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Improving offspring survival outcomes for mammalian livestock species

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Introduction

Selection for improved survival in mammalian livestock creates unique challenges. Individual survival is a lowly heritable binary (0/1) trait, influenced by both direct and maternal effects which can be difficult to accurately disentangle (all parents are survivors). Further, survival in young animals is influenced by variation in maternal factors, like dam parity or birth type, along with age and environmental challenges, such as the thermal environment, nutrition, disease or management activities. Potential explanatory factors for survival, survival outcomes and the birth type and pedigree of all individuals, dead or alive, are often poorly recorded, particularly in extensively managed livestock. Therefore, quality data at scale is hard to achieve, making robust genetic evaluation difficult. Recording and analysis difficulties meant that historically genetic evaluation for survival outcomes were not implemented routinely and/or negligible genetic trends for survival were observed (e.g. Moore *et al.* 2018). The objective of this paper is to discuss aspects of selecting for improved offspring survival using direct and indirect selection criteria, using examples from pigs, sheep and cattle.

Discussion

Look after the dam and she will look after the offspring. Most dam and offspring deaths occur leading up to, during or within 1 week of parturition. Further, in mammals the maternal environment is crucial to early survival outcomes for offspring. At the extreme, if the dam dies, walks away from or kills her offspring following parturition, or lactation initiation or access to colostrum and milk fails, the offspring will die without human intervention regardless of any otherwise favourable characteristics of offspring. However, dam loss, offspring rejection and lactation failure are frequently unrecorded. For remaining dams, the maternal environment for offspring is expressed through anatomical, physiological and behavioural differences amongst breeding females. Therefore, appropriate management of (nutrition, parasite control) and characteristics of the dam throughout gestation, leading into and during the parturition event and in the early post-partum period, are critical for both dam and offspring survival.

Difficulty of parturition is a trait that received early interest in cattle and sheep because of more extensive management and limited opportunity for human assistance at parturition. For example, 41% of ewe and 67% of early lamb deaths are connected to lambing difficulties (see review by Jacobsen *et al.* 2020). The implementation of a lambing ease (LE) multi-trait analysis, which currently includes data where available for any of lambing difficulty score, dead at birth lambs, lamb birth weight and gestation length is used to estimate breeding values for direct and maternal LE, and is successful in reversing adverse direct and halting adverse maternal genetic trends in LE which arise from selection for higher weaning weights (Fig. 1, Sheep Genetics). These traits are connected to lamb survival outcomes (Bunter *et al.* 2023). The indicator traits for LE analyses exclude measures such as internal pelvic dimensions, which

are heritable and informative of parturition difficulties, but too invasive and impractical to record. A complication for sheep is that LE is influenced by litter size, recording in litters of multiples can be incomplete and the antagonism between high birth weight and poor LE is modified by litter size, requiring separate genetic LE traits for single and multiple births.

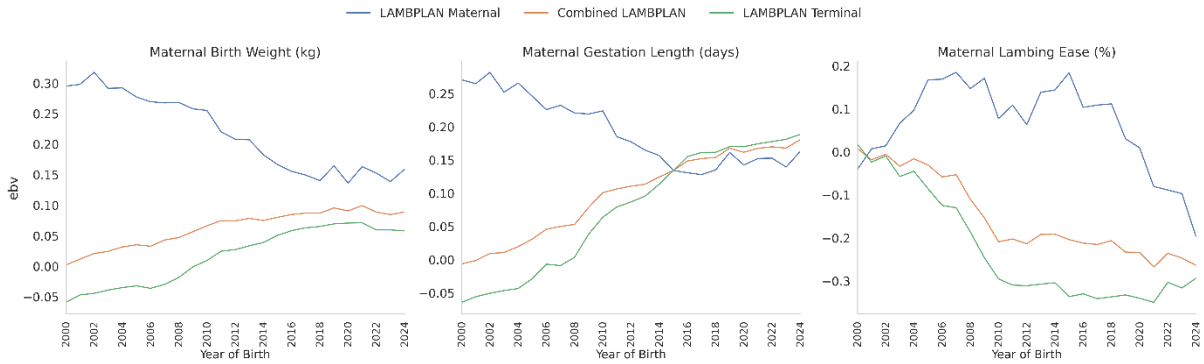

Figure 1. Genetic trends in maternal effects for lambing ease (LE: % un-assisted), birth weight and gestation length: breeding values for LE were available only for the terminal breeds group from 2007 and were genomically enhanced in 2021 (Source: Sheep Genetics, MLA, Australia).

