for their business. Four breeders regarded the topics of EBVs for meat quality, EBVs for carcase traits and import protocols as highly important for their business. In addition, three breeders mentioned reproductive performance of the sow and piglet survival as an important topic.

Table 1. Rankings of individual research topics relevant for genetic improvement of pig production by Australian breeders.

Research Topic	Respondent									Average score
	A	B	C	D	E	F	G	H	I	
EBVs for carcase traits	1	6	1	1	7	4	1	3	3	3.00
EBVs for feed intake in the growing pig and lactating sow	4	4	3	5	1	1	3	4	2	3.00
EBVs for meat quality	6	7	2	2	6	3	2	5	4	4.11
Import protocols	2	1	5	3	5	5	8	1	7	4.11
Use of gene markers	3	5	4	4	4	6	6	2	6	4.22
EBVs for structural soundness	5	8	8	8	8	2	4	6	1	5.55
EBVs for robustness	7	2	6	6	3	7	7	7	8	5.88
Competitive effects	8	2	7	7	9	8	9	8	9	7.44
Any other topics, please specify					2[1]		5[2]			

Scores: 1 = highest priority to 9 = lowest priority

[1] Preventing an increase in mortalities (pre-weaning) with increasing litter size

[2] EBVs for reproductive traits of the sow looking further than number born alive (weaning to conception interval, return to service, number weaned, milking ability of sows)

Five main project areas are proposed based on this feedback by breeders, recommendations from the review of Australian pig genetics during the last 5 years by Walters (2006) and research priorities of the strategic plan of Australian Pork Limited. These main project areas are:

1. Development of a flexible profit function to include sow and piglet performance, growth and feed efficiency, carcase uniformity and retail value, and meat quality.
2. Accelerating genetic improvement of retail carcase value together with meat and eating quality traits.

3. Promoting better lifetime performance in the sow through the inclusion of feed intake data.
4. Selection strategies for uniform lean meat growth through to heavier carcase weights.
5. Facilitation of knowledge transfer of genetic technologies to the Australian industry and the provision of fee-based consultancy services.

The priorities of specific research trials and strategies for technology adoption and industry training will be determined by the Pig Genetics Consultative Group. Specific research trials will then be developed in cooperation with interested breeders.

Development of a flexible profit function

1. Background

Profitability of pig production is influenced by a number of traits and selection decisions should be based on an economic index ($Index). The $Index is the sum of EBVs of individual traits multiplied by their economic value. Economic values for individual traits quantify the change in profit when each trait is changed by one unit, keeping other factors constant. The $Index sets the direction of a breeding program and is essential for quantifying the economic returns from genetic improvement.

The number of traits in breeding objectives continues to increase over time. Initial focus was on production and reproduction traits (ie. Stewart, 1989 and review by Stewart, 1998). Further additions to the breeding objective include meat quality traits (Hovenier, 1993; von Rohr et al., 1999) and more recently fat quality (Hofer, 2006). However, Knap (2005) points out that genotypes superior in production efficiency may have lost their ability to respond to suboptimal environmental conditions; they have become less robust. Knap and Wang (2006) distinguish between two main approaches in regard to breeding for animal robustness. The first, direct approach relates to performance-related robustness, focusing on directly measurable fitness or robustness traits like survival and longevity. The second, indirect approach is based on reaction norm analysis (ie. Kolmodin et al., 2002; Strandberg, 2006) to consider in breeding programs the animals' ability to respond to changes in the environment, which is also called environmental sensitivity. Avenues to incorporate survival and longevity (de Vries et al., 1989, Knap and Wang, 2006) as well as environmental sensitivity (Kolmodin and Bijma, 2004, Knap, 2005) into breeding objectives have been proposed.

2. General outline of proposed project

It is proposed to extend the existing profit function in PIGBLUP to consider a wider range of traits including sow and piglet performance, growth and feed efficiency, carcase uniformity and retail value and meat quality traits. This work will be based on profit functions developed previously by de Vries et al. (1989), Cameron and Crump (2001) and Hermesch (2005).

Input parameters for the new profit functions will be developed in consultation with breeders and abattoirs to reflect relevant industry values. These include payment grids and costs of production. Economic values for some traits are dependent on the mean and variation of the trait (eg. Hermesch, 2005). Information about means and variation will be required for a range of traits.

