Animal welfare research – progress to date and future prospects

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Abstract

The welfare status of an animal is dependent on its ability to cope and exist in harmony with its environment, such that good physical and psychological health is maintained. Improving animal welfare is an increasingly important aspect of livestock production systems due, in a large extent, to increased consumer concerns about animal production practices. Animal welfare is an integrated part of quality assurance programmes for sustainable animal production, considering that welfare, health, management, economy, consumer acceptance and environmental impact are interdependent. The major welfare concerns in the livestock industry in recent years relate to the rearing and management of dairy calves, the welfare of the dairy cow, effect of husbandry management procedures on the welfare of beef cattle, rearing of sows in gestation and farrowing crates, and the broiler (meat) chicken sector. The paper will focus on scientific research underpinning these welfare concerns, with a particular focus on research conducted on the island of Ireland.

Keywords

Animal welfare • beef • dairy • pig • poultry • welfare assessment

Introduction

In Ireland, the proportion of respondents to an European Union (EU) survey who believe the welfare of farmed animals should be better protected than it is now increased by 22% from 2006 to 80% in 2016 (European Commission, 2016a, 2016b, 2016c, 2016d). Indeed, it is now widely accepted that as sentient beings with a capacity to feel pain and experience emotions, our farmed animals deserve to experience a life that is worth living (Mellor, 2016). During the last century, dairy production systems expanded and intensified giving rise to growing public concerns surrounding the welfare of dairy animals (Barkema *et al.*, 2015; Wolf *et al.*, 2016; Mee & Boyle, 2020). There is growing evidence that such expansion is associated with challenges to the welfare of dairy animals on farm (Osawe *et al.*, 2021). Thus, the issue of dairy calf and cow welfare is becoming increasingly present in research agendas in Ireland, and internationally. Beef cattle production within the EU, and in Ireland in particular, is less intensive than areas of animal agriculture associated with the greatest welfare concerns such as pig and poultry production. Nonetheless, there are aspects of beef cattle production such

as the castration, weaning, transport and housing of beef cattle which have the potential to cause stress, pain and injury if not managed correctly. In Ireland, commercial pig farming is a small, intensive industry, with nearly all pigs bred and reared indoors on slatted or semi-slatted systems. According to the 2020 pig census, 284 pig farms contain 96% of the 1.7 million pigs in the country (DAFM, 2020). Indeed the average size of commercial herds is among the largest in Europe. Volatility and high prices of cereals and compound feeds, a relatively low pig price and a high level of farm credit mean that Irish pig farmers are particularly vulnerable to economic pressures. This contributed to the need to achieve economies of scale in Ireland and internationally, and management of pig farms in a way that is as resource and labour efficient as the law allows. The broiler (meat) chicken sector is undergoing a period of welfare-driven transformation. Over 100 million broiler chickens are produced per year in Ireland¹, and this sector is

¹<https://www.teagasc.ie/rural-economy/rural-development/diversification/broiler-production/>.

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of major importance globally with over 100 million tonnes of chicken meat produced annually. In fact, the Organisation for Economic Co-operation and Development (OECD) figures for 2020 indicate average global consumption levels (kg/capita) of 14.9 for poultry meat, 10.7 for pork, 6.4 for beef and veal and 1.8 for sheep meat. More broiler chickens are farmed than any other type of animal (FAO, 2019), which suggests that more individuals are impacted by changes to on-farm welfare standards than with any other livestock enterprise.

Animal welfare assessment

Over the last decades, the welfare of farm animals has become increasingly important, both for the general public and for the scientific community. National (e.g. Department of Agriculture, Food and the Marine (DAFM), Animal Health and Welfare Act 2013) and EU regulations (Simonin & Gavinelli, 2019) or international codes of welfare (World Organisation for Animal Health [OIE]) increasingly include provisions that address the welfare management of livestock. Animal welfare is not a new concept and was defined by Brambell since 1965. The original Brambell Five Freedoms were simply expressed around concepts “stand up, lie down, turn around, stretch, flap wings”. Subsequently, the five freedoms were developed into a useful framework to identify welfare components and problems (Botreau *et al.*, 2007, 2009; Velarde & Dalmau, 2012). However, due to the general nature of these ideal states, there were limitations to the use of the five freedoms to describe animal welfare (Botreau *et al.*, 2007).

The Welfare Quality project was the largest European project concerning animal welfare (Blokhuys *et al.*, 2010). It was designed to develop European standards for welfare assessment on farms (Blokhuys *et al.*, 2010). The Welfare Quality project re-examined the original concepts of the “Five Freedoms” and developed and extended them into Welfare Quality Assessment Protocols (Botreau *et al.*, 2007; Blokhuys *et al.*, 2010).

