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

Opportunities from understanding health and welfare of sows

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Abstract

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.

Introduction

Modern pig farming was established during the 1960's with the aim to increase production efficiency (Svendsen and Svendsen 1997). Pig farming is typically characterised by a large scale of operation, high genetic potential for performance and large groups of animals transferred between facilities (gestation, farrowing) on tight schedules. Concurrently, the observation of individual animals has declined due to lower staffing levels and the introduction of group housing during gestation. Since 1997, the average time spent per weaned pig has decreased from 42 to 20 minutes in 2009 (Merks *et al.* 2012). Further, apart from treatment of obviously ill sows, routine assessment for potential health issues is not performed, despite increased ease during their confinement in farrowing crates and the knowledge that the farrowing period is the most critical period in sow's life. Attention to sow health can increase herd immunity, lower sow mortality and positively affects production results (Friendship and O'Sullivan 2015).

Historically, selection has also been focused on highly heritable traits, such as growth rate or fatness. With the development of software to capture large amounts of data, increased computing power, and with the application of BLUP (Best Linear Unbiased Prediction) methodology, genetic progress has been achieved for several economically important traits (e.g. reproductive, carcase, and efficiency) included in breeding goals, increasing performance levels overall. The review of Oliviero *et al.* (2019) reported an increase from 11 piglets/litter to 14 or more, between 1990 and the 2010s. With selection for higher reproductive performance, sows tend to invest more into piglet development and milk production, leading to behavioural, immunological and physiological problems (Prunier *et al.* 2010) and placing them at higher risk of diseases or premature removals (Rauw *et al.* 1998; Hermesch and Luxford 2010; Ocepek *et al.* 2016).

Good health contributes to good welfare. Presence of disease is a sign of compromised health and demonstrates reduced ability to adapt to environmental challenges (Huber *et al.* 2011; Maes *et al.* 2019). Insufficient management of sows with higher requirements can lead to reduced milk production, reproductive problems, thin body condition, shoulder sores, and other undesirable consequences affecting welfare (Lundgren *et al.* 2012; Lundeheim *et al.* 2014). Therefore, breeding organisations are continuously adapting their breeding objectives with the aim to improve welfare, accommodating demands by both farmers and consumers (Merks 2000). In order to address welfare concerns, new phenotypes related to vitality from birth to slaughter, uniformity, robustness, health and welfare (e.g. mothering ability, sow longevity, reduction in aggressive behaviour) have been investigated (Merks *et al.* 2012). However, such phenotypes are typically recorded in nucleus farms, with higher health status rather than commercial farms (Culbertson *et al.* 2017). Health-related traits typically have low heritability estimates, but where individual variation in these traits exists, genetic selection for improved health is possible (Colditz and Hine 2016). The purpose of this paper was to consider three aspects of understanding associations between sow health and breeding values for performance traits. We investigated: 1) whether health status affects performance and alters breeding values; 2) whether higher genetic merit for performance traits changed health status or unanticipated removals; 3) whether sows with higher genetic merit for performance traits have some changes in their feed intake or feeding behaviour, which is also indicative of sow health.

Phenotypes used for genetic evaluation are assumed to be between sows with equal health status

