BURLEIGH DODDS SERIES IN AGRICULTURAL SCIENCE

Understanding the behaviour and improving the welfare of pigs

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SCIENCE PUBLISHING

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Introduction

The welfare of farmed animals such as pigs is an increasing concern for consumers and regulatory agencies. This collection summarises and reviews the wealth of recent research on understanding pig behaviour and improving their welfare. Part 1 of the book provides an initial review of genetic and developmental factors influencing pig behaviour. The book then moves on to assess ways of optimising pig welfare at differing production stages in Part 2. Chapters cover breeding and gestation, farrowing and lactation, weaning, growing and finishing as well as transport, lairage and slaughter. The book then reviews our understanding of the most important current welfare issues, such as pain assessment in relation to piglet management procedures, castration and its alternatives, tail biting and docking, as well as the nature of environmental enrichment. The final part of the book addresses welfare assessment methodologies, including detection of health problems, understanding of emotional responses of pigs, practical use of welfare indicators and advances in technologies for automated monitoring of pig behaviour and welfare.

Part 1 Determinants of behaviour

The first part of the book opens with a review of advances in understanding the genetics of pig behaviour. Chapter 1 begins by discussing the maternal behaviours that are relevant for piglet survival, including savaging, crushing and nursing. It then goes on to address other behaviours that are important for pig production, focusing on feeding behaviour, tail biting and aggressive behaviour between pigs. The chapter also examines the contrast of direct and social genetic effects on growth rate and reproduction traits, with an analysis of the characteristics of pigs with high social breeding values for growth rate, and concludes with an overview of potential future research trends in the subject.

Chapter 2 focuses on developmental influences on pig behaviour. It begins by discussing prenatal effects on the development of pig behaviour, considering aspects of the pre-conception and post-conception environments. These include housing conditions and nutrition of the mother, heat stress, infectious diseases and sow management. The chapter moves on to discuss environmental effects during the early postnatal period on the development of behaviour, considering both the physical and social environment as well as human interactions.

Part 2 Management of behaviour in different production stages

Part 2 begins with Chapter 3 which considers factors affecting the welfare of pigs during breeding and gestation, covering gilts, sows and breeding boars. Particular focus is given to the factors influencing aggression and lameness which constitute important welfare issues. The chapter reviews the physical, social and nutritional aspects of various housing systems in which weaned and pregnant gilts and sows are housed and provides recommendations on optimising their welfare in commercial conditions.

Chapter 4 examines sow and piglet welfare during farrowing and lactation. Optimising welfare in this stage involves resolving the concerns regarding continued use of close confinement systems, such as the farrowing crate for the sows, and the lack of provision of environmental enrichment to provide for behavioural needs. For piglets the main welfare and health issues surround high levels of piglet mortality and its pre-disposing risk factors. The chapter concentrates on managerial and environmental interventions that attempt to reconcile the behavioural and physiological needs of both the sow and piglets to optimise their welfare whilst appreciating stockperson needs in how best to implement them. This is illustrated by a case study of the development of a novel free farrowing system.

The subject of Chapter 5 is optimising pig welfare at the weaning and nursery stage. The welfare of pigs at the nursery stage is an area of special concern because of the many factors that have the potential to seriously decrease piglet wellbeing at this time. Major challenges include separation from the mother, often at a very young weaning age in modern pig farming, the new environment they are introduced to, hitherto unknown sources of feed and water, and regrouping with non-litter mates. In this chapter, the most important sources of environmental, nutritional and social stress are explained, and strategies to increase weaner welfare are summarised. These include innovative housing systems providing greater environmental complexity and the importance of trained and skilled stockpeople.

Chapter 6 discusses optimising pig welfare at the growing and finishing stage. It begins by defining the different behavioural issues that can impact welfare during this period, such as tail biting, belly nosing and aggression. The chapter then addresses how these behavioural issues can be affected in the wide range of different production systems, which encompass differences in many aspects of the physical and social environment. It concludes by highlighting the importance of human inputs in the system to improve pig welfare and also reviews potential research trends for the future as herd size increases.

