Breeding Focus 2021 - Improving Reproduction

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Preface

“Breeding Focus 2021 – Improving reproduction” is the fourth workshop in the series. The Breeding Focus series was developed to provide an opportunity for exchange between industry and research across a number of agricultural industry sectors. With this goal in mind, workshops have included presentations across multiple agriculturally relevant animal species to take participants outside their area of expertise and encourage them to think outside the box. Reproduction is a main driver for profitability and genetic gain. We will discuss existing knowledge, identify gaps and explore genetic and management strategies to improve reproduction further in multiple species.

Successful reproduction is a complex characteristic comprising the formation of reproductive cells, successful mating and fertilisation, embryonic and fetal growth and eventually a successful birthing event. In livestock species, reproduction traits have mostly low heritabilities, which makes it challenging to improve reproduction as part of a multiple trait breeding objective. The complexity arises not just from the cascade of processes required to result in successful reproduction, but the relevant traits are different in males and females and they are influenced through health and fitness, nutrition, climate and other environmental and management factors.

Challenges to the improvement of reproduction can vary widely for different species. For less domesticated species such as abalone, the ability to produce and reproduce the animals in captivity presents a major challenge. In bees, reproduction has not been given great attention and little research has been undertaken to understand the underlying genetics of drone and queen reproduction. However, in all industries reproduction is recognised as the basis for genetic and economic gain. It directly influences the selection intensity that can be applied. It also determines how many animals are not required for replacement and can be sold. In all industries, irrespective of the challenge, cost-effective and easy to measure phenotypes of reasonable heritability are central. New technologies and approaches enable the development of novel phenotypes for genetic improvement which will be combined with a growing amount of genomic data in livestock species and together these developments provide new and exciting opportunities to improve reproduction further.

We would like to thank everyone who has contributed to this event for their time and effort: the authors for their contributions to the book and presentations, the reviewers who all readily agreed to critique the manuscripts. We would like to express a special thanks to Kathy Dobos for her contributions into the organisation of this workshop and the publication. Thank you!

Susanne Hermesch and Sonja Dominik

Armidale, May 2021

Review: Cattle fertility and genetic improvement of fertility in developing countries

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Cattle fertility is generally described as the ability to reproduce. However, fertility is a complex trait and the end result of a living and healthy calf is shaped by many interacting factors including the genetics of both cows and bulls. A multitude of traits have been defined to measure fertility and provide a way to enhance the ability to reproduce through genetic improvement, but most traditional traits are found to be lowly heritable such as calving to first insemination, first to successful insemination, or non-return rate. Nonetheless, including these traits into breeding objectives alongside production traits has improved overall productivity of cattle herds and is now common practice in most developed countries. In developing countries, however, the largest obstacles are reliable recording of phenotypes and the highly variable and often challenging environmental conditions which strongly influence the expression of fertility traits. Breeding for other traits, such as heat tolerance or disease resistance, can however indirectly improve fertility. Studies on *Bos indicus* cattle and other native breeds show that there is phenotypic variability between breeds and that some fertility traits, such as onset of puberty, are highly heritable. Until the infrastructure for phenotypic recording, the expertise for genomic evaluations, and the distribution channels of suitable genetics (artificial or live breeding stock) is established within developing countries, the most promising possibility to increase cattle fertility remains in the improvement of environmental and management conditions. However, enabling developing countries to establish and maintain these infrastructures themselves should be the primary goal to enhance breeding progress.

Reproductive challenges in abalone breeding

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Abalone aquaculture in many countries has only recently closed the on-farm life cycle (managing all stages from production to reproduction) due to pressure on wild stocks and a move towards selective breeding for genetic improvement. Abalone breeding strategies rely on efficient maturation and spawning strategies to consistently produce healthy resilient animals. Maturation is controlled through temperature, photoperiod, and the availability of nutrients in the wild. These physical parameters are mimicked to promote synchronised maturation in aquaculture facilities through controlled photoperiod, controlled water temperatures and provision of macroalgae to supplement manufactured feeds. Spawning in the wild is subject to environmental pressures including temperature, tide, lunar cycle, photoperiod, food availability, and major storm events. The most common methods of inducing spawning in aquaculture systems are hydrogen peroxide and/or seawater UV irradiation coupled with heat shock which induces free radicals in the water. This activates prostaglandin and