Health can be defined as the ability to manage all challenges throughout life, and is a prerequisite for expressing genetic potential (Huber *et al.* 2011; Maes *et al.* 2019). Phenotypes compared for genetic evaluation are generally assumed to represent animals with similar health status. Sows with known ill-health (e.g. medicated) eat less during lactation (Bunter *et al.* 2009), resulting in poor body condition, lower number of weaned piglets, prolonged wean to conception interval, lower litter size in the following parity and other undesirable consequences. However, incidences of health issues that may affect phenotypes recorded are typically poorly observed. Bunter and Vargovic (2019) demonstrated that less than 5% of sows were medicated for health issues at some stage during their gestation, while many more showed some signs of ill-health (ranging from minor to moderate severity) or compromised physiological parameters that could negatively affect production and longevity. Minor deviations from normal health status and physiological parameters typically do not have significant impact on sow performance. However, at the end of gestation, approximately 5% of sows had elevated rectal temperature, indicating health issues, 2.5 - 3.5% had severe locomotion issues, 22.1 - 52.8 % of sows had more than 10 lesions resulted from fighting and 5.8 - 15.4% of sows had moderate to severe injuries on the vulva. In addition, around 10% of sows had uneaten meals, which is also an indicator of health issues and approximately 5% of sows were inferred, from urinalysis to have a urinary tract infection (UTI). Urinary tract infection is often unidentified, but can have a high prevalence in pig production and negatively affects reproductive performance and longevity (Almond 2005). With respect to physiological parameters, low levels of haemoglobin negatively affect appetite (Vargovic *et al.* 2019), and can also cause preterm delivery, or compromise birth weight and neonatal health (Allen 2000). However, identifying sows with UTI or low haemoglobin levels requires specific testing, and is laborious, therefore it is not routinely performed on farms. Since overall health of individual animals is generally unknown, the genetic variation in health amongst individuals is also unknown. Further, unhealthy animals have altered phenotypes in comparison to healthy animals, and that could possibly affect breeding values.

When health status is known, it is possible to predict if sows will have health-related undesirable performance outcomes. The accuracy of prediction is dependent on the variables fitted in models. The higher the accuracy, the better the model is at distinguishing between sows with and without undesirable outcomes (Figure 1). The undesirable outcomes evaluated were: 1) farrowing failure (FFAIL), which included low number of born alive piglets, high number of stillborns relative to litter size, abortions and farrowing difficulties; 2) high number of stillborns relative to litter size (SBFAIL); 3) the occurrence of any stillborn piglet in litter (SBLIT); 4) lactation failure (LFAIL), which included low number of weaned piglets, poor mothering ability or shortened lactation; 5) unanticipated removals around weaning (REMW), 60 days post-farrowing (REM60) or 142 days post-farrowing (REM142); and 6) the probability of sows being mated within 7 days post-weaning (rebreed).

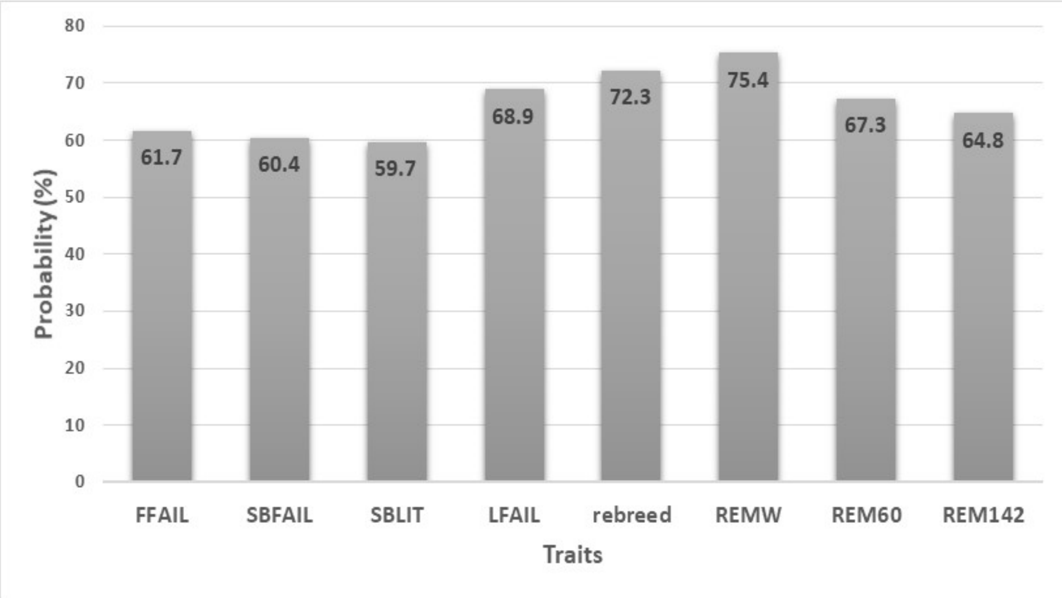

Figure 1. The accuracy of predicting undesirable outcomes (traits) from previously recorded health-related variables

