Mothers matter: how management of animals during pregnancy affects their progeny

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Research conducted over the past two decades has started to reveal how stress, ill health or poor nutrition during pregnancy may be hidden causes of reduced progeny performance in farm animals

INTRODUCTION

Maximising animal health, welfare and productivity is important for all livestock farmers. The traditional view is that two interacting components dictate animal performance in these areas: genetics and the environment (including physical, social and infectious components). However, a new area of research has highlighted the influence of the prenatal environment on progeny biology from birth to slaughter.

Scientific interest in the ways that maternal experiences during pregnancy affect offspring was triggered by epidemiological findings in humans. Medical epidemiologists in the UK identified links between infant birth weight (as an indicator of foetal growth) and subsequent adult health. More recently, the consequences of maternal stress during pregnancy have been examined in humans; for instance, in offspring born to women affected by major stressful events (such as natural disasters or terrorist attacks), or individual women affected by things such as bereavement during pregnancy. In many cases, offspring are found to be affected by their mother's experience and have various behavioural and health problems throughout their life.

TERMINOLOGY

Prenatal stress can be defined as any challenge to pregnant mothers that threatens the later optimal development of progeny. Such effects are also described as 'foetal programming'. Furthermore, 'transgenerational' effects are also defined, whereby maternal challenges during pregnancy affect not just the resulting progeny, but their subsequent offspring too. Such effects are mediated by 'epigenetic' changes, such as DNA methylation, which affect gene expression without altering DNA sequence. The study of epigenetic mechanisms is a highly active research field with much yet to be understood and discovered. Mathers and McKay[1] have discussed what they call the four Rs of epigenetics. In their terminology, environmental signals are received (for instance, by the foetus via the mother) and recorded through altered patterns of DNA methylation or other changes. These changes survive subsequent cell divisions, and are remembered by the organism, and then revealed in the form of alterations to biological phenotypes. In this way environmental effects can be inherited from one generation to the next, and impacts of even short-lived events (such as periods of stress or under-nutrition) can be seen over a long time period. In human terms, this means stressful events experienced by your mother – or indeed grandmother – could influence your biology and susceptibility to disease.

PRENATAL CHALLENGES IN LIVESTOCK

The interest in these effects on human health has led to extensive research in rodents, and some work in larger animals, particularly sheep, as models to better understand the basic biology. Increasingly, investigations of prenatal effects have also explored the relevance for livestock farming, and the implications of maternal challenges during pregnancy on animal health and welfare outcomes, and on farm production efficiency.[2,3,4] Here we concentrate on the importance of prenatal stress and nutrition in cattle and sheep production.[5,6]

STUDIES IN CATTLE AND SHEEP

Stress

Maternal stress can affect development in numerous ways. Stress hormones can pass across the placenta and affect offspring brain development. In some cases, exposure to increased levels of stress hormones before birth leads to permanent changes in brain function and impairs immune systems. Stressful challenges can also have other effects on physiology, some of which may transmit to the foetus, or can also affect the foetus through impaired placental function.

Common livestock production practices such as handling, restraint and transportation can be stressful for cows, and may have implications for their progeny. For example, exposing pregnant cows to repeated transport during gestation increased the stress reactivity of their offspring.[7] Poor-quality animal handling facilities, or poor stockhandler behaviour, may also increase the stress experienced by cows, either during their daily life or for particular handling

events (such as hoof trimming).
For sheep, the maternal gestation challenge which has been most studied is winter shearing.[6,8] Studies consistently show that shearing the ewe during pregnancy increases lamb birth weight. Exposure of ewes to various other forms of stress during pregnancy has produced more variable outcomes.[6] Yet various stress treatments applied to gestating ewes have caused changes in physiological and behavioural parameters: for instance, rough handling of ewes by humans[9] during late pregnancy caused lambs to be more fearful. Increased fear levels in stock is a welfare problem, but may also impair productivity through reduced growth and increased disease susceptibility.

