Breeding Focus 2014 – Improving Resilience

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Preface

Technology transfer relies on an active engagement of researchers with industry to enable a two-way exchange that keeps researchers up to date with current industry issues and informs industry stake holders of the latest research relevant for their business. The AGBU pig genetics workshops have been conducted since 1991. This has been a unique opportunity for pig industries worldwide to stay up-to-date with current genetic research. The challenges faced by individual breeding operations are similar across species, including livestock and aquaculture, and cross-fostering of ideas as well as sharing discussions between industries are beneficial and desirable. As a result, 'Breeding Focus 2014' was developed to extend this opportunity for exchange between industry and research to livestock and aquaculture species. Genetic improvement of resilience is the topic for Breeding Focus 2014. It is our aim to address other topics of interest as an on-going series of Breeding Focus.

Resilience is the ability of an organism to recover quickly from adverse events such as illness, change in environmental stressors or other, possibly unknown, antagonistic effects to the biological system. Resilience is widely used in psychology, ecology, technology, sociology as recently illustrated and discussed by Zollli and Healy (2012) in their book 'Resilience: Why Things Bounce Back'. The term 'Robust-yet-fragile' (Doyle, J. C, 2010, http://leecenter.caltech.edu/booklet.html) is used by the authors to highlight the distinction between resilience and robustness, an expression often used in agriculture and animal breeding. Robustness relies on highly effective and specialised processes to maintain productivity which may make it vulnerable to unanticipated and yet unknown threats. In contrast, characteristics of resilience rely on simple building blocks and dynamic processes which are highly flexible and able to modify the organism or system in order to bounce back from set-backs. For example, Zolli and Healy (2012) outlined how the simple modularity of DNA has resulted in high resilience of living organisms because the highly flexible structures of DNA are able to adapt to a wide range of changing and initially unknown situations.

In animal breeding, disease resilience refers to the ability of an animal to maintain production at a given level of infection. It is noteworthy, that disease resilience in this definition is used synonymously with productivity. The concept of disease resilience can be further extended to a broader definition of resilience, e.g. environmental resilience. It generally characterises the ability of an animal to recover from any type of setback and return to an acceptable level of performance that optimises productivity and profitability for a wide range of challenging circumstances. Although the challenges faced by various species may differ between industries, the mechanisms and principles applied to breed animals with improved ability to bounce back from various challenges may be similar across species. As animal breeders, we benefit from exchanging ideas about pathways and approaches to breed for improved resilience. It is the aim of this workshop and book to discuss and outline industry experiences and strategies for genetic improvement of resilience of animals.

Breeding disease resilient pigs

Susanne Hermesch, AGBU

Animal breeding continues to play a role in improving the stability of farming systems by selecting resilient animals and developing methods of selection for disease resilience, disease resistance and disease tolerance. Routine veterinary observations on clinical and sub-clinical diseases as well as growth in challenging environmental conditions may be used as measures of disease resilience. However, disease resilience can only be measured reliably when a sufficient infection challenge is present in the standard farming system. Deliberately exposing a large number of animals to high infection levels to obtain more accurate measures of their disease resilience is not feasible due to welfare concerns and reduced profitability. Improvement in disease resistance and disease tolerance will lead to superior disease resilience. However, within-host infection levels have to be known for a reliable distinction between disease resistance and disease tolerance and this information is not expected to be available for farm animals. Genetic variation has been identified for direct measures of disease resistance, i.e. pathogen load, and indicators of disease resistance, i.e. susceptibility to disease and immune parameters. Selection strategies for direct measures of disease resistance (pathogen load) with beneficial health and welfare consequences for groups of animals lead to more robust environments that have lower levels of disease-causing organism and are less challenging for animals. Selection strategies for disease resistance with these consequences should be implemented in breeding programs. Multiple parameters including mean growth, mean pathogen load or mean of certain immune traits for groups of pigs as well as information on variation in air quality or heat load could be used to quantify the general infection challenge better. Variation in some of these environmental measures has already been observed in pig farms with good health and management procedures indicating that it is possible to select for disease resilience in commercial pig breeding programs.