Based on prior analyses across two farms, some health-related observations similar to those described further below were fitted as common predictors to all outcome traits. In this example, the overall quality of prediction of undesirable performance outcomes using a single set of predictors ranged from failure (R^2<60%) or poor (60%<R^2<70%) for farrowing traits (FFAIL, SBFAIL, SBLIT), to fair (70%<R^2<80%) for prediction of forced removals (REMW) or poor rebreeding success (rebreed). By using common predictors across all outcome traits, it is hard to predict which sows will have farrowing failure (FFAIL, SBFAIL, SBLIT). However, the usefulness of these common measurements was clearly demonstrated for lactation outcomes, rebreeding success and removals, and interventions may have been possible to improve outcomes. Further, different and/or farm specific predictors can have utility for traits like FFAIL, SBFAIL and SBLIT (Vargovic, 2020).

Since it was possible to demonstrate that the performance of sows is affected by ill-health, we then tested whether sows re-rank for breeding values, when poor health status is accounted for. An example Health Index (HI) value was generated for sows recorded on two farms (previously described in Vargovic, 2020), and fitted in models for outcome traits. The variables included in this HI had predicting ability for outcomes across farms (Figure 1). In total, there were 12 variables that distinguished between mild, to moderate and severe health issues for each individual. The 12 variables included: low levels of haemoglobin (<95 g/l), low caliper increments (thin sows), poor locomotion score, severe injury to legs, severe injury to the vulva, shoulder sores, more than 50% of feed not eaten before farrowing, more than 2 teats injured, extensive lesions from fighting, pre-farrowing mastitis, rectal temperature >38.7°C and dirtiness around the vulva. Each of these variables was categorised as absent (0) for mild or no health issues, or present (1) for moderate to more severe health issues and summed to obtain the overall HI value. A higher score represented more severe health issues experienced concurrently by an individual sow. The mean (SD) for this Health Index was 1.12 (1.09), with minimum possible score = 0 and maximum = 12. The highest score observed was 9 (N = 1 sow). Breeding values for 1103 sows were generated for outcome traits (FFAIL, SBFAIL, SBLIT, LFAIL, rebreed, REMW, REM60, REM142), as well as for the number of piglets born alive (NBA) or weaned (NWEAN). A base model included breed nested within farm and parity. The HI value was subsequently fitted as an additional covariate nested within farm. For each trait breeding values were estimated both with and without the Health Index value included as a covariate.

When the HI value was fitted as a covariate in models, this additional information resulted in overall lower residual variances for all traits. Heritabilities did not change with this additional information. Spearman correlations between breeding values with and without HI fitted in models were between 0.96 - 0.99, demonstrating that, on average, additional information about health has no effect on re-ranking of animals, because the majority of animals are generally healthy. The lowest correlation was found for trait LFAIL, 0.96. Relatively few animals experienced more than one variable categorised as severe (Table 1). However, sows with HI scores of 3 or more had, on average, substantial changes in EBVs for affected traits (Table 1). Thus, re-ranking will occur for sows with significant health issues if knowledge of their health status is accommodated in the model.

The results in Table 1 show that the information about health status of animals is more relevant for the number of weaned piglets compared to born alive piglets, and it was expected to see significant re-ranking of sows with known health status. This demonstrates that sows with poor health should not be compared to contemporaries in good health. Some of the health-related traits, such as urinary tract infection or injuries affecting sows were previously shown to have heritability around zero (Vargovic 2020). In contrast, variation in haemoglobin levels, appetite or the incidence of mastitis are lowly heritable. While there is genetic variation in some health issues, it is currently unclear which health issues should potentially be accommodated as a systematic effect and which ones used as selection criteria.