The final chapter of Part 2, Chapter 7, considers pig welfare during transport, lairage and slaughter. Preslaughter practices, such as transport and handling, as well as methods of slaughter, can significantly affect pig welfare, carcass and meat quality. Chapter 7 provides an overview of research findings on the effects of transport, handling and slaughter practices on behavioural and physiological responses of pigs, and the consequences for carcass and meat quality. It provides recommendations about best practice, illustrating how economic losses are limited when the design of trucks is improved, the recommended transport, handling, stunning and slaughter practices are used and environmental conditions are properly controlled.

Part 3 Current welfare issues

The first chapter in Part 3 analyses evidence of pain in piglets subjected to widely-used invasive management procedures. Chapter 8 begins by considering the why and how of invasive management procedures in piglets, before reviewing pain mechanisms and assessment. It examines the reactions in pigs submitted to tissue-damaging procedures, breaking these down into three groups: neural, hormonal/metabolic and behavioural consequences. The chapter focuses on the detailed evidence for acute and longer-term pain associated with the practices of surgical castration, tail docking and tooth resection that are currently contentious in the pig industry.

Chapter 9 considers alternatives to castration of pigs. Piglets have been traditionally been surgically castrated to avoid boar taint risk as well as aggression and mounting behaviour. However, castration without anaesthesia and analgesia induces pain and has become a controversial practice on welfare grounds. Alternatives to surgical pig castration that guarantee acceptable meat quality and welfare are required if castration is to be abandoned. The chapter deals with the main alternatives which are commercially available at present: raising entire males or immunocastration. It summarises the effects on welfare and meat quality, as well as dealing with other aspects such as societal and farmers' acceptance of these alternatives. The nutritional, management and breeding strategies, which can be implemented to enhance welfare and meat quality when raising entire males are described. The methodologies being used, or under development, to assess boar taint risk at the slaughter line are summarised.

The next chapter addresses understanding and preventing tail biting in pigs. As Chapter 10 shows, tail biting is a behavioural problem of pigs associated with detrimental welfare for both the perpetrator and victim. It is seen to some extent on most farms worldwide and causes considerable economic loss, leading to widespread adoption of tail docking for risk reduction. After highlighting the prevalence and economic importance of the problem of tail biting, the chapter then reviews the current understanding of the mechanisms underlying tail biting and the key risk factors. Ethical considerations associated with tail biting are also discussed. This is followed by an examination of strategies to manage pigs without tail biting, highlighting intervention measures for when a tail biting outbreak occurs, before concluding with an overview of potential future research trends.

Part 3 concludes with a discussion on the role of environmental enrichment in optimising pig behaviour and welfare. Modern pig housing environments provide animals with essential resources but, from an animal's point of view, they are often quite barren and deprive them of the opportunity to make full use of their natural behavioural repertoire. The lack of stimulation resulting from such environments compromises animal welfare. This issue can be addressed by providing enrichment across all aspects of an animal's environment that facilitate engagement in species-specific behaviours. Chapter 11 provides an overview of different types of enrichment, ranging from artificial point-source objects to social and cognitive enrichment. It discusses the existing body of evidence for welfare-enhancing effects of different enrichment provision, focussing on whether potential enrichment promotes natural behaviours, reduces abnormal behaviours, and whether effects are sustainable over the long-term. The chapter concludes with a comparative evaluation of enrichment from an animal welfare perspective, highlighting the potential of social and cognitive enrichment.

Part 4 Assessment of welfare states

The final part of the book starts with Chapter 12 which provides an overview of the physiological and behavioural responses common to pigs experiencing ill-health and describes animal-based outcomes directly impacted during an acute or chronic disease state. In addition, strategies to prevent and monitor disease at the herd level are discussed. Lastly, the chapter explores strategies for managing sick pigs as the critical next step when prevention is unsuccessful.