Inferring genetic resilience of animals to infectious pathogens – opportunities and pitfalls

Andrea B. Doeschl-Wilson & Graham Lough, The Roslin Institute & University of Edinburgh, Scotland

Farm animals suffer constant bombardment with cocktails of infectious pathogens present in the environment. Eliminating these pathogens from farms is not always feasible. Therefore, improving the resilience of animals, i.e. their ability to maintain high production levels whilst infected, may constitute a desirable defence strategy. Despite compelling evidence for genetic variation in host resilience for some types of infections, genetic studies of this trait face a number of theoretical and practical issues. The aim of this article is to bring these issues to light and to propose potential approaches that may help to overcome these in future research. In particular, we demonstrate how alternative definitions of resilience give rise to different statistical methods and data requirements, and may produce different outcomes of selection. We examine the relationship between resilience, resistance and tolerance and the necessary data requirements for disentangling these traits. Using a recent large scale infection experiment in controlled environmental settings as a case study, we illustrate why resilience is not synonymous to tolerance, as often suggested. We address potential pitfalls and solutions for situations when pathogen challenge cannot be specified, or varies over time, and conclude with some practical considerations for inferring resilience genetics from field data.

On-farm measures to monitor the health and immune status of pigs

Alison M. Collins, NSW DPI

Resilience is defined as the ability of an animal to recover from disease and the associated production and profitability losses. Laboratories have developed tools to quantify pathogen load and populations of protective bacteria, and to measure the immune response in immunized or diseased pigs. The expression of disease is affected by pathogen numbers, the presence of potentiating or multiple pathogens and virulence factors associated with the pathogen. However disease expression is also affected by host factors including genetics and immune responses and environmental factors such as air quality, temperature and humidity. All of these factors can be measured and, if correlated with production parameters, may prove useful to monitor disease expression and resilience in pig herds.

Immune competence in livestock

Brad C. Hine, Bonnie A. Mallard, Aaron B. Ingham & Ian G. Colditz, CSIRO & University of Guelph, Canada

Selection for production traits with little or no emphasis on health-related traits has led to an increase in the incidence of disease in many of our livestock species. Currently we are developing testing procedures to assess 'general immune competence' of beef cattle, dairy cattle and sheep on-farm. Immune competence traits will be combined with measures of temperament and ability to cope with management induced stress to estimate an animal's resilience. By exploring associations between resilience and important production traits we aim to develop breeding strategies which will identify animals highly suited to their production environment.

Performance and resilience of poultry in Thailand

Siriporn Tongsiri & M. Gilbert Jeyaruban, AGBU

The layer chicken industry is an important sector of livestock production in Thailand because of its link to household income generation, employment generation and foreign exchange earnings. Exportation of eggs and egg product generates over 1,170 million of Thai baht ($AU 39 million) foreign income annually after 2009. However, outbreaks of exotic diseases through the importation of exotic strains of poultry had negative economic impacts on the industry. This has forced the egg industry of Thailand to develop a sustainable layer industry based on breeds and strains that have high survival rate under the harsh climatic conditions in Thailand and simultaneously maintain commercially viable productivity. Rhode Island Red (RIR) and White Plymouth Rock (WPR) breeds were imported in 1944 and maintained under existing poultry management conditions in Thailand, having been identified as the prime genetic resources to build a sustainable poultry industry in Thailand. Since 2004, a structured genetic improvement programme has been implemented to improve the productivity of these two breeds and their crosses, while maintaining a high survival rate (>90%) under the existing backyard poultry management conditions in Thailand. Preliminary analyses reveal that the performances of the newly developed strains, especially for egg production, were similar to that of the exotic breeds in Thailand. Survivability under tropical poultry management conditions is a trait that describes resilience of laying hens. The survival rate of the newly developed strains under backyard poultry management conditions in Thailand were 97.5%. This survival rate of the newly developed strains was higher than the survival rates of indigenous chicken under similar conditions. This implies that the newly developed strains could reduce over reliance on the importation of commercial layer birds and thereby, reduce the risk of introducing exotic poultry diseases which jeopardise the sustainability of poultry production in Thailand.