Table 1. Average difference in EBVs for born alive (NBA) and weaned piglets (NWEAN) between models with and without Health Index (HI) value included

Number of sows	HI	NBA	NWEAN
352	0	0.006	0.053
425	1	-0.0001	0.007
218	2	-0.005	-0.037
71	3	-0.008	-0.084
37	>3	-0.023	-0.199
9	>4	-0.030	-0.269

Does genetic merit alter the risk of sows experiencing poor health or welfare?

Currently, little is known about how variation in genetic merit influences the risk of poor health and welfare to sows. This phenomenon can be difficult to demonstrate and the extent of impact remains poorly quantified, particularly amongst contemporaries within a population. Improved genetic merit is expected to improve performance for corresponding traits (Leenhouwers *et al.* 2003), but may also have antagonistic consequences for other traits, some of which are related to health and welfare. For example, higher EBVs for piglet birth weight significantly increased the number of weaned piglets, but reduced sow longevity (Bunter *et al.* 2018). This is because higher birth weight is a desirable characteristic for piglets and increases their probability of survival, but also requires significant energy reserves from sows during both gestation and lactation. When higher genetic merit for birth weight is not accompanied by adequate nutrition for sows, the risk of sow removals increases. Similarly, higher EBVs for fatness are positive for farrowing outcomes (Bunter *et al.* 2010) and reduce return to service for sows (Bunter *et al.* 2018). However, higher EBVs for fatness are not desirable for slaughter pigs because of increased carcase fat and resulting payment penalties. Understanding which of the economically important traits places sows (or other classes of animals) at risk could assist with identifying management adaptations. In addition, breeding goals need to account for the changes in health status that may occur. This is relevant, even if it does not change the opportunity to monitor individual sows, because most commercial sows do not have known genetic merit levels.

We examined if any health issues were increased for animals with higher genetic merit. To achieve this comparison, data on specific health issues (see Vargovic 2020) were collected on pedigreed sows for which breeding values could be obtained. Two farms supplied estimated breeding values (EBVs) for a range of traits obtained from their in-house genetic evaluation systems. All EBVs were estimated using data recorded prior to the recording of the health data, eliminating the contribution of data from the current parity to EBVs for these sows. Both farms estimated breeding values separately by line, for sets of traits specific to each line. Breeding values for each trait were re-expressed as a deviation from within line mean breeding values of project sows prior to performing regressions on breeding values within farm. Breeding values were available for the following traits: average daily gain (ADG), back fat (BF), loin depth (LD), total born (TB), stillborn (SB), born alive (NBA), teat number (Teats), return to oestrus within 7 days (rebreed), wean to conception interval between first and second parity (WCI), and litter weaning weight (LWT). Health traits were: absence or presence (0/1) of a urinary tract infection from urinalysis (UTI), haemoglobin levels (HB), and caliper increments representing body condition of sows (CAL). These health traits were regressed on the breeding values one trait at time, after accounting for parity group and breed within farm. The exception was for the presence of UTI, where logistic regression was performed.