Disease

Debilitating ill health during pregnancy can have a negative effect on the offspring after birth. The effects of ill health in the dam may be mediated by a number of interacting mechanisms. For example, ill health is stressful for the mother, which may perturb normal foetal development, with rodent studies showing that stimulation of the maternal immune system can cause variation in offspring biology. Added to this, the dam may not feed properly, losing body condition, which could cause additional problems for her developing offspring. Furthermore, experiences of pain or sickness associated with disease may also act as a prenatal stressor. Fisher et al[10] exposed ewes to endotoxins during pregnancy (mimicking a bacterial infection); a single maternal exposure to endotoxin during pregnancy caused lambs to show an increase in physiological stress response at 18 months of age. Moreover, also in sheep, Wassink et al[11] found that footrot treatment during gestation caused an improvement in flock financial performance through better lamb survival and growth.
Studies in cattle have also revealed how maternal disease may have additional hidden consequences for progeny. An observational study of Swedish dairy farms found decreased calf size at birth if the dam had clinical mastitis during the 49-day period prior to calving.[12] Calves born to cows that had a disease from conception to 50 days before calving had a higher risk of developing respiratory disease. Moreover, calves whose mothers experienced disease had a lower growth rate. Similarly, Lents et al[13] reported that dry cow treatment of beef cows with intramammary antibiotics improved calf growth during the subsequent lactation, while Loyacano et al[14] found that failure to treat dams for nematodes or liver fluke during gestation resulted in decreased offspring birth and weaning weights.

Nutrition

The mother provides all the resources that a foetal animal requires to grow and develop properly. Maternal nutrition is important, with protein and energy supplies affecting offspring quality. Micronutrient and vitamin levels in feed are also important for offspring development. Even when receiving an otherwise adequate diet, small deficiencies of key nutrients could alter brain development and leave progeny permanently impaired.
An understanding of the importance of ewe nutrition, particularly in late gestation, has been around for some time now. In ewes, general under-nutrition in the last third of pregnancy reduces lamb birth weight, increases lamb mortality, impairs ewe maternal behaviour and ewe-lamb bonding, and can reduce lamb vigour and growth to weaning.[6] Beyond the overall plane of nutrition, provision of specific nutrients in maternal diets is also important in dictating postnatal lamb health and welfare. Deficiencies in cobalt and selenium, for instance, can impair lamb growth, vigour and survival.[6] Similarly, in cattle, restricting the protein and/or energy intake of cows during gestation has significant effects on offspring immunity, morbidity, mortality, stress response, metabolism, birth weight and growth.[5]

Environment

Studies have examined the effects of environmental conditions on offspring birth weight and other parameters. Calves from dams exposed to winter weather were lighter than those born to cows maintained in a thermo-neutral environment.[15] Alternatively, heat stress can adversely affect offspring. Tao and Dahl[16] reviewed studies that have applied heat stress to dairy cattle during gestation; in seven of eight studies calf birth weight was significantly reduced. Effects on birth weight have implications for welfare: low birth weight is associated with increased neonatal morbidity and mortality rates, and can impair postnatal growth, performance and carcass traits. Prenatal effects of the maternal environment are not restricted to birth weight, however. Calves born to dry cows exposed to heat stress had a reduced efficiency of transfer of IgG from colostrum to their circulation, and an impaired T-lymphocyte immune response[17] compared to progeny whose mothers had access to cooling (sprinklers and fans).