Chapter 13 reviews the assessment of emotions in pigs, specifically focusing on determining negative and positive mental states. It begins by examining behavioural indicators of emotion such as behavioural tests, qualitative behaviour assessment, vocalisations, play behaviour, defence cascade responses and facial expression and body posture. The chapter also assesses cognitive indicators of emotion in pigs such as judgement bias. This is followed by a discussion of neurophysiological indicators of emotion in pigs, encompassing the physiology of both negative and positive emotions. The chapter concludes by considering future trends in this rapidly evolving field.

The subject of Chapter 14 is the welfare assessment of pigs under farm conditions. The chapter begins by providing an overview of approaches to welfare comparisons and frameworks for animal welfare evaluation. It examines the measures employed in animal welfare assessments, dividing them into two groups: measures of input and measures of outcome. The required properties for welfare measures are emphasised in terms of their validity, repeatability and feasibility. Sections on practical welfare indicators relating to the dimensions of good feeding, good housing, good health and appropriate behaviour are then provided, with consideration of the welfare relevance, reproducibility and practicality of individual measures. Finally, indicators of positive welfare and the practical use of iceberg indicators are considered.

The final chapter of the book focuses on advances in technologies for automated monitoring of pig welfare. The pig sector has undergone a major transformation characterized by intensification, geographic concentration, vertical integration and increasing scales of production, which creates new challenges for animal welfare. Sensor technology offers multiple advantages for monitoring welfare in pigs under these conditions. Chapter 15 reviews recent advances in technologies for monitoring key indicators of pig welfare by considering the domains of good feeding, good housing, good health, and appropriate behaviour. As an example, it presents how an accelerometer-based nest-building detection system can contribute to improvement of pig welfare. Finally, future trends in development of monitoring technology including solution-oriented research, integration of key welfare indicators and wider adoption of image analysis are highlighted, with further possibilities for more validation studies on open datasets and advances in robotics.

Overall, the book seeks to provide practical and up-to-date information on how the welfare of farmed pigs at all production stages can be assessed and improved, and where further scientific study towards this objective can be progressed.

Part 1

Determinants of behaviour

Chapter 1

Advances in understanding the genetics of pig behaviour

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1 Introduction

The pig is an explorative animal with a large ability to adapt to different environments. Its large litters (no other animal as large as the pig gives birth to so many young) demand a maternal behaviour that is very different from other livestock. A successful maternal behaviour is crucial for the efficiency of piglet production. Pigs are generally kept in groups and their social behaviour has an impact on animal welfare in positive and negative ways. Social interactions influence growth of young pigs and reproduction of sows. Common pig production routines, like tail docking and keeping sows in crates, are strongly connected to pigs' behaviour and these routines are highly problematic from an animal welfare perspective.

Apart from the joy of research in general and animal science in special, there are several reasons to study and learn more about the genetics of pig behaviour:

- Pig behaviours influence animal welfare;
- Pig behaviours influence work satisfaction of care takers;

http://dx.doi.org/10.19103/AS.2020.0081.01

- Pig behaviours influence production profit; and
- Some pig behaviours (e.g. tail biting) or their interventions (e.g. tail docking) influence consumers' acceptance of pig production.

There seems to be a genetic variation in most behavioural traits that have been studied in pigs, and many examples will be given in this chapter. The chapter starts with a review of the genetic background of various behavioural traits, with references to molecular genetic studies as well as quantitative genetic studies. The group model with its direct and social genetic effects is described and consequences of selection for social breeding values are presented. Some future perspectives on methods and breeding goals, and the room for selection for changed behaviours, are discussed.