Current payment grids are based on backfat and weight of the pig. However, the retail value of a carcase is determined by the weight and composition of its primal cuts. A comparison of two carcasses with the same P2 and weight measurements showed a difference of $6 in carcase retail value based on the weight of their primal cuts (B. Ward, personal comm. 2006) providing first evidence that backfat and weight alone do not predict carcase retail value reliably. Therefore, it is proposed to determine variation in carcase retail value and to quantify the effect of improving weight and composition of primal cuts on retail value of the carcase.

Breeders may supply replacement stock to a range of commercial farmers with a range of production and market systems. Amer (2006) discusses approaches to formulating breeding objectives and points out the importance of customised indexes. However, resources and infrarstructure required for customised indexes are often lacking in livestock industries. In PIGBLUP, special emphasis will be placed on the simple use of the $Index by highlighting components of the profit function that have the largest impact on economic values. Breeders may then be able to focus on these key components if resources and time are limited.

Accelerating genetic improvement of retail carcase value together with meat and eating quality traits.

1. Background.

The economic benefit of reducing backfat depends on the mean and variation in backfat (Hermesch, 2005). Some breeders have achieved cumulative genetic progress of -3 to -4 mm (reduction in backfat) since the mid 1990's and further improvement in backfat has limited or no economic benefit in some populations. However, low backfat levels do not guarantee good carcase retail value since backfat alone is a poor predictor of the composition of individual carcase cuts which determine the retail value of the whole carcase. Therefore, additional measurements need to be incorporated in genetic evaluations to enhance selection for higher retail value of the whole carcase. These may include ultrasound measurements taken on the live animal as well as measurements recorded in the abattoir.

Comparison of Australian sire genotypes showed that significant differences between sire genotype groups were evident for some meat and eating quality traits (Bunter, 2005). However, there was also overlap between sires for production and meat and eating quality traits from different sire genotype groups. Bunter (2005) stated that it is possible to identify sires with desirable meat and eating quality characteristics within sire genotype groups that exhibit less favourable meat and eating quality characteristics overall, providing they have progeny or other relatives recorded for meat and/or eating quality traits.

Heritability estimates are moderate to high for carcase traits and low to moderate for meat quality traits (van Wijk et al., 2005; Fernandez et al., 2003 Hermesch, et al., 2000a). The recent study by van Wijk et al. (2005) included weight of boneless subprimals of ham and loin, which had heritability estimates of 0.39 and 0.51.

Heritability estimates for boneless subprimals are limited and further information is beneficial for the improvement of these traits. It is also well established that carcase composition traits have unfavourable genetic relationships with meat quality traits (van Wijk et al., 2005; Fernandez et al., 2003; Hermesch et al., 2000b) and effective breeding programs need to consider both trait groups to improve retail carcase value as well as pork quality. Special emphasis should be on traits that are cost effective to measure and/or can be recorded on live animals. For example, Schwab et al. (2006) demonstrated selection for intramuscular fat content based on ultrasound measurements and Hofer et al. (2006) outlined implementation of a routine genetic evaluation and selection procedure for backfat quality in pigs.

2. General outline of proposed project

The extension of the profit function outlined above requires that variation in carcase retail value is quantified. Initial research trials should evaluate the feasibility of a wide range of ultrasound and linear measurements on the live animal (ie Doeschl-Wilson et al., 2005) as well as carcase and meat quality traits to predict carcase retail value and pork quality. A subset of these traits will then have to be recorded on a large number of animals to obtain genetic parameters for these traits under practical recording conditions.

A number of abattoirs have been identified where measurements of carcase and meat quality traits of progeny groups of purebred sires can be recorded. However, abattoir measurements should be linked with measurements taken on the live animal on farm, since it is beneficial for genetic improvement to have measurements available on the selection candidate.

It will be the aim of these research trials to incorporate sires from multiple seedstock suppliers. This will ensure the development of a sire evaluation scheme for carcase and meat quality traits. Most of these sires will be part of the across-herd genetic evaluations of the NPIP and EBVs for carcase and meat quality traits will be made available for AI boars of the NPIP.