induces maturation of gametes and spawning. A variety of neuropeptides and hormones have been identified and characterised for their roles in gametogenesis, maturation, mating behaviour, and fertilisation. This has resulted in successful stimulation of gametogenesis by gonadotropin releasing hormone and spawning induction with egg laying hormone. As more of the hormonal cascade responsible for maturation and spawning is revealed alternative methods to prevent or induce reproductive behaviours have become possible. Despite the development of methods for artificial maturation and spawning induction, achieving synchronous spawning of male and female abalone at the desired time remains a major challenge for hatcheries. Precise control of spawning is critical for many advanced technologies, including the production of selected family lines, generation of hybrids and triploids, and for research programs. Applied solutions are under development to control maturation and spawning as well as develop the tools to measure environmental risk to abalone reproduction. To date, reproductive disruption strategies have focused on triploids to induce sterility, interspecific hybridisation, and ploidy. In contrast, the role of pollution in endocrine disruption has been demonstrated in abalone having adverse effects on reproduction and health.

Opportunities from understanding health and welfare of sows

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Farm revenue directly relies on production performance and animals are frequently compared based on their performance outcomes. However, high genetic potential for productivity, if not accompanied by adequate nutrition for sows and appropriate management practices, can compromise health, reducing reproductive performance and increasing mortality of both sows and piglets. Phenotypes recorded are assumed to be from sows with equal health status, which, in practice, is debateable. Differences in health status may compromise the performance of individual sows. Since many health variables are hard to record, alternative strategies may be required to identify poor health. In this paper, we investigated the extent to which health status affected performance and demonstrated that poor health alters breeding values, with the impact depending on the severity of health issues and their incidence. Secondly, we looked at whether sows with higher genetic merit for performance traits had different health status, or unanticipated outcomes. We demonstrated that higher genetic merit for reproductive traits was accompanied by improved reproductive health but could also have some unintended detrimental consequences (e.g. reduced sow longevity). Thirdly, we investigated whether sows with higher genetic merit for litter size differed in their feeding behaviour, since feeding behaviour is also indicative of sow health. Variation in genetic merit for some selection criteria was associated with changes in feeding behaviour, but generally not with feed intake given that feed allocation during gestation was already restrictive. Overall, understanding some of the components presented in this study and the association with genetic merit for reproductive traits offers opportunities to find a balance between performance and welfare of animals.

Saltwater crocodile (Crocodylus porosus) embryo survival: risk factors

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Saltwater crocodiles (*Crocodylus porosus*) lay clutches of eggs deposited into nests constructed of various quantities of vegetation, mud, soil and so on. If left in the nest, few embryos survive so producers instead collect the eggs and incubate them artificially to improve the hatch rate. After hatching, the crocodiles are grown to produce skins for the luxury leather trade. Despite artificial incubation, substantial production losses from embryo mortality still occur. Significant production gains could be made from understanding, and avoiding, the risk factors that affect embryonic mortality. Herein, we provide an overview of saltwater crocodile reproduction and current industry practices with a focus on the identified risk factors that contribute to reproductive failure. Further, the consequence of high nest embryonic mortality on post-hatch performance of the surviving embryos has not yet been fully explored. However, it is recommended that these two life stages should not be viewed independently but rather as a continuum to provide some predictability for producers to increase their production efficiency.