2 Maternal behaviour

One way to express the goal for piglet production is 'a high number of healthy piglets with a low variation around the target weaning weight'. The level of this target weight depends on management system and factors like weaning age, nutrition value of piglet feed and use of nurse sows. Although several genetic studies of maternal behaviour are found in the literature, maternal behaviour traits are usually not included as selection traits in pig breeding programs. Instead, the selection traits are piglet survival and piglet growth, traits more directly reflecting the goal and also more easy to record than behavioural traits. Nevertheless, we can achieve a better understanding of opportunities and limitations of piglet production from genetic studies of nest building, savaging, crushing and nursing.

Sows obviously need straw or other construction material to build a nest, but an increased activity with a typical behavioural pattern before farrowing can be seen also in sows not provided any building material. Sows actively engaged in nest building before farrowing calms down when the nest is built and thereafter move less during farrowing, thus reducing the risk of crushing new-born piglets and increasing the possibility for all piglets to achieve colostrum (Ocepek et al., 2017). Accordingly, Ocepek and Andersen (2018) found that nest building activity is associated with a lower proportion of starved piglets and overlaid piglets. Nest building is related to oxytocin and preliminary results of Rydhmer and Jonas (2016) show an association between the oxytocin synthesis gene and nest building behaviour. An association between the oxytocin gene and stillborn piglets, but not between the gene and survival of live born piglets, was found in the same project (Jonas and Rydhmer, 2018).

Savaging of new-born piglets (infanticide) is associated with low plasma oxytocin levels at farrowing (Gilbert, 2001). Around 5–11% of primiparous sows savage their piglets (Chen et al., 2008; Gäde et al., 2008) and the repeatability is around 0.4 (Gäde et al., 2008). An ongoing threshold selection against savaging at herd level seems plausible; farmers avoid selecting gilts for replacement born by savaging sows. Old studies reported high heritability estimates for savaging, but Gäde et al. (2008) estimated the heritability at 0.02. Several QTLs for savaging have been found (Chen et al., 2009b) and for some of them genes involved in anxiety are located in homolog chromosome regions in humans (Daigle, 2018). This is an example of studies where pigs are used as model for humans in studies of psychiatric disorders (Daigle, 2018).

Bauer (2019) recently presented a doctoral thesis on genetic components of savaging. He found associations between savaging and genes involved in the regulation of dopamine, vasopressin and oxytocin levels, and also genes involved with mitochondria and energy production "suggesting that alteration of the genome impacting on the way the cells produce energy could have a behavioural impact" (Bauer, 2019). Savaging sows show a more active behaviour and they are more responsive to piglets (Jarvis et al., 2004; Chen et al., 2008). Outdoor raised sows selected for the maternal effect on piglet survival had a higher frequency of savaging (compared to a control line) when they farrowed indoors (Baxter et al., 2011). This could be interpreted as savaging being the outcome of a low ability to cope with a confined environment under high pressure. Assuming that the pressure on the sow increases with increasing litter size, this is however contradicted by a negative genetic correlation between litter size (total born) and savaging (r_g = -0.34) estimated by Gäde et al. (2008).

Farmers' judgement of sow behaviour was studied by Stratz et al., 2016. A good farrowing behaviour included remaining in lying position during farrowing, not snapping or biting piglets and having a rapid farrowing. The heritability for this farrowing behaviour was estimated at 0.07. Farrowing behaviour was correlated to piglet weight at weaning (r_g = 0.52) and to piglet vitality (r_g = 0.32). It has previously been reported that unsavaged piglets are heavier at birth than savaged piglets (Grandinson et al., 2002) and it can be hypothesised that the genotype of the piglet influences the risk of being savaged. This would motivate the use of a genetic model including two genetic effects - a direct (piglet) and a maternal (sow) - in the model when analysing savaging. No such genetic analysis has been found in the literature.