In addition to ease of parturition, which has significant consequences for survival of dams and offspring, other measures of maternal characteristics are important. Robust traits across species and environments typically include litter size, which is antagonistic to progeny survival predominantly through a negative effect on birth weight, and traits representing maternal health, behaviour and condition, along with teat and udder characteristics (Bunter and Johnston 2013b). With respect to sows, the paper of Vargovic *et al.* (2022) is a good illustration that factors with predictive power for poor survival outcomes are not always robust across different farms, and heritability of these factors also varies between useful to negligible (Vargovic 2020). Consequently, the alternative maternal catch-all can be to select directly for offspring weaned, which is useful where offspring pedigree is not always recorded, but less useful to control offspring losses with increased litter size variation. This approach can be further hindered in pigs by cross-fostering, which reduces sow trait heritability for pigs weaned and does not adequately capture piglet losses.

The importance of offspring characteristics. Genetic evaluation models at the offspring level offer opportunities for gains connected to traits which can be recorded directly on offspring, particularly where characteristics vary between full-sib litter mates. However, traits measured on offspring are affected by both direct and maternal contributions. Thus, offspring characteristics at birth require knowledge of both dam and offspring pedigree for appropriate analysis, which is frequently limiting. Further, the influence of an animals' own genes on future characteristics will generally increase with age.

In all mammalian species, higher birthweight is generally favourable for survival providing it is not accompanied by parturition difficulties, making birth weight a strong focus for selection. However, in singleton births particularly it becomes possible for birth weights to become too high, increasing the risk of damage or death for mother and offspring during parturition through dystocia (noted above). In contrast, very low birth weights or shortened gestation lengths can also increase mortality. In pigs, historical recording of litter weight at birth (a single record per sow) can be altered to recording of individual birthweights to improve selection for piglet survival and future performance. Concurrent genetic and environmental improvement means that antagonistic relationships between litter size, birth weight and piglet survival can be

partially offset through selection, enabling piglets to survive better with less intervention (fostering) at lower birthweights (Fig. 2) in larger litters (not shown).

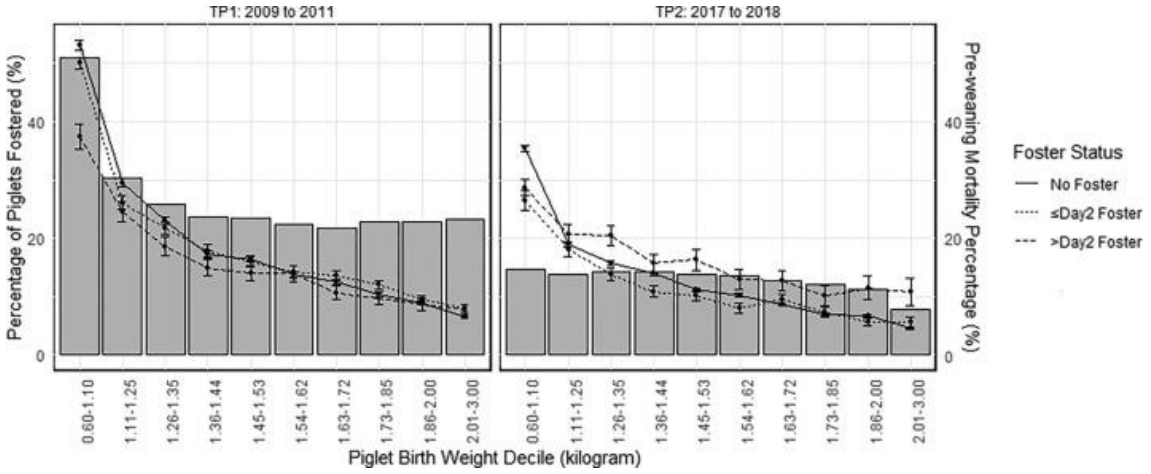

Figure 2. Pre-weaning mortality (%) in two time periods (TP1 & TP2): bars indicate percentage of piglets fostered and lines represent foster status of piglets (Source: Harper 2023).