The emotions that animals experience are a key component of animal welfare and the focus on emotions as an element of positive animal welfare is well recognised (Lawrence *et al.*, 2019). Animal-based indicators provide the best means of assessing welfare, as they directly reflect the experience of the animal within its environment (Whay *et al.*, 2003). It is now acknowledged that welfare assessment protocols should also include measurements of the affective state of the animal (i.e. how it feels) and assess its ability to have positive experiences, as it is now accepted that good welfare does not simply mean the avoidance of negative experiences, but must also include positive ones (Yeates & Main, 2008). The five domains model (Beausoleil & Mellor, 2015; Mellor & Beausoleil, 2015; Mellor, 2016) assess animal welfare under the following five criteria:

nutrition, environment, health, behaviour and mental state. The three orientations approach (Fraser *et al.*, 1997; Webster *et al.*, 2015; Mellor, 2016) assess animal welfare under three criteria: biological functioning, affective state (feelings and emotions) and natural living. Affective states are one of the three commonly discussed components of animal welfare (Mendl *et al.*, 2009, 2010; Mendl & Paul, 2020), the remaining two being natural living and physical health (Fraser *et al.*, 1997).

Dairy calf welfare

Young calves are particularly vulnerable to poor health and static morbidity and mortality rates across the dairy industry worldwide suggest this is an area where animal welfare must be improved (Mee, 2020). In Ireland, dairy bull calves or beef breed heifers are most typically sold from the farm pre-weaning and they most commonly leave the dairy farm within the first 2–4 wk of life (>75%; Barry *et al.*, 2020). Dairy breed heifer calves stay on the farm and are reared as replacements for the dairy herd. The optimal rearing of female replacement calves is a fundamental component of the future success of dairy herds (Roche *et al.*, 2015). For example, if replacement heifers are reared with technically proficient practices, which implement high standards of animal welfare, there is lower morbidity and mortality.

Technical proficiency in calf rearing involves a number of areas, pre-weaning nutrition of calves (e.g. colostrum, transition milk and milk [whole milk and milk replacer] feeding as well as concentrate feeding) and management practices (e.g. environmental conditions, weaning procedures) as these can have a pronounced effect on physiological health, welfare, behaviour and mortality of the calves (Miller-Cushon *et al.*, 2013; Webb *et al.*, 2013; Leruste *et al.*, 2014; Sutherland *et al.*, 2014) and can influence their future performance (Soberon *et al.*, 2012; Gelsinger *et al.*, 2016).

To provide protection from infectious diseases in early life, neonatal calves are dependent on the passive transfer of antibodies from colostrum (Godden, 2008). Recent research focused on establishing the quality of colostrum in the Irish national dairy herd (Conneely *et al.*, 2013; Barry *et al.*, 2019). Good-quality colostrum is defined as that which has an immunoglobulin G (IgG) content >50 mg/mL; in general, colostrum from Irish dairy cows is of high quality (>85 mg/mL IgG; Conneely *et al.*, 2013; Barry *et al.*, 2019). However, there is considerable variation both within and between herds indicating the requirement to test colostrum quality before feeding, a practice currently rarely undertaken (Barry *et al.*, 2019). Some of the factors found to affect the quality of colostrum of Irish dairy herds include parity, month of calving, time between calving and colostrum collection and weight of colostrum (kg) (Conneely *et al.*, 2013).

Due to the compactness of the calving season, over 90% of farmers report storing colostrum for use at a later time; almost one-quarter of farmers are storing it at room temperature (Barry *et al.*, 2019), a practice which leads to exponential growth of bacteria which can inhibit IgG absorption by the calf (Cummins *et al.*, 2017). This can have negative consequences on calf health.

As there is considerable variation in cow type within the Irish dairy herd (Coffey *et al.*, 2016; O'Sullivan *et al.*, 2020) and a resultant difference in calf birth weight, it necessitated the examination of colostrum feeding strategies based on calf birth weight. The results showed that passive transfer was maximised when calves were fed 8.5% of their birth bodyweight in high-quality (>50 mg/mL IgG) colostrum, when compared to either 7% or 10% of their birth bodyweight (Conneely *et al.*, 2014a, 2014b). This research also showed the benefits of improved calf health when transition milk is fed for at least four feeds after the initial colostrum feed (Conneely *et al.*, 2014a).

Following colostrum and transition milk feeding and in order for calves to grow at an appropriate rate, they need adequate nutrition (milk feeding volumes); traditionally, Irish dairy farmers offered 4 L of milk to each calf daily. This volume is insufficient, particularly in early life when the calf's rumen is not fully developed and cannot adequately utilise nutrients from concentrate (Lorenz, 2021). Feeding calves 15% of their birth bodyweight in high-quality milk increases weight gain during the pre-weaning period and ensures that the nutritional requirements of the calf are satisfied (Conneely *et al.*, 2014b), while also ensuring they express normal behaviour (Sinnott *et al.*, 2021).