When nucleus farmers recorded how often the sow showed careless behaviour among the piglets, the heritability of carefulness was estimated at 0.1–0.2 in two different breeds (Vangen et al., 2005). Hellbrügge et al. (2007, 2008) studied maternal behaviour on thousand German Landrace sows in a nucleus herd. The main piglet mortality cause was crushing by the sow. The sow's reaction to a recorded distress call was heritable (h^2 = 0.13). A stronger reaction was genetically correlated with higher piglet survival, but the correlation was low and not significant. The sow's reaction to an unknown sound (music) was also heritable and showed a higher correlation with piglet survival (r_g = 0.26, SE ±0.18) and with number of piglets crushed during the first days (r_g = -0.28, SE ±0.19). The sow's reaction when separated from the piglets three weeks after farrowing had a low heritability but was highly correlated with the reaction to an unknown sound (r_g = 0.89, SE ±0.35). The reaction when separated from the piglets was also correlated with piglet survival (r_g = 0.44, SE± 0.31). Standard errors are given for these estimates to illustrate that although behavioural records from thousands of sows takes a lot of time to collect, it is hardly enough to estimate genetic parameters for these complex traits.

According to Stratz et al. (2016), a good nursing behaviour includes not lying on the udder, feeding piglets until satiation and having a well-developed udder with functional teats. The heritability for assessed nursing behaviour was estimated at 0.10 and the nursing behaviour was genetically correlated with piglet weight at weaning (r_g = 0.86).

Selection for increased litter sizes increase the demands on the sow; it should avoid crushing any piglet and provide enough milk to all piglets. For animal welfare reasons we want to get rid of the farrowing crates. Genetic predisposition for larger litters in combination with loose-housing are motives for selection for maternal abilities. As described above, there are several heritable maternal behaviour-traits, but recording behaviour is time-consuming and thus expensive. Selection for high piglet survival and piglet growth rate, using both direct (piglet) and maternal (sow) breeding values, may be a better alternative than introducing behavioural tests in the breeding program of dam lines.

3 Feeding behaviour and the consequences of selection for feed efficiency

Being an omnivore, the pig is an explorative animal with a high capacity to adapt to a wide range of feeds and environments (discussed by Brunberg et al., 2016). Pigs show a large variation in feeding behaviour as a consequence of the management system, such as ad libitum feeding in feeders or restricted group feeding in troughs once per day, and there is also a genetic variation (Rohrer et al., 2013). Automatic feeders are often used to record individual feed intake of growing pigs. This equipment also provides large amounts of feeding behaviour data that until now have not been of much use for selection. Kavlak and Uimari (2019) analysed data from more than 3000 pigs fed with electronic feeders at a test station. The feeding behaviour traits were number of visits per day, time spent in feeding per day, time spent feeding per visit and feed intake per visit. Heritabilities of these traits were estimated at 0.17–0.47, but none of them were genetically correlated to any production trait. The authors thus concluded that there is no reason to include feeding behaviour in the genetic evaluation.

Several quantitative trait loci (QTL) for feeding behaviour have been found. Reyer et al. (2017) found QTLs for daily feeder occupation time and number of daily feeder visits. Some candidate genes were identified; one of them (MC4R at chromosome 1) with effect on energy homeostasis influencing feed intake. Although both daily feed intake and nutrient needs change with age, strong genetic correlations have been found between feeding behaviour traits recorded at different ages (Kavlak and Uimari, 2019). In a genome wide association study, the QTLs identified for feeding behaviour recorded during two age periods on growing pigs were, however, not the same (Guo et al., 2015). When 338 Duroc boars with records on daily feed intake, number and duration of visits per day and feed intake per visit were genotyped; six SNPs associated with feeding behaviour were located in genomic regions where QTLs for feeding behaviour have been found earlier (Ding et al., 2017). Five candidate genes with biochemical and physiological roles relevant for feeding behaviour were recognized close to these markers. Several of the candidate genes were involved in the development of the hypothalamus; on organ important for the regulation of hunger. Future functional genomic studies may reveal the genetic regulation of feeding behaviour and feed intake.