New phenotypes for genetic improvement of fertility in dairy cows

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While the inclusion of fertility in dairy cattle breeding programmes has improved the genetic trend for fertility, further increases are desirable, especially in pasture-based systems such as those in New Zealand (NZ) and Australia, where maintaining compact, seasonal calving intervals is an important objective to match pasture growth to feed requirements of the cow. There is interest in the use of novel traits to aid the improvement of fertility, because traditional phenotypes derived using mating and calving data have low heritabilities. Potential novel traits include mid-infrared spectroscopy predicted fertility (MFERT), age of puberty, serum biomarkers, traits derived from sensor technology, body condition score and conformation. In this chapter, we focus on MFERT (using Australian data) and age of puberty (using NZ data), because these traits can potentially be available on large numbers of animals comparatively early in life. We estimated the heritability of MFERT (0.18 ± 0.04), the heritability of traditional fertility traits (ranging from 0.02 ± 0.00 to 0.04 ± 0.00) and the genetic correlations between MFERT and traditional fertility phenotypes (0.06 ± 0.15 to -0.53 ± 0.10). Based on our estimates of genetic parameters for MFERT and the number of records currently available, including MFERT in the fertility index is unlikely to increase the response to selection, but this may change when more records for MFERT become available. Age of puberty has been recently measured in approximately 5,000 NZ Holstein-

Friesian heifers. Preliminary analysis of age of puberty, obtained by monthly blood progesterone testing, indicates that the heritability is between 0.20 and 0.30. Both MFERT and age at puberty have heritabilities higher than most traditional measures and may be useful for the development of fertility Estimated Breeding Values that use multiple sources of information, including traditional fertility traits.

The influence of bull fertility on beef herd productivity

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Reproductive performance of beef breeding herds is the most critical aspect of livestock systems as it constrains the productivity of the entire supply chain worldwide. If reproductive performance is low, productivity is impaired, and the system is less sustainable. Reproductive performance is complex and requires contributions from both male and female fertility. Compounding this dichotomy, underlying fertility traits are polygenic in nature and multifactorial. Female fertility has received focussed attention for several years resulting in improved management strategies, biotechnologies for its physiological control, and genomic selection approaches that target fertility indicator traits. Although improvements are still possible, great advances have been achieved in recent years. On the other hand, bull fertility has received relatively little attention. This could be partly because most bulls have some degree of fertility, management strategies are often put in place to overcome the detrimental effects of subfertility, or subfertility (or infertility) is often simply unknown. We would argue that male fertility is largely unexplored in the context of sustainable intensification of animal production and plays a major role.

Improving reproductive performance in pigs

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With the introduction of best linear unbiased prediction (BLUP), pig breeding companies have been able to effectively select for improved reproductive performance in pig production. The improvement in litter size, however, has come at a cost, with an increase in both stillbirths and early neonatal deaths, along with decrease

in individual piglet birth weights. Consequently, the potential number of piglets weaned is not reached. To balance these detrimental consequences, breeding companies needed to include alternative traits into breeding objectives. This paper initially explores how traditional litter size traits: total born (TB), number of piglets born alive (NBA), number of piglets alive on day five (LS5) after farrowing have been implemented into breeding programs. Then, we look at how litter size traits have been balanced in breeding programs, by focusing on survival traits, including average piglet birth weight, and pre- and post-weaning survival of progeny. Indirect traits, such as antibody response to vaccination against PRRSV, immune competence and E-coli resistance are also important to maximise sow performance and progeny survival in the presence of disease. Lastly, we briefly discuss the inclusion of sow reproductive traits, such as wean to conception interval and longevity. This paper gives a general overview of how overall reproductive performance has been improved in pig production globally.

Breeding for improved fertility of honey bees

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Honey bee (*Apis mellifera*) colony productivity and fitness is dependent on queen and drone quality, a culmination of the larval rearing environment, sexual selection and beekeeper-driven trait selection and management. Selection for both production and fertility traits of honey bees is not widely practised across commercially managed populations as it is in other livestock species. Scant research has been undertaken on drone and queen phenotypes, reproductive productivity and performance as it relates to selection for fertility traits. The opportunity for increased hive productivity through maximising fertility traits, in tandem with established commercially important colony level traits in honey bees exists globally. In this review, research on the characterisation, heritability, and breeding of known fertility traits of honey bees is discussed and recommendations are given on the most practical candidate traits for selection.