The current carcase and meat quality module in PIGBLUP will need to be extended to include a wider range of carcase, meat and eating quality traits. It is envisaged that new traits will be included as generic traits providing users with more flexibility in the choice of their traits for genetic evaluations. PIGBLUP is the engine behind the NPIP and PBSELECT which will also be updated accordingly.

Promoting better lifetime performance in the sow through the inclusion of feed intake data.

1. Background.

There is evidence (Kerr and Cameron, 1996) that feed intake of the sow during lactation has a positive genetic relationship with feed intake capacity of the grower pig. Selection for feed efficiency and lean meat growth has led to a reduction of feed intake capacity in the growing pig. Consequently, the feed intake capacity of sows during lactation has been reduced through selection for improved feed efficiency and leanness. At the same time, litter size has been increased through selection. For example, total genetic gains of 1 to 2 piglets have been achieved in top Australian pig populations over the last 10 years. Together these selection responses put pressure on sows to maintain body condition during lactation, which is essential for high lifetime performance (see review by Eissen et al, 1999 for details).

Breeders are concerned that sows may not be able to carry the large litters and a trial to test the capacity of sows to nurture large litters for Australian genotypes has been suggested. Eissen et al. (2003) showed that nursing a large litter had negative effects on lactation and post-weaning performance of primiparous sows. In addition, sows of three genotypes responded differently to increasing litter size, shown by an interaction between genotype and litter size for daily feed intake and backfat loss during lactation.

Welch (2005) proposed the use of feeding cards as a management tool in the farrowing houses to maximize feed intake of the lactating sow and to minimize sow losses. This data available from routine management practices may also be used for genetic improvement of sow lactation feed intake.

Based on 1996 to 2000 performance and cost structures relevant for the US, Stalder et al. (2003) stated that a replacement gilt must stay in the breeding herd for three parities before the initial investment in her is repaid. This target is not achieved by a large proportion of sows in Australia. Genetic avenues to improve sow longevity include selection of superior lines and selection for sow longevity within lines. Rodriguez-Zas et al. (2003) found a maximum difference in longevity between major genetic lines of approximately one parity. In addition, estimated length of productive life was lowly heritable (5 to 10%) based on linear model analyses (Serenius and Stalder, 2004). However, estimates of heritability were higher for sow longevity (16 to 19%) based on survival analyses. Survival analysis is the more appropriate method of evaluating longevity traits. Survival analysis is also more computational demanding and further research is required for multi-trait analysis of linear and survival traits.

The reproductive module in PIGBLUP includes litter size, 21-day litter weight and weaning to conception interval. All breeders have incorporated litter size in their breeding programs and substantial genetic gains have been achieved in some populations. However, selection for litter size alone is associated with lower average piglet birth weight and higher litter mortality rates. Index calculations have shown that genetic response in litter size of one piglet is accompanied by an increase in litter mortality of half a piglet (Hermesch, 2001). This is not a sustainable breeding practice and inclusion of further weight traits, in particular litter birth weight, has been recommended to breeders (see AGBU Pig Genetics Information sheets; Breeder 2 and Breeder 3). Resulting from these discussions at various genetics workshops, breeders have started to increase the number of reproduction traits recorded on farm and the PIGBLUP reproductive module needs to be extended to accommodate these extra traits including a module that accommodates sow longevity.

2. General outline of proposed project

Two specific projects have been identified so far including the analysis of existing data on sow lactation feed intake and development of a trial to test the capacity of sows to nurture large litters. Other analyses of reproductive traits of the sow and development of specific projects will be considered following consultation with breeders.

Litter records are available with daily feed intake measures of lactating sows along with information on litter size and piglet mortalities until weaning. Data are available since May 2002 allowing the analysis of sow lifetime performance. First analysis of this data set will quantify factors that affect feed intake of the sow during lactation. Not all breeders may be willing to record daily feed intake during the whole lactation and it will be determined whether it is sufficient for genetic improvement to record feed intake for part of the lactation only.

A 'sow-capacity trial' will be developed to evaluate the response of different maternal genotypes to increasing litter size. Special emphasis will be on subsequent rebreeding success and litter performance.