The main motive for genetic studies of feeding behaviours seems to be their relation to feed efficiency; an important goal trait in most pig breeding programs. According to a French selection experiment lasting for nine generations, selection for more efficient pigs (low residual feed intake (RFI)) results in pigs with lower physical activity during both day and night, as compared to pigs selected for high RFI (Meunier-Salaün et al., 2014). The low RFI line also seemed to be less affected by tail biting, which may be a consequence of the lower activity level. When comparing the high and low RFI lines, no behavioural difference was found in a novel object test (Meunier-Salaün et al., 2014). Colpoys et al. (2014) also compared the behaviour of pigs selected for high or low RFI and concluded that low RFI pigs were more calm in the home pen as well as in novel object and human approach tests, thus less reactive to novelty.

Changes (or lack of changes) in feeding behaviour can also be used as an indicator of robustness, for example, the ability to cope with heat (Cross et al., 2018). Furthermore, feeding behaviour can be used as an indicator of behavioural traits difficult to record, such as risk of becoming a victim of tail biting (Wallenbeck and Keeling, 2013). Rohrer et al. (2013) found that pigs with a reactive coping style, recorded in a backtest, tended to eat fewer but longer meals per day. Data from feeding stations are 'for free', and with increased knowledge in bioinformatics, the use of the large amounts of data from feeding stations will maybe increase in future herd monitoring and breeding programs.

Published by Burleigh Dodds Science Publishing Limited, 2021.

4 Tail biting

Tail biting is a multi-factorial problem, with both environmental and genetic causes. Breuer et al. (2005) found a positive genetic correlation between tail biting and lean tissue growth rate and a negative genetic correlation between tail biting and backfat thickness. Brunberg et al. (2013b) reported a genetic association between tail biting and fatness; biters and victims had a different expression of the gene PDK4 compared to pigs not involved in tail biting. The PDK4 gene has an impact on fat content in pigs (Lan et al., 2009). Selection for lean pigs may thus increase the risk of tail biting. Using metabolites from pigs as phenotypes in a genome-wide association study, Dervishi et al. (2019) showed that pigs predisposed to be bitten may have an impaired lipolysis process.

There are several challenges related to genetic analyses of tail biting and - although highly relevant for pig welfare - genetic studies of tail biting are scarce. If a pig becomes a tail biter or a victim of tail biting depends both on the pig itself and on its group mates (discussed by Brunberg et al., 2016). Data from several thousand pigs may be necessary to get accurate genetic estimates. Tail biting behaviours are often recorded as binary traits, which increases the need for large data sets even more. Bitten tails can be recorded by repeated visual monitoring, but the frequency is often low which puts high demands on the statistical model used for genetic analysis. To identify biting pigs by direct observations or video recording is very time-consuming. Furthermore, the expression of tail biting differs over time as a pig can change from being a non-biter to being a biter (Ursinus et al., 2014).

Breuer et al. (2005) estimated the heritability of performing tail biting in Landrace pigs at 0.05. More recently, Canario and Flatres-Grall (2018) estimated the heritability of being a victim at 0.06 in Tai Zumu pigs. The genetic correlation between being a biter and being a victim is not known. Brunberg et al. (2013a) found some SNPs that had the same associations to both being a biter and being a victim, but these SNPs were not associated with being a neutral pig. Neutral pigs are pigs neither being biters nor victims in pens where tail biting is ongoing. Wilson et al. (2012) found that some SNPs are associated with being neutral whereas other SNPs are associated with being a biter or a victim. A study on gene expression in the brain also suggested that biters and victims have more in common than neutral pigs (Brunberg et al., 2013b).

Neutral pigs (in pens with tail biting) performed less pig-directed behaviours, such as belly nosing and tail in mouth, compared to pigs in pens without tail biting (Brunberg et al., 2013a), and 100 transcripts were differently expressed between those two types of pigs. Several of the transcripts were also differently expressed in neutral pigs as compared to both biters and victims (Brunberg et al., 2013b). This suggests that neutral pigs' gene expression is not a consequence of not being involved in tail biting, but rather a cause for

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