Clearly optimal practices for colostrum feeding and artificial rearing are required for all calves in the dairy herd. However, there is ample research to indicate deficiencies in the nutritional and housing management of male dairy calves worldwide (Boyle & Mee, 2021). This is because of their lower economic value (Marquou *et al.*, 2019), exacerbated in recent years by breeding practices (Kelly *et al.*, 2020). Herd expansion is also associated with an increased likelihood of shipping calves surplus to the needs of the dairy herd (mostly males) abroad and of early slaughter (Osawe *et al.*, 2021) which are contentious practices (Haskell, 2020). Recent research outlines ways to protect the welfare of such animals including incorporation of animal-based outcomes relevant to health and welfare at calf slaughter, greater use of sexed semen and more focused breeding plans as well as expanding calf housing facilities (Balzani *et al.*, 2021; Mee & Boyle, 2021; Osawe *et al.*, 2021). However, future research is essential to investigate the calf transport conditions. This includes the appropriate movement age to ensure their health is not compromised, feeding strategies immediately prior to

transport, mixing of herds both during and after transport, and management systems at the destination farm.

Any calf management system, regardless of whether for replacement heifer rearing, beef production or a combination of both, should ensure calf health and welfare are not compromised. Welfare assessment protocols can be a key tool in protecting the welfare of calves on dairy farms. To this end, a reliable, feasible and time-efficient welfare assessment protocol, for male and female dairy calves, during milk feeding and weaning was developed (Barry *et al.*, 2019). Although there are a number of welfare assessment protocols available (e.g. the Welfare Quality® project), one did not exist which combined the three factors of animal-based data (e.g. physiological health parameters, general appearance assessment and behavioural measurements), routinely collected data and resource-based indicators (management and environment). Specifically, there were no available welfare assessment protocols for dairy heifer and bull calves, to give an overview of all calves but also to allow for differentiation of the sexes. Figure 1 details the three main areas of the welfare assessment protocol which involved (i) management practices, ascertained via one-to-one survey with calf manager, (ii) independent animal assessment, and (iii) evaluation of environmental conditions (Barry *et al.*, 2019).

Early dairy cow–calf separation

The importance placed on the ability of dairy cows to express their natural behaviour is also evidenced in the growing body of research accumulating in the area of cow–calf contact rearing systems. The dairy industry and the public are increasingly interested in management systems that allow cow–calf contact (Sirovnik *et al.*, 2020). The cow is highly motivated to visit her calf (Johnsen *et al.*, 2021), indeed will push up to 90 kg to access it (Wenker *et al.*, 2020). There is currently no evidence to indicate early separation is beneficial to cow health (Beaver *et al.*, 2019). In fact, systems which allow contact between the dam and the calf reduce the risk of mastitis in dairy cows (Beaver *et al.*, 2019).

Newborn dairy calves are usually permanently separated from their dams within a few hours after birth. This is a typical practice in dairy farming and applies to conventional production systems (Kennedy *et al.*, 2014). Heretofore, best practice was to remove the calf from the cow immediately post-calving for biosecurity reasons (Lorenz *et al.*, 2011) and to promote greater health (e.g. minimise risk of Johne's disease; Kennedy *et al.*, 2014). However, consumers are currently questioning this practice of immediate removal in terms of the welfare implications for both the cow and calf. While a number of studies are being undertaken internationally examining the effect of retaining the calf with its mother post-calving (Beaver *et al.*, 2019), pasture-based systems of dairy production, such as those that predominate in Ireland and New Zealand, pose a

Figure 1. An overview of the components involved in assessing calf welfare. Management and environmental factors affect the animals. Animal welfare can be best assessed by using animal-based measures, while measures on management and environment can help to find factors affecting animal welfare. IgG, immunoglobulin G.

unique problem. These systems are characterised by compact seasonal calving patterns and by their reliance on pasture in the diet which necessitates the early turnout of dairy cows to pasture (Kennedy *et al.*, 2005). Future work will ascertain the effects of retaining the calf with its mother until weaning on animal welfare, productivity and on the implications for workload on the farmer in a pasture-based scenario (One Welfare; García Pinillos *et al.*, 2016). Recommendations for future calf management will be dependent on these results.