The reproductive module in PIGBLUP will be extended to incorporate multi-trait analysis of litter size, litter weight traits, sow lactation feed intake, weaning to conception interval, litter survival and sow longevity. Training will be provided to breeders to facilitate the adoption of these new traits. In addition, information about these traits will be disseminated to industry through workshops and information sheets.

Selection strategies for uniform lean meat growth through to heavier carcase weights

If pigs perform consistently across different environments it leads to more uniform performance resulting in less variation between animals. There is no doubt that reduced variation between pigs in carcase weight and backfat for example leads to increased profitability since payment grids have often narrow optimal margins. In addition, a shift to higher carcase weights is one avenue to reduce costs of production per pig. While the costs of production will be reduced it has to be ensured that heavier carcases also achieve a high price and that penalties for poor carcase composition are minimal. The penalties for increased fatness levels above a certain threshold are severe in most Australian payment grids.

One avenue may be to define sires with more uniform progeny performance. For example, within-litter variation for backfat was heritable and selection for uniform low backfat in dissection results had favourable correlated responses in level of backfat, loin depth and ham weight (Knol et al., 2005). Some of these results may have been influenced by scale effects and research is underway to explore genetic variation in environmental (residual) variation (Rowe et al., 2006; Sorensen and Waagepetersen, 2003) and selection strategies for reduced residual variation (Mulder and Hill, 2006).

Variation in performance is reduced if progeny groups perform consistently across different environments, which may be characterized by different feeding levels. Australian results showed that the response in performance with higher feed intake levels differed among progeny groups of sires (Hermesch et al., 2006). The use of reaction norm models (Kolmodin et al., 2002; Strandberg, 2006) should be explored to evaluate environmental sensitivity of Australian pigs over a range of Australian environments.

Performance of animals within a group has been shown to be influenced by aggression and competitive interactions between animals with profound impacts on both productivity and welfare of animals (see review by Muir and Bijma, 2006). Competitive or associate effects are defined as the impact each animal has on all pen mates. Therefore, performance of each animal depends on its own direct effect and the sum of all associated effects of its pen mates (associates). The theoretical background of interaction among individuals in a group for animal breeding purposes has recently been outlined by Bijma and Muir (2006), who point out that associate effects may be more predominant when resources are limited. Small estimates of associate effects have been presented by Arango et al., (2006) for an average group size of 13.7 pigs. The performance of an animal is influenced by the sum of associate effects of all other pigs kept in the same group and even small competitive effects may have a profound impact on performance in large groups. These studies have not discussed that competitive interactions between animals may also lead to higher variability of performance within a group (pen). Estimation of associate effects is computationally demanding and analyses may be slow to converge (Arango et al., 2006). Therefore, alternative methods should be evaluated to identify aggressive and competitive pigs. This may include information on feeding behaviour recorded with electronic feeders.

Variation in performance between animals is due to genetic and non-genetic components. In addition, genotype by environment interactions may exist and specific management strategies have to be developed for Australian genotypes to improve uniform performance of pigs over the whole growth trajectory. This requires cooperation between researchers from a range of disciplines who work closely with Australian pig breeders and producers.

The facilitation of knowledge transfer of genetic technologies to the Australian industry and the provision of fee-based consultancy services.

Infrar-structure has been put in place to facilitate the adoption of genetic evaluation systems based on the PIGBLUP engine. This includes PIGBLUP, the across-herd genetic evaluations of the NPIP and PBSELECT, an on-line service for producers to obtain EBVs for selection candidates along with genetic and environmental trends. Uptake of any new technology is a long term process involving the initial demonstration of the technology and reliable support of new and existing users. Support may only be required from time to time, however, users expect a quick response by AGBU staff.

There is a limited understanding of genetic principles in the Australian pig industry. The economic benefits of using superior genetics can be substantial given that 5 to 50% of variation in economically important traits is influenced by genetic merit of animals. For example, Hermesch and Crump (2003) showed that the economic difference was $ 37.5 per litter between choosing a young boar from the top 10% over an average young boar. On average, half of this difference will be realized by his progeny increasing profitability for a 200-sow herd by $ 8,184 per year in this example.

The preparation of Pig Genetics Information sheets will continue along with specific seminars and training workshops to industry groups. In addition, the demand for fee-based consultancy services has increased over recent years. Most of these services are required only from time to time and will be provided as required.

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