Examining the relative importance of female reproduction in beef breeding herds when fully accounting for production costs

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The reproductive performance of beef females, defined as cow weaning rate (CWR), which is the number of calves weaned per cow joined per year, has been shown to be a major driver of on-farm profitability along with

the survival and growth performance of progeny. There is often debate as to which trait is of higher priority when selecting replacement animals in breeding herds. When fully costed during the derivation of economic values, reproduction has a high demand for nutrient resources because it involves the feed requirements not only associated with pregnancy but that required for milk production. This can represent nearly a doubling of the nutrient demands of the cow compared to when she is in a dry state and therefore, a significant financial investment when supplementary feed needs to be supplied. The importance of CWR was examined relative to that of progeny growth, defined as finished sale liveweight (FSWT), using a breeding objective based on net return per cow mated. A base scenario involving a self-replacing commercial herd that purchases replacement bulls from seedstock herds was simulated with a herd weaning rate of 85%, producing 600 kg grass finished steers at 22 months of age and a sale price of $2.62/kg liveweight. The average mature cow weight was 600 kg and the supplementary feeding period was 6 months long with supplementary feed costing $240/tonne. The impact changes in production system characteristics such as breeding time horizon, supplementary feed cost, sale prices, FSWT and age, and mature cow weight have on this relationship were examined. Cow weaning rate increases in importance when herd fertility was lower (50-70%), animals of greater value were sold at the same age (higher FSWT, 690 kg or higher sale price, $3.05/kg liveweight), supplementary feed costs were lower ($180/tonne), mature cow weights were lower (400 kg), and genetic changes are valued over longer time horizons (20 years). When animals were sold at different ages (12 up to 32 months), the importance of CWR varies in relation to the requirement for supplementary feed. In all instances CWR has a positive economic value and often placing substantial emphasis on fertility is justified. Additionally, the precise importance of reproduction changes with the perception of the future commercial herd and production system characteristics, in particular the cost of providing supplementary feed. It follows that for the best outcomes in terms of profit improvement, the selection importance placed on reproduction should be determined on a case by case basis. The traditional approach of focusing almost exclusively on final market endpoint(s) should be abandoned in preference to giving at least equal consideration to the impact the cow herd has on commercial profitability.

Improving reproduction in ewes

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Improving reproductive performance in sheep is important from both economic and welfare perspectives. To achieve successful change at an industry level, it is necessary to record phenotypes and pedigree and apply sophisticated analyses (single step best linear unbiased prediction, SSBLUP, using genomic data tied to reference phenotypes) to obtain accurate breeding values for selection candidates. Breeders are then able to incorporate this information into breeding decisions. This paper outlines practical issues affecting the ability of sheep breeders to obtain suitable phenotypes for genetic evaluation, ultimately influencing the choice of traits and models used for genetic evaluation. A new genetic evaluation system replaces breeding values for number of lambs weaned with the corresponding components of reproduction (conception, litter size and rearing ability) along with providing new breeding values for other ewe traits (maternal behaviour and condition scores). An illustration of genetic gains in reproductive traits made to date by industry, on average, versus a flock accurately recorded for reproductive outcomes, demonstrates that despite low trait heritabilities typical of reproductive

traits, genetic gain can be achieved through sustained selection for reproductive performance, and this is more evident when recording of reproductive data is comprehensive.

Selection for reproductive efficiency in turkeys and broiler chickens: egg production, hatchability and fertility

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Improvements in meat poultry production have primarily been through breeding for faster growth and bodyweight, feed efficiency, yield and to a lesser extent the reproductive traits. Improved biosecurity and the targeted use of feed enzymes has also had an effect in improving performance. From a breeding perspective, the identification and selection of animals with higher genetic potential to achieve substantial and continuous improvement is critical. The identification of selection candidates for reproductive traits such as fertility and hatchability has traditionally been more difficult due to phenotyping and lower heritability. This is true for both broiler chickens and turkeys. The reproductive traits are important as they determine chick and poult cost at the start of a commercial production cycle before returns accrue after growth, slaughter and processing. The objective is to describe the different traits that affect reproductive performance in turkeys and broilers, as well as the different models used in genetic evaluation. Reproductive traits such as egg production, fertility and hatchability, clutch length and broodiness are described as are the benefits of genomic information. The heritability estimates for egg production ranged from 0.05 to 0.17, while those of fertility and hatchability ranged from 0.04 to 0.22. Estimated heritability for clutch length and broodiness was 0.21 and 0.15, respectively. Heritabilities and accuracy increased with the addition of genomic information. Furthermore, for longitudinal traits such as egg production, with information collected over a production curve, we show that a random regression approach appropriately captures all the factors affecting the traits. Using genomic data to evaluate reproduction performance using transmission ratio distortion revealed haplotypes and functional pathways that if managed, could increase hatchability and fertility in a turkey breeding program. Overall, the incorporation of genomic information resulted in better estimates of genetic parameters, thereby presenting the potential for better improvement of reproductive performance in turkeys.