Dairy cow welfare

Much research on dairy cow welfare in Ireland focused on the issue of pasture access for dairy cows. Pasture-based systems are viewed as superior to housed systems for cows, as they allow cows to perform their natural grazing behaviour, which is a high-priority activity for them (Krohn, 1994). Pasture access also promotes more synchronous

herd lying behaviour, as well as increasing cow comfort which facilitates longer lying bouts and overnight lying durations (Crump *et al.*, 2019). However, lying duration at pasture is dependent on grass allowance; cows on a low feed allowance spend less time lying (O'Driscoll *et al.*, 2019). Furthermore, access to pasture may lead to more positive state of mind in dairy cows (Crump *et al.*, 2021). Grazing also benefits health, sometimes reducing lameness (Olmos *et al.*, 2009a) and mastitis (Fontaneli *et al.*, 2005) and improving reproductive health (Olmos *et al.*, 2009b). However, cows at pasture may be more likely to suffer metabolic/nutritional stress (Olmos *et al.*, 2009b), and may be at increased risk of parasitism and other health problems including grass tetany, ketosis and subacute ruminal acidosis (EFSA, 2009). Recent Irish research demonstrated that cows had greater skin damage to the head and neck during the housed period (Crossley *et al.*, 2021) but more nasal discharge during the grazing season. Therefore, it should not be assumed that welfare is automatically better when cows are outdoors. The ideal

situation would allow the cow to choose, as environmental conditions may alter her preference (Legrand *et al.*, 2009), although, in general, cows show an overall preference for pasture (Arnott *et al.*, 2017). Management of the system (in terms of animal husbandry) may be as important as the type of production system (confinement, pasture-based or hybrid) in ensuring good dairy cow welfare (Mee & Boyle, 2020).

Irish research shows that increased comfort levels in cubicles during the winter housing period were associated with improved claw health in heifers, mediated through an increase in lying time (Leonard *et al.*, 1994). Overcrowding reduced lying time, with negative consequences on claw health (Leonard *et al.*, 1996a, 1996b). Cows prefer to stand on softer surfaces; when the passageway and feed face were covered in rubber flooring, cows spent more time standing at the feed face, whereas cows on a concrete floor spent more time in the cubicles (Boyle *et al.*, 2007). In Ireland, cows must be managed off pasture during the winter months due to low grass growth and the risk of damage to the ground conditions. This period of confinement can last anywhere between 3 and 6 mo, and traditionally cows were kept in cubicle houses. However, these are expensive to build, so alternatives to indoor housing of cows were also examined. Keeping cows on out-wintering pads during the dry period did not negatively impact lameness and hoof health (O'Driscoll *et al.*, 2008a; 2008b), or mastitis incidence (O'Driscoll *et al.*, 2008b), and in fact, conferred welfare benefits by allowing more synchronised lying behaviours (O'Driscoll *et al.*, 2008c). As cows are herd animals, synchrony of lying behaviour is an internally motivated natural behavioural characteristic and is considered reflective of natural behaviour patterns and, as such, good welfare (Crump *et al.*, 2019). Out-wintering pads also provided welfare benefits to yearling heifers, reducing limb lesions and increasing comfort, social and play behaviours (Boyle *et al.*, 2008). Research investigating the effect of milking frequency on dairy cow welfare concluded that in general once-a-day milking resulted in improved hoof health and mobility, by allowing increased time for cows to lie (O'Driscoll *et al.*, 2010, 2015), and did not negatively impact cow comfort (O'Driscoll *et al.*, 2011). However, once-a-day milking reduces phagocytic activity of polymorphonuclear neutrophils (PMNs) and monocytes, and would be detrimental for the immune system in high-yielding dairy cows during early lactation (Llamas Moya *et al.*, 2008a).

It is increasingly recognised that the human–animal relationship is a key factor influencing the welfare of dairy cows (Hemsworth & Coleman, 2011). Negative tactile interactions such as slapping cause cows to become fearful, which results in avoidance of humans, and may reduce milk yield (Breuer *et al.*, 2000). Conversely, an improved farmer–cow relationship can reduce stress indicators (Ebinghaus *et al.*, 2020) and fear, and improve yield (Hemsworth *et al.*,

2002). Fearful responses increased with time spent at grass and decreased with time spent indoors (Crossley *et al.*, 2021), suggesting that as cows are less exposed to humans they become less comfortable around them. The impact on their well-being is unclear, however.

Affective state is defined as an umbrella term that encompasses both emotions and mood (Kremer *et al.*, 2020), and in dairy cows, it may be assessed by measuring spontaneous physiological responses (including cortisol, heart rate variability, eye/nose temperature and eye white) and spontaneous behavioural responses (escape and wound directed behaviours, vocalisations and facial expressions). Affective state can also be evaluated using preference tests, approach/avoidance tests and motivation tests (Ede *et al.*, 2019). Potential indicators of positive welfare include comfort index, duration of lying bout time and duration, exploration/chewing of branches, licking while standing on three legs, rumination, synchronisation of behaviours, allo-grooming and avoidance of distance (Mattioli *et al.*, 2019).