OTHER POSSIBLE RISKS TO PRENATAL DEVELOPMENT

A recent SRUC study has identified key factors that could negatively affect prenatal development in farm animals. The results could help farmers review their management of breeding animals and provide evidence-based advice on enhancing the health, welfare and productivity of their stock. The highest risks for prenatal development of beef cattle were maternal stress at weaning and restricted access to feed after weaning, viral disease, competition for feed, and social mixing. Excessive loss of body condition during pregnancy could also have a negative impact on calf development, and subsequent performance.
Sources of stress for housed ewes might include poor handling from farm staff and/or dogs, or poor-quality housing conditions. More generally, poor winter weather, viral and bacterial disease, under-nutrition, lameness, and parasite infections were all identified as possible problems for ewes that could affect lamb development.
Social stress during pregnancy was identified as an issue for both cattle and sheep. Social stressors can be a potent source of maternal stress in other farmed species.[3] Cows or ewes may experience social stress through high stocking density, or by being kept in groups of inappropriate size or composition, or being subjected to regular or intermittent

mixing with unfamiliar individuals. Feeding set-ups that increase competition and aggression may also cause social stress. Such stress can impair the performance of mothers and have negative consequences for the progeny.

WHAT SHOULD YOU LOOK OUT FOR?

Common negative outcomes of a maternal problem during pregnancy are: reduced birth weights and low offspring viability (perhaps causing more deaths after birth); reduced growth rate; impaired immune function (increasing disease risk); increased stress reactivity; and altered behaviour patterns (such as animals being more fearful or flighty). It is important to remember that negative effects of maternal stress or poor nutrition are not just seen at birth or during early life. Research in humans and laboratory animals has shown that variation in the prenatal environment can cause changes which will stay with the offspring throughout their life. In a farming context, this means that particular attention should be paid to the selection of replacement stock, as some individuals may show permanent impairments to performance and their reproductive capacity, even when their genetic background is strong. It also shines a spotlight on the importance of the farm environment. For example, dairy farms often invest considerably in genetic improvement of the herd. However, poor management of pregnant/dry cows could adversely affect offspring phenotype, limiting the capacity to fulfil genetic potential.

WHAT TO DO?

The prenatal period is important in defining how individuals respond to their environment throughout life. Research in farm animal species has demonstrated the important role that variation in maternal state can have on progeny health, welfare and production. In particular, prenatal stress or poor maternal nutrition can affect how well offspring cope with their social, physical and infectious environment during later life. Studies show that maternal health status and other experiences of stress in pregnant cattle and sheep can affect their progeny. Such effects may be an important and overlooked source of variation in calf or lamb outcomes under commercial conditions. Farmers and their vets can use this information to review farm management practices. Given that this is an emerging research area, there are many unanswered questions and much of the advice in this article is of a general nature in terms of the importance of good pregnancy management. Further work is required to identify which possible causes of prenatal stress matter under commercial conditions, and how farmers could adapt their management to improve performance. Paying closer attention to the management of pregnant animals may allow farmers to achieve higher standards of health, welfare and production efficiency in the next generation of stock. Not all possible prenatal hazards can be controlled under farm conditions; for example, weather conditions or feed supplies may be unpredictable. Nonetheless, farmers would be well advised to review their management practices for pregnant animals, as this might reveal some areas where changes could be made to help boost progeny performance. Relevant questions to ask include:

- Could the social environment be improved? Could management be changed to limit mixing of unfamiliar animals? Could housing be changed to limit how much animals fight after being mixed into new social groups, or have to compete for food? Are animals provided with an appropriate space allowance, and do all have a dry place to lie down?
- Is the farm's health plan reviewed regularly, and successfully implemented? Do treatment strategies include adequate pain management, where appropriate?
- Is body condition scoring of stock used to monitor feeding strategy? How successfully do farmers meet body condition targets at different stages of the production cycle? Do farmers know what they are feeding (are forages analysed?) and is nutrition being discussed regularly with the vet or a nutritionist?
- Could handling facilities or practices be improved to reduce stress in stock?