Genetic improvement of cow reproduction in northern Australia beef cattle breeds

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Northern Australia is characterised by high temperatures, seasonally fluctuating feed quality and unique parasitic challenges. *Bos indicus* and *bos indicus* derived breeds are favoured for their ability to withstand these challenges and produce in the harsh northern Australian environment. Cow reproduction is an important driver for breeding profitable beef enterprises but has typically been difficult to select for with traits generally being lowly heritable, sex-limited and expressed late in life. The key cow reproduction trait in the Australian BREEDPLAN genetic evaluation is days to calving which has been demonstrated to be highly correlated with calving success (i.e. did the cow calve or not). The development of two highly heritable ovarian ultrasound scan traits when implemented as part of genomic selection may be a game changer in creating opportunities for genetic improvement of cow reproduction in northern beef herds. Age at puberty and lactation anoestrus interval are both highly heritable (h^2 estimates of approximately 0.50 and 0.40, respectively) and correlated to days to calving -the key cow reproduction trait currently analysed in BREEDPLAN. The purpose of this chapter was first to outline the current genetic improvement program for female reproduction in northern Australia beef cattle breeds, and secondly to show how the incorporation of ovarian scan traits and genomic selection are providing a new and exciting opportunity to make significant genetic improvement for female reproduction.

Climatic constraints facing sheep reproduction

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Increasing climatic variability can be expected to challenge the health, welfare and productivity of sheep, globally. Cold temperatures are broadly recognised to affect reproduction via an increase in neonatal lamb mortality from exposure to combinations of cold, wet and windy conditions, but such conditions are rarely implicated in the reduction of ewe or ram fertility. The opposite is generally true for heat stress; the impact of heat stress on reproduction is not widely recognised and its ability to impair reproduction is most likely to affect the fertility of ewes and rams. Heat stress, however, arguably poses a broader risk to sheep reproduction than cold exposure, because the components most at risk of impairment are so wide ranging. Gametogenesis, follicle development, ova quality, embryo survival, placental vascularisation leading to impaired fetal growth, lactation and lamb survival may all be negatively affected by heat stress. The sheep, with a 5-month gestation, invariably negotiates climatic extremes at key times of reproduction. Given there is limited evidence indicating mammals can be simultaneously tolerant of heat and cold stressors, somewhere in the middle is a compromise around the time of mating, which suggests the potential to select for thermal tolerance in either direction. In other species, selection for growth and muscling increases susceptibility to heat stress, and in the Australian sheep, a greater emphasis is being placed on these traits. It is not known if such recent selection increases vulnerability to heat stress. The question is, as the climate continues to rapidly warm, which thermal extreme do breeders select for, if indeed they have been, or will, or can?

Lamb survival, a challenge for the decades

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Lamb survival to weaning is the major profit driver in the Australian sheep industry, and equally an important issue for animal welfare and ethical livestock production. Research aimed at improving lamb survival and reproductive efficiency remains consistently one of the highest-ranking priorities identified by industry consultation groups. The extensive body of knowledge generated by research efforts across Australia have led to comprehensive management guidelines and extension programs to support their uptake. Nevertheless, reported rates of loss in many regions remains higher than acceptable, despite lamb loss rates in general improving under improved management strategies. One of the biggest challenges is to break down this complex phenotype into measurable meaningful component traits. As for any complex phenotype, a combination of improved management and genetic selection may be most likely to lead to success but for either application, phenotypes must be less dependent on uncontrollable environmental influences than counts of losses. Dystocia has been conclusively shown to be one of the most important causes of lamb loss and development of approaches to measure incidence of dystocia will aid the development of new phenotypes to facilitate genetic and management strategies to improve lamb survival.