Pain, because it is one of the most unpleasant negative affective states, is of particular importance, it causes the most public concern (Weary *et al.*, 2006) and is widely recognised as an important issue for dairy cow welfare. Pain can result from many issues, including lameness, mastitis, dystocia and tail docking and disbudding. Tail docking is not legal in Ireland, yet Crossley *et al.* (2021) demonstrated that cows with docked tails were present on almost 65% of farms visited, indicating that this is nonetheless a significant issue. Research to identify (Gleerup *et al.*, 2015) and manage pain in dairy cows (Stillwell *et al.*, 2014, 2019) is ongoing.

Future challenges

In response to policy changes which focus on driving milk production in the absence of quota constraints, herd sizes are increasing (Kelly *et al.*, 2020) and grazing practices are becoming more intensive (Roche *et al.*, 2017), which has potential impacts for the behaviour and welfare of cows (Boyle *et al.*, 2015). Significant scientific advancements greatly increased our understanding of what constitutes good welfare for dairy cows and how best to assess it. As a result, we are better equipped to improve the welfare of the dairy cows in our care, which is vital if the Irish dairy sector is to respond to future challenges.

The European Green deal, which aims to overcome the threat of climate change and environmental degradation by making the economy of the EU sustainable, targets a 55% reduction in greenhouse gas emissions by 2030 (European Commission, 2020a), and a 50% reduction in the sales of antimicrobials for farm animals (European Commission, 2020b). Improving the welfare of dairy cows can contribute to these goals. Cows experiencing good welfare are likely to be less stressed and consequently less susceptible to disease (Chrousos, 2009;

von Keyserlingk *et al.*, 2009), and require less antimicrobial treatment as a result. Healthy animals are also likely to remain in the herd for longer (De Vries & Marcondes, 2020). Extending the dairy cattle productive lifespan could decrease the environmental footprint of milk production because fewer heifers need to be raised (De Vries & Marcondes, 2020). Therefore, improving dairy cow welfare is of key importance to reducing the environmental impacts of dairy farming.

Consumer food preferences are evolving. The number of people adopting a vegan diet is increasing (Alcorta *et al.*, 2021) and those that continue to consume animal products seek confirmation that food is produced in an ethical, animal-friendly manner (Cembalo *et al.*, 2016). However, while recent work confirmed Ireland is performing well in certain areas of cow welfare, there remains considerable scope to improve (Crossley *et al.*, 2021). Indeed, Ireland's recent Animal Welfare Strategy highlights the importance of doing so (DAFM, 2021). Demonstration of high cow welfare standards is also crucial to maintain Ireland's image as a sustainable producer of dairy products in order to maximise market returns for increased dairy production in competitive markets worldwide (DAFM, 2015). As such, dairy cow welfare must be a priority. In this regard, there is a requirement within the Irish dairy sector for schemes to monitor, benchmark and incentivise improvements to cow and young stock welfare on farms.

Beef cattle welfare

At present, there is no specific EU legislation addressing the welfare of cattle kept for beef production (European Commission, 2001). Welfare concerns with veal production led to the implementation first in 1991, and later in 2008, of legislation laying down minimum standards for their protection (Council Directive 2008/119/EC, 2008).

Castration

The castration of male calves intended for beef production is probably the most significant acute tissue- and structure-altering procedure that beef cattle commonly undergo, apart from the act of slaughter itself. Thus, castration has the capacity to represent a major source of acute stress and trauma, and also one which may reasonably be used to investigate links between acute stress and alterations in immune system function in cattle. There are also concerns regarding the ethical and social acceptability of castration procedures.

Calves are castrated because it reduces management problems associated with aggressive and sexual behaviour. However, from an animal welfare perspective, the inflammation and pain due to handling and tissue trauma are potent activators of the hypothalamic–pituitary–adrenal

(HPA) axis (Earley & Crowe, 2002) and cause distress. The three main castration methods are: a rubber ring or latex bands to restrict the flow of blood to the scrotum, bloodless castration by crushing the spermatic cords with the Burdizzo and surgical castration. There is a general perception that delaying castration could extend the production advantages of keeping animals as bulls until weaning or beyond puberty. Keane (1999) showed no advantage in delaying castration of bulls from birth up to 17 mo of age in terms of live weight, growth rate or carcass weight at slaughter.