CONCLUSIONS

The management of livestock during pregnancy is important, not only to ensure high levels of health and welfare in breeding stock, but also to maximise outcomes for their progeny. Prenatal effects may cost the industry in terms of loss of productivity (eg. reduced growth rates, poorer fertility or increased mortality), increased veterinary and medicine costs where health is affected, and increased labour costs if animals are more stress-reactive and harder to handle safely. Avoiding possible negative impacts on breeding females, and their offspring, could provide an additional route for farmers to improve production efficiency. Veterinarians can support this effort by increasing awareness of this issue and supporting farmers' self-appraisal of current gestation management practices, and identifying possible changes.

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REFERENCES

1. Mathers JC, McKay JA. Epigenetcs – potential contribution to fetal programming. Advances in Experimental and Medical Biology 2009; 646: 119-123
2. Greenwood PL, Bell AW, Vercoe PE, Viljoen GJ (eds). Managing the prenatal environment to enhance livestock productivity. Springer: London, 2010
3. Rutherford KMD, Donald RD, Arnott G et al. Farm animal welfare: assessing risks attributable to the prenatal environment. Animal Welfare 2012; 21: 419-429
4. Merlot E, Quesnel H, Prunier A. Prenatal stress, immunity and neonatal health in farm animal species. Animal 2013; 7: 2016-2025
5. Arnott G, Roberts D, Rooke JA et al. Board invited review: The importance of the gestation period for welfare of calves: maternal stressors and difficult births. Journal of Animal Science 2012; 90: 5021-

5034
6. Rooke JA, Arnott G, Dwyer CM, Rutherford KMD. The importance of the gestation period for welfare of lambs: maternal stressors and lamb vigour and well-being. The Journal of Agricultural Research 2014
7. Lay DC, Randel RD, Friend TH et al. Effects of prenatal stress on suckling calves. Journal of Animal Science 1997; 75: 3143-3151
8. Kenyon PR, Moriss ST, Revell DK, McCutcheon SN. Shearing during pregnancy – review of a policy to increase birthweight and survival of lambs in New Zealand pastoral farming systems. New Zealand Veterinary Journal 2003; 51: 200-207
9. Coulon M, Hild S, Schroeer A et al. Gentle vs. aversive handling of pregnant ewes: II. Physiology and behavior of the lambs. Physiology and Behavior 2011; 103: 575-584
10. Fisher RE, Karrow NA, Quinton M et al. Endotoxin exposure during late pregnancy alters ovine offspring febrile and hypothalamic-pituitary-adrenal axis responsiveness later in life. Stress 2010; 13: 335-343
11. Wassink GJ, King EM, Grogono-Thomas R et al. A within farm clinical trial to compare two treatment (parenteral antibacterials and hoof trimming) for sheep lame with footrot. Preventive Veterinary Medicine 2010; 96: 93-103
12. Lundborg GK, Oltenacu PA, Maizon DO et al. Dam-related effects on heart girth at birth, morbidity and growth rate from birth to 90 days of age in Swedish dairy calves. Preventive Veterinary Medicine 2003; 60: 175-190
13. Lents CA, Wettemann RP, Paape MJ et al. Effects of dry cow treatment of beef cows on pathogenic organisms, milk somatic cell counts, and calf growth during the subsequent lactation. Journal of Animal Science 2008; 86: 748-755
14. Loyacano AF, Williams JC, Gurie J, DeRosa AA. Effect of gastrointestinal nematode and liver fluke infections on weight gain and reproductive performance of beef heifers. Veterinary Parasitology 2002; 107: 227-234
15. Andreoli KM, Minton JE, Spire MF, Schalles RR. Influence of prepartum exposure of beef heifers to winter weather on concentrations of plasma energy-yielding substrates, serum hormones and birth weight of calves. Theriogenology 1988; 29: 631-642
16. Tao S, Dahl GE. Invited review: heat stress effects during late gestation on dry cows and their calves. Journal of Dairy Science 2013; 96: 4079-4093
17. Tao S, Monteiro APA, Thompson IM et al. Effect of late-gestation maternal heat stress on growth and immune function of dairy calves. Journal of Dairy Science 2012; 95: 7128-7136