Based on the regression results (not tabulated), sows observed with UTI from urinalysis were more likely to have lower breeding values for litter size and back fat and more positive (undesirable) EBVs for wean to conception interval. Therefore, higher genetic merit for these traits was accompanied by improved reproductive health. Genetic merit for litter size did not affect observed levels of haemoglobin in sows, despite the expected reduction in sow haemoglobin levels with increased litter size due to the requirements of the piglets. These are examples of a desirable association between selection (increased litter size) and sow health parameters. In contrast, pig breeding objectives typically select for lower back fat. However, sows with higher back fat EBVs had higher (more desirable) haemoglobin levels. Sow haemoglobin level was 4.00 g/l higher per mm back fat breeding value, consistent with observations by Normand *et al.* (2012). The number of weaned piglets also increased by 0.23 piglets/litter for each mm in back fat breeding value. A plausible explanation could be that there is an underlying association between iron levels and the appetite of sows, resulting in better milk production and more piglets weaned. Similarly, CAL increased with EBVs for back fat and loin muscle depth. Therefore, breeding goals which target leaner slaughter pigs also potentially result in leaner sows with lower CAL, which is detrimental for sow performance. Historical selection for larger litter size (NBA) in combination with increased leanness also increased the probability of unanticipated removals on one farm, despite improved litter size at farrowing. Adjustment of nutrition or management practices could potentially alleviate this risk.

Relationship between feed intake or feeding behaviour and reproduction and longevity

As previously noted, specific testing for health issues is laborious, costly, and potentially not feasible logistically. Relatively recently feed intake and feeding behaviour have become of interest, since deviations from the normal feeding pattern can also indicate health issues. Most publications related to feed intake and feeding behaviour traits are focused on data from growing pigs with *ad libitum* access to feed (e.g. Labroue *et al.* 1999) or to feed intake recorded during lactation (e.g. Hermesch 2007). The general assumption of these studies is that the animals recorded are healthy. Sows with a higher feed intake during lactation wean heavier piglets, have better body condition at weaning, a lower wean to service interval, and farrow more total born piglets in subsequent parities (Eissen *et al.* 2003; Bunter *et al.* 2006). High feed intake in lactation, therefore, contributes to improvements in reproductive performance and sow longevity (Koketsu *et al.* 1996; Anil *et al.* 2006). Sows that are unwell are known to reduce intake during lactation (Bunter *et al.* 2009).

From the breeding perspective, using feed intake data recorded during lactation as a selection criterion might be challenging. Recording is expensive (using specialised feeders) or laborious (manual). However, data routinely recorded during gestation by electronic sow feeders (ESF) offers an alternative avenue that does not require any additional labour, only data processing. Daily feed intake recorded during gestation (under restricted feeding) is not a consistently heritable trait and therefore not useful from a breeding program perspective (Vargovic *et al.* 2020). However, some other traits from ESF data might be considered. Phenotypes regarding missed meals, variable feeding patterns or speed of eating are moderately heritable and therefore possibly useful selection criteria (Vargovic *et al.* 2020). Genetic correlations indicate that sows that missed meals or that had irregular feeding patterns during gestation were also more likely to have poor feed intake prior to farrowing (Vargovic 2020), leading to other undesirable consequences. These studies demonstrated the importance of normal feed intake and feeding behaviour on subsequent reproductive performances and longevity. At least some of this normal feeding behaviour represented sows in good health, whereas in appetence is common for several health issues.

Following on from this work, it was examined whether variation in genetic merit for reproductive traits also had implications for feed intake or feeding behaviour recorded on gestating sows. Because F1 sows typically do not have their own breeding values, mid-parent breeding values for pedigreed F1 sows were calculated from within-gender centred breeding values of purebred parents from two lines for back fat (BF, SD: 0.40 mm), born alive in first (NBA1, SD: 0.435 piglets/litter) and later parities (NBA2, SD: 0.53 piglets/litter), wean to conception interval between first and second parity (WCI, SD: 0.79 days) and number of parities in a lifetime (TNL, SD: 0.29 litters/lifetime). Traits derived from ESF data were regressed on these mid-parent breeding values one trait at a time in models accounting for mating-year-month, diet, shed, pen and parity as systematic effects (Table 2).