The issue of pain relief during castration of bulls is increasingly important in the scrutiny of the ethical treatment of farmed animals. Systemic analgesia with a non-steroidal anti-inflammatory drug (NSAID), ketoprofen, was more effective than local or epidural anaesthesia in modulating cortisol and inflammatory responses, and in the suppression of immune function (Earley & Crowe, 2002). The NSAID, ketoprofen, effectively suppressed the surgical castration-induced peak cortisol response, and the 12-h integrated cortisol response by 56% relative to surgery alone and by 40% relative to surgery with local anaesthesia in 5.5-mo-old Friesian calves. Furthermore, a combined administration of ketoprofen and local anaesthesia delayed the peak cortisol response by 4 h relative to surgery alone (Earley & Crowe, 2002). Calves at 47 d of age have lower plasma cortisol responses to castration compared to older castrated calves (76–165 d of age), and the use of an NSAID is a better alternative to local anaesthesia for the alleviation of inflammatory and pain-associated behavioural responses to castration (Ting *et al.*, 2005). The findings showed that calves at 47 d of age exhibited lower stress responses (plasma cortisol and inflammatory responses) to Burdizzo castration compared with older calves (76–165 d of age). Issues of pain relief during routine husbandry procedures are likely to become increasingly important as societal scrutiny into the ethical treatment of farmed animals converges with the scientific evidence on the acute and chronic painfulness of routine husbandry practices.

Weaning

In Ireland, spring-born suckler beef calves are typically weaned at the end of the grazing season in autumn, between 6 and 9 mo of age, at which time they are also housed (Drennan & McGee, 2009). Weaning of the beef calf under modern cattle production systems constitutes a multi-factorial stressor as it incorporates nutritional, physical and psychological elements (Hickey *et al.*, 2003b). The weaning process involves separating the calf from its mother, resulting in numerous stressful events including dietary change, housing and social reorganisation. Indeed weaning of beef calves is one of the most stressful events in the calf's lifetime (Hickey *et al.*, 2003b; Blanco *et al.*, 2009; Lynch *et al.*, 2010a, 2010b, 2011; O'Loughlin *et al.*, 2011, 2012, 2014).

Lynch *et al.* (2010a) identified that beef calves that were abruptly weaned and returned to familiar pasture had a less marked stress response than calves that were abruptly weaned and introduced to a new environment of a slatted floor shed and were offered a new diet of grass silage *ab libitum* plus supplementary concentrates simultaneously. The more marked stress response was attributed to decreased number of lymphocytes, the attenuated production of interferon- γ (IFN- γ) and greater concentrations of the acute phase protein, fibrinogen, post-weaning in abruptly weaned and housed calves compared with those that were abruptly weaned and returned to pasture.

Additionally, Lynch *et al.* (2010a, 2010b) demonstrated that movement from a pasture environment to a housing environment in a slatted floor shed is capable of inducing a transient stress response in beef calves and cows. Collectively, these studies identified a profile in which neutrophilia and concurrent lymphopenia are evident for a brief period following relocation. Due to the pronounced neutrophilia and lymphopenia observed by Lynch *et al.* (2010a, 2010b), a more in-depth examination of the effects of abrupt weaning on neutrophil function and lymphocyte immunophenotypes was undertaken by Lynch *et al.* (2012). Transient neutrophilia was evident post-weaning, and this population of circulating neutrophils was less active in terms of phagocytosis than the neutrophil population in circulation prior to weaning (Lynch *et al.*, 2012). Utilising the profile of changes observed in neutrophil number and function and lymphocyte subsets identified by Lynch *et al.* (2012) as sensitive biomarkers of weaning stress in beef calves, the provision of concentrate supplementation pre-weaning was examined to determine if this practice could ameliorate the stress response post-weaning. Calves that were offered concentrate supplementation pre-weaning had a lesser degree of neutrophilia compared with calves that were not supplemented pre- and post-weaning (Lynch *et al.*, 2012). Other weaning management practices include the use of anti-suckling devices (nose clips) for a period prior to weaning (Haley *et al.*, 2005), fence-line contact between calf and dam post-weaning (Stookey *et al.*, 1997) and a combination of both practices before complete separation (Newberry & Swanson, 2008).

There are limited studies on the effects of weaning on beef cows. In line with the findings of Lynch *et al.* (2010b) and other studies examining the effects of weaning stress in beef calves (Hickey *et al.*, 2003b; Blanco *et al.*, 2009), weaning resulted in neutrophilia and concurrent lymphopenia which was coupled with decreased *in vitro* production of IFN- γ and increased acute phase response in beef cows. Thus, it is apparent that the beef cow is stressed by separation from her calf. However, when the magnitude and duration of these perturbations in the cow are compared with those in the calf, it appears that stress response is activated to a lesser degree and for a shorter

period (Lynch *et al.*, 2010b). Early weaning is not practiced in Ireland due to favourable climatic conditions for grass growth. Beef cows express distinct distress behaviours, such as increased vocalisations and locomotor activity following abrupt separation from their calves (Price *et al.*, 2003). Therefore, it is reasonable to assume that physiological and immunological alterations in abruptly weaned beef calves would also be seen in beef cows following abrupt separation from their offspring.