Breeding Sydney rock oysters and its effects on resilience

Wayne A. O'Connor, Michael C. Dove1, Emma L. Thompson, Laura M. Parker, Pauline M. Ross & David A. Raftos, NSW DPI, Macquarie University & University of Western Sydney

Winter mortality and QX disease have had severe impact on the Sydney Rock Oyster industry. A selection program was established in the '90s to breed lines that are resistant to these diseases. Selection was also undertaken to enhance growth and collectively this has had positive effects on resilience to environmental factors such as ocean acidification. This paper provides an overview of the work that has been done to elucidate the genetic basis of resilience in the breeding lines and how it might be used in the future.

Breeding barramundi for resilience in the face of global climate change

Dean R. Jerry, Carolyn S.K. Smith-Keune, Lauren Hodgson & Jeremy van der Waal, James Cook University

Barramundi, *Lates calcarifer*, is an iconic and important tropical finfish species that is primarily farmed in open pond, raceway and sea cage facilities. In Australia, barramundi naturally occur in an area ranging from the Ashburton River, Western Australia (22° 30' S), across northern Australia, and as far south on the east coast as the Noosa River, central Queensland (26° 30' S). This area covers ~16 degrees of latitude and encompasses a wide range of environmental temperature regimes (water temperatures +5 °C warmer in the north of the species' distribution and -5 °C cooler in the south). Barramundi populations are also genetically structured, with 6 major genetic strains and up to 21 identifiable sub-populations evident. This genetic variability, coupled with differences in thermal exposure, is likely to be associated with temperature adaptation among populations. If properly defined and managed, this may represent a reservoir of adaptive genetic capacity within the species useful for aquaculture exploitation.

Climate modelling predicts that up to the year 2080 tropical Australia may experience temperature increases of around 5 °C. Given that current extreme summer temperature events place stress on farmed fish there is concern that future farming may be negatively impacted by climate change. Consequently, the whole organism and physiological tolerances of barramundi strains were characterised to identify the extent of genetic adaptive capacity for future breeding programs to exploit.

To establish whether barramundi strains exhibit adaptive differences in their upper thermal tolerances fish were subjected to a series of experiments where they were exposed to elevated water temperatures. The ability of strains to cope with thermal stress was then evaluated in a variety of ways including swimming barramundi in flumes and establishing time and water speed when the fish fatigues (critical swimming speeds (U_{crit})) and time to loss of swimming equilibrium, hypoxia tolerance, basal metabolic rate, through to whole transcriptome and gene pathway profiling. Climate modelling was also conducted to predict the impact future climate may have on aquaculture productivity and suitable farming environments.

Experiments provide evidence of local adaptation to temperature among barramundi strains, with barramundi from far northern Australian populations exhibiting the capability to withstand and swim at hotter temperatures for more sustained periods. Transcriptome analyses also show differences in the way barramundi from populations with different thermal profile backgrounds regulate genes in response to thermal stress and highlight the strong underlying genetic basis to thermal tolerance. This raises the possibility of identifying specific thermal tolerance marker genes in this species, if the barramundi aquaculture industry wanted to include thermal tolerance as a trait in their breeding objective in future improvement programs. Barramundi from all populations were shown to be tolerant of temperature-induced low oxygen conditions (hypoxic events) and only exhibited slight population-level differences in their energetic metabolism in response to temperature. Finally, climate modelling predicts that barramundi farming in northern Australia may actually benefit from warmer climate, resulting in increased growth rates and productivity, and an increase in suitable farming sites with thermal profiles suitable for barramundi aquaculture.

Genetic variation of handling resilience of Tasmanian Atlantic salmon affected by amoebic gill disease (AGD)

Richard S. Taylor, Peter D. Kube, Brad S. Evans & Nick G. Elliott, CSIRO & Salmon Enterprises of Tasmania

One of the primary breeding goals of the Saltas selective breeding program is resistance to amoebic gill disease (AGD), which is the main health issue affecting production of Atlantic salmon (*Salmo salar*) in Tasmania. Fish farmers regularly assess the intensity and frequency of gross AGD signs ("gill score") in a random subsample of fish from each caged population. Fish are proactively treated at low to moderate infection levels by bathing in fresh water, with each caged population requiring up to 13 treatments in a 15 month marine production cycle. However, the process of densely crowding fish and pumping to the bath can cause up to 5% handling mortality in a transaction or cumulatively over a production cycle. Losses are higher at high gill score, but there is evidence that some high gill score fish are resilient to handling and some low gill score fish can be quite susceptible.