Table 2. Regression coefficients (b) for feed intake and feeding behaviour traits on EBVs for selection criteria (N=2,526 sows)

		Trait EBV				
Trait	Units	BF	NBA1	NBA2	WCI	TNL
Range EBV		-1.26 to 1.45	-1.53 to 1.61	-2.09 to 2.11	-2.06 to 4.51	-0.77 to 1.28
AFI	kg/day	ns	ns	ns	ns	-0.005
AFT	min/day	0.42	0.40	0.27	ns	ns
AFR	grams/day	-5.42	-4.96	-3.33	ns	ns
MISSF	days	ns	ns	ns	0.15	ns
BELOW1	days	ns	ns	ns	0.16	ns
DA_bin	%	ns	-0.003	-0.003	ns	-0.007
SDA-I	kg	0.02	0.02	0.016	ns	ns

Abbreviations: *BF: back fat (mm); NBA1 and NBA2: number of born alive piglets in first and other parities (piglets/litter); WCI: wean to conception interval between parity 1 and 2 (days); TNL: total number of parities (litters/lifetime); AFI: average feed intake (kg/days); AFT: average time spent eating (min/day); AFR: average rate of feed consumption (grams/min); MISSF and BELOW1: number of days with missed meals or intake below 1 kg (days); ABOVE30: number of days with more than 30 min/day spent in feeders (days); DA_bin: appetite of sows, where allocation consumed = 1, otherwise = 0, averaged across gestation (%); SDA-I: standard deviation from the difference between allocation and consumption (kg); ns: not significant*

Sows with higher BF spent more time eating (b: 0.42 minutes/mm) and had a slower rate of feed consumption (-5.42 grams/minute/mm). Sows with higher genetic merit for litter size (NBA1 and NBA2) also spent more eating and had a reduced rate of feed consumption. This information should be accounted for in systems where sows are only allowed limited time to eat or in systems where sows are unprotected while eating, to avoid altered behaviour or reduced feed intake, with implications for their health and performance. Sows with higher genetic merit for litter size (NBA1 and NBA2) also experienced less desirable feeding patterns (higher SDA-I and lower DA_bin), consistent with a reduced ability to consume their feed allocations towards the end of gestation (Vargovic *et al.* 2020). This may have resulted from physical restriction due to increased litter sizes and suggests that increasing the energy level of the diets in the last part of gestation may be required if volume is limiting. Physical limitations to intake during late gestation are likely relevant for other species. Sows with higher EBV for wean to conception interval had more days during gestation when their intake was below 1 kg or completely absent. This premise was supported in many studies; e.g. Waller *et al.* (2002) reported that unhealthy sows with poor appetite also had prolonged wean to conception period. Regression coefficients (b) demonstrated that variation in genetic merit for selection criteria was associated with changes to feeding behaviours but generally not feed intake (e.g. AFI), which was restricted for all sows regardless of genetic merit.

Summary

- The incidence of sows with ill-health was higher than is typically identified via medication records, demonstrating that additional attention for closer observation of sows is required to maximise performance outcomes. When health status is known, it is possible to predict if sows will have some health-related undesirable performance outcomes.
- Ill-health may alter phenotypes and therefore affect breeding values, but the impact will depend on the severity of health issues and their incidence. Severe health issues changed breeding values. This demonstrated that animals with poor health status should not be compared with contemporaries in good health without accounting for variation in health status. This result is also generally relevant for other species. However, routinely identifying ill-health remains a challenge for both phenotypic outcomes and to apply in breeding programs.
- Higher genetic merit for reproductive traits was accompanied by improved reproductive health. While selection can induce desirable changes, it is important to recognise selection may also have unintended consequences, in the same or different class of animals (e.g. higher EBV for birth weight reduced sow longevity). The breeding goal should fully encompass all possibilities.
- Variation in genetic merit for some selection criteria was associated with changes to feeding behaviours, but generally not feed intake given that feed allocation was already restrictive. Sows with higher genetic merit for litter size increased time spent eating and had a reduced rate of feed consumption with less desirable feeding patterns. Generally, higher genetic merit in reproductive traits was associated with better appetite. Data from ESF systems is an alternative source of phenotypes to identify ill-health and for application in breeding programs.

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