Transport

The infrastructure of the beef cattle industry is associated with a need for the transportation of cattle, by road and sea, including within the EU, and internationally. The buying and selling of cattle from one producer to another, the finishing of weanling calves at large feedlots and the endpoint of slaughter all necessitate transportation. Transportation can combine physical and psychological stressors, and weaning, method of and the handling during (un)loading, commingling of unfamiliar animals, loud noises, overcrowding, food and water deprivation, extreme temperature and the novelty of the truck or new feedlot facility can be individually stressful, let alone in combination with each other. Kenny & Tarrant (1987) observed that confinement on a moving vehicle is the most stressful component of transportation. The transport of livestock can have major implications for their welfare, and there is strong public interest and scientific endeavour aimed at ensuring that the welfare of transported animals is optimal (Earley & O'Riordan, 2006; Earley *et al.*, 2010, 2011, 2012, 2013). Physical factors such as noise or vibrations, psychological/emotional factors, such as unfamiliar environment or social regrouping, and climatic factors, such as temperature and humidity, are also involved in the transport process. Increased neutrophil and decreased lymphocyte numbers following transportation are documented (Earley & O'Riordan, 2006; Earley *et al.*, 2010, 2011, 2012, 2013).

Transport journeys from Ireland to France (23 h) and Italy were investigated both with bulls and heifers, in which the cattle remained in their vehicle transporters (Earley & Murray, 2010; Earley *et al.*, 2012). The percentage of time that bulls spent lying was 63.5% for the sea journey and 35.4% for the journey from the French lairage to the Italian feedlot. While transient changes in physiological, haematological and immunological variables were found in the transported and control animals relative to baseline levels, the values were within the normal physiological range for the age and weight of animals involved. Physiological measurements made after the road and sea journeys indicated that the 24-h rest in the lairage, with hay and water freely available, was adequate to maintain homeostasis. Within the conditions of the studies (Earley & Murray, 2010; Earley *et al.*, 2010, 2011, 2012, 2013), there was no evidence to suggest that the health, welfare or performance of animals was adversely impaired

as a consequence of the transport journeys. Earley *et al.* (2011) investigated the effect of transport by sea, from Ireland to Lebanon, on performance, physiological, immunological and behavioural responses of bulls and found no evidence to suggest that their welfare was impaired by the journey. Nevertheless, under normal commercial shipping conditions, adverse weather or disease outbreaks (in humans or animals) can prolong the journey or delay the unloading process and thereby pose potential threats to animal welfare. Hence, animal transportation is a very relevant issue for animal welfare and therefore is subject to specific legal requirements such as European Convention for the protection of animals during international transport (1968) and European Council regulation 1/2005 (EU, 2005) on the protection of animals during transport and related operations. Teagasc research on animal transport has informed the latter regulation.

Housing

The main critical issues for beef cattle welfare during housing were identified by EFSA (2006a, 2006b, 2012), the European Commission (2001) and the EU Welfare Quality® project (2009); these include: housing conditions, areas for feeding, walking and resting, space allowance and flooring, social and maternal behaviour, dominance, grouping and regrouping of animals. Most recently, concern for the welfare of finishing cattle, particularly in relation to housing conditions (space allocation and floor type), was expressed at national, EU and OIE levels. There is the view that conventional slatted floors without access to lying areas should be replaced by more animal-friendly systems. Outdoor wintering of beef animals is not an option on many Irish farms due to poaching of ground conditions. Winter housing is therefore a necessary alternative and is dominated by concrete slatted floored sheds. The main floor types used for accommodating beef cattle in Ireland are concrete slatted floors (CSFs), CSF overlaid with rubber mat (RM) and loose bedded systems, mainly containing straw (Mazurek *et al.*, 2010). Many farms have a combination of both these floor types.

As well as facilitating winter feeding and management, accommodating cattle indoors provides additional benefits such as preventing land poaching and protecting animals from inclement weather conditions. Since the 1960s, the number of beef cattle on CSF increased (Wechsler, 2005). Although they cost more to construct initially, CSFs are popular due to the lower labour input required for the removal of slurry than would be required with solid floor systems (Lowe *et al.*, 2001a).

The duration of the indoor housing period varies from 3 to 6 mo depending on climate, soil type and management system. In some systems, particularly with spring-born beef bulls, the housing period is not limited to the winter months as bulls may be housed after their first summer and finished intensively indoors over a period of 9 or 10 mo (Keane & Allen, 1998;

Keane, 2003; Drennan & McGee, 2009). While steers tend to have shorter housing periods than bulls, the amount of time they spend indoors is greater as they are usually slaughtered at 24 mo or above (Keane & Allen, 1998; Keane, 2003; Keane, 2010), thus spending two winter periods housed indoors.