We have assessed genetic variation of handling resilience using a high density crowded non-destructive swim-trial on fish in the freshwater hatchery and later compared this to marine swim-trials at low and advanced levels of AGD. Our results demonstrate that handling resilience is a heritable trait at normal commercial AGD thresholds and measures are mostly repeatable between freshwater and marine conditions. During advanced AGD losses are more closely related to gill score and confirm the need for careful fish handling.

Resilience, tolerance, robustness and genotype x environment interaction in Merino sheep breeding

Sonja Dominik & Andrew A. Swan, CSIRO & AGBU

The concepts of environmental resilience, robustness and tolerance in domestic livestock species are discussed in general and illustrated using specific examples from the Australian Merino industry. It is discussed how these concepts relate to the more commonly known notion of genotype x environment (GxE) interaction. The Merino sheep breed consists of genetic strains that have been selected for suitability to specific environments and has reached a high level of specification for quality wool production. At the same time Merino sheep produce across a wide range of climatic environments and next to wool contribute substantially to Australia's prime lamb production. By gathering scientific and anecdotal evidence, it is explored if the Merino sheep breed is resilient, robust or tolerant to environmental fluctuations, including the environmental differences that are generated by the stud and commercial sector. It is outlined how GxE interaction is currently considered in MERINOSELECT, the national genetic evaluation system for Merino sheep, and future opportunities to consider environmental resilience, robustness or tolerance in livestock breeding programs.

Robustness as a breeding objective for sheep in New Zealand

Mark J. Young & Beverley C. Thomson, Beef + Lamb New Zealand Genetics & On Farm Research

Failure of ewe robustness has negative impacts on flock profitability. It leads to loss of productivity, additional costs through regaining of body reserves and substantial wastage due to death or culling. However, breeding for robustness or resilience in sheep is hampered by lack of a clear understanding of the trade-off between maintenance of body reserves in the ewe and productivity across successive annual production cycles. Whether it is acceptable to have large fluctuations in bodyweight or body condition score in order to sustain high production will probably depend on the severity of the environmental challenge as well as levels of production. Anecdotal evidence from industry suggests that some sheep are as productive as others but with smaller fluctuation in body reserves. Such “observations” need to be backed up by well-designed trials and recording protocols to characterise variation in typical farm environments and quantify the interactions between ewe wastage, ewe productivity and their indicator traits. Further work is needed to critically review the value of robustness to maternal sheep and develop protocols for assessment of robustness and optimal strategies for its inclusion in breeding objectives.

Breeding for resilience and resistance in Merino sheep

Sam F. Walkom & Daniel J. Brown, AGBU

Resilience is poorly defined in the Australian sheep industry. However, there are a number of traits available to the industry which provide scope to understand an individual’s potential resilience and resistance to environmental stressors. These traits include body condition score, body weight and condition change throughout the year and reproduction. The parasite resistance traits of worm egg count and fly strike resistance are also of interest. Currently, genetic improvement programs are focussed on improving the quality and quantity of wool growth, reproduction and lean meat production. However, significant phenotypic and genetic correlations between production and resilience and resistance traits could be leading to unintentional changes in the performance of the national flock when faced with differing environmental and disease challenges. These relationships are not always favourable making it a complex area for breeders to easily resolve, in particular how much emphasis to place on each of these traits. Furthermore, the Australian sheep industry is located across a range of variable environments and thus the importance of these resilience and resistance traits is likely to vary across those environments. We combined the current knowledge of the relationships between traits and evaluated the impact of various measurement and index selection scenarios to compare the impact of both production, resilience and resistance traits on current breeding strategies available to the Merino industry. The results suggest that selection purely on production traits has and may continue to influence the resilience of the Merino component of the national sheep flock. At this point in time breech wrinkle is the only trait that is predicted to change in an undesirable direction when using the standard MERINOSELECT indexes made available by Sheep Genetics. More desirable gains can be achieved in the additional resilience and resistance traits when they are valued in the indexes, with generally little impact on the standard production traits. When more accurate economic values for resilience and resistance traits can be derived, breeding objectives should be revised and appropriate selection traits identified, and accommodated into the selection indices used by breeders.