Several other physiological traits recorded on offspring have been proposed but can be costly to record and become biased by failing to record non-surviving progeny in industry settings. Genomically enhanced selection offers improved opportunities in this regard, particularly if dead progeny are routinely genotyped (Sharif-Islam *et al.* 2022), which rarely occurs. More recent traits connected to survival outcomes across species include immune competence (Harper, 2023). Species specific issues can also be targeted, such as: resistance to *E.coli* and PRRS in pigs; myostatin genotype on calving outcomes; and polledness to reduce calf losses through dehorning (Bunter *et al.* 2013a), each making use of technology to develop genomic tests to achieve this. However, implementation problems can include creating population bottlenecks due to too few eligible parents or an absence of maternal antibodies without accompanying vaccination programs for dams (e.g. resistant E.coli genotype).

Data challenges. Developing a robust genetic evaluation system suitable for industry-wide selection decisions aimed at improving animal survival can be difficult to achieve. To be effective and cost-efficient, we either need large scale recording of phenotypes accurately in a cost-effective manner across the wider industry or use smaller scale high-cost phenotyping leveraged with genotyping through reference populations connected to the broader industry. The latter is easier in sheep and cattle, but harder across competing breeding companies in pigs. There are also challenges with regards to choice of traits and appropriate timing of recording for trait expression, data structure (i.e. all parents are survivors) and completeness of recording – with censoring of data for dead animals or dams, along with identifying contemporaries. If there is intervention by human rearing to prevent mortality, an animal is no longer in the same management group as its unassisted contemporaries and the informativeness of the data is reduced. Quality phenotypic data at scale is therefore hard to achieve, making robust evaluation difficult at an industry level. This can also contribute to difficulties in obtaining a suitable reference data set for assisting accuracy with genomic selection.
Numerically, survival outcomes for individuals are binary, whereas survival outcomes for litters can take more values (% survival). Regardless, low incidence for recorded mortality provides insufficient variation to work with. Further, error is typically associated with recording survival outcomes in practice accurately for all individuals. For example, offspring can be unobserved in extensive environments, or were not 'real' animals, being inferred from other data – such as pregnancy scan counts, or are not recorded unless weaned. Therefore,

losses are typically under-estimated. In addition, explanatory data or indirect selection criteria for survival (e.g. dam identities and characteristics, litter size, birth weights, lambing or calving ease scores, date of birth) may be unrecorded for many animals or litter mates, when both direct and maternal effects need to be accounted for, and are frequently censored at an even higher incidence for dead animals.

Some informative indirect traits, such as gestation length, are poorly recorded generally, requiring known breeding dates, take the same values for full siblings and have low CV, limiting the usefulness of this data to discriminate amongst offspring or litters. In pigs particularly, deliberate cross-fostering interferes with assessing piglet survival outcomes, and in sheep or cattle, cross-suckling can also naturally occur. Finally, the impact of major weather events (e.g. a cold front resulting in lamb deaths) or other specific environmental issues of large effect are unlikely to be established through routine herd recording systems. These types of events can elevate mortality in a non-random way across sires, for example, inflating genetic variances. Thus, using both direct survival outcomes and indirect traits to contribute towards assessment of survival outcomes and other characteristics may increase robustness of evaluations. For a robust genetic evaluation system, it is important to choose a strategy which makes the best use of data which can be reliably recorded. When this is achieved, genetic variation is evident and genetic improvements become feasible.

Conclusions

To be effective, selection for improved offspring survival is likely to require a multi-pronged approach, using 0/1 survival data (direct selection) and/or specific characteristics (indirect traits) of dams or their offspring known to have impact on survival outcomes across the wider population. For national genetic evaluation systems, robust trait choice and achieving quality data at scale may be difficult but is possible, and significant genetic variation is revealed. This data should be accompanied by analysis systems using genotypes to increase accuracies of breeding values, along with breeding goals which place importance on survival. In this scenario, favourable genetic trends can be achieved.

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