There are suggestions to increase the space allowances per animal on CSF to 3.0 m² for a 500-kg animal $\pm$ 0.5 m² per 100 kg above or below this (Scientific Committee on Animal Health and Animal Welfare [SCAHAW], 2001). The majority of studies carried out on the effect of space allowance on the performance and welfare of finishing beef cattle on CSF investigated space allowances below 3.0 m². Fisher *et al.* (1997a, 1997b) reported that housing finishing heifers, weighing 560 kg, at space allowances below 2.0 m², instead of at 2.5 and 3.0 m² per animal, impaired performance and lying time. Furthermore, Hickey *et al.* (2003a) reported a reduction in carcass weight and a decrease in the production of IFN- γ to the mitogen Concanavalin-A, a marker of cell-mediated immunity, in steers, weighing 610 kg, housed at 1.5 m² per head compared to 3.0 m². Similarly, Gupta *et al.* (2007) found that housing bulls at 1.2 m² compared to 2.7 m² reduced performance and raised plasma cortisol concentrations suggesting that the performance and stress response of animals at the lower space allowance was inhibited. Keane *et al.* (2017) investigated the effect of space allowance and floor type on performance and welfare of finishing beef heifers at either (i) 3.0 m², (ii) 4.5 m² or (iii) 6.0 m² space allowance per animal on a CSF and (iv) 6.0 m² space allowance per animal on a straw-bedded floor, for 105 d. The number of heifers lying at any one time was greater on straw than on CSF. Space allowance and floor type had no effect on the number of hoof lesions gained or on any of the haematological or metabolic variables measured. Hence, increasing space allowance has no negative impact on performance but did improve cleanliness.

The increased popularity of CSF led to an increased interest in floor types that combine the labour-saving efficiency of CSF with a softer floor surface (Benz *et al.*, 2002). Rubber mats were developed for this purpose, as they can be overlaid on CSF with relative ease. There are numerous different types of RMs available. The structure of individual varieties can vary greatly in terms of hardness, friction, compression and abrasiveness; therefore, their effects on animal performance and welfare vary greatly between studies. Lowe *et al.* (2001a) compared CSF with CSF overlaid with RM and found no difference in average daily gain (ADG) or carcass weight of cattle. In contrast, Keane *et al.* (2015) reported a greater ADG for cattle on CSF overlaid with the Durapak RM than on CSF, but found no difference in carcass weight.

Wechsler (2011) recommended that CSF should not be used for housing beef cattle and instead must be replaced with alternative floor types such as RM or straw. Previous research

showed that cattle on RM can develop more leg swellings (Graunke *et al.*, 2011) and hoof lesions (Earley *et al.*, 2015, 2017; Keane *et al.*, 2015) compared to those on CSF. Others have concluded that the RM may not be the ideal replacement for CSFs however, as they do not provide sufficient claw wear thereby causing overgrown claws (Bergsten, 2010). This can lead to further problems such as heel erosion caused by a displacement of the main load-bearing points (Dembele *et al.*, 2006). The results of Keane *et al.* (2015) indicate that housing bulls on an RM improved daily live weight; however, this result was not reflected in slaughter or carcass weight. While there was no evidence of lameness in bulls on RM in that study, the increased number of hoof lesions suggests that hoof health may be compromised. In a recent study, Earley *et al.* (2017) reported similar findings in finishing beef steers using three different RMs. Prior to the adoption of concrete slatted housing, the most common floor type for cattle housed indoors was straw bedding (Maton *et al.*, 2012). From an animal welfare perspective, straw bedding is preferable (Burgess & Hutchinson, 2005) as cattle display a strong preference for straw bedding and would rarely choose to lie on a slatted floor if there was any other floor type available (Lowe *et al.*, 2001b). However, straw bedding has its limitations in relation to labour efficiency, space requirements, straw availability and cost (Tuytens, 2005). For example, in Ireland, if all beef producers replaced CSF with straw-bedded systems, the national supply of straw would run out within 1 mo (Wilkinson, 1998).

Additional topics at present that feature most prominently are (i) antimicrobial use and resistance, and (ii) calf health, with particular reference to factors affecting morbidity and early mortality. The two topics are interdependent and are addressed in more detail in Mee *et al.* (2022).

Pig welfare

Pigs are protected by a specific EU directive (Council Directive 2008/120/EC) which lays down minimum standards for their protection (e.g. standards relating to flooring, living space, access to materials for rooting). Most Irish pigs are managed in high-density, low-complexity environments, which are sub-optimal with regard to the animals' biological needs. Unfortunately, the consequence is a high prevalence of health and welfare problems for pigs across all production stages (piglets: Quinn *et al.*, 2015; sows: Boyle *et al.*, 1998, 1999; Quinn, 2014; weaner, grower and finisher pigs: Quinn, 2014; van Staaveren *et al.*, 2017, 2018; da Costa *et al.*, 2020).

Sows and gilts

Tethering of pregnant sows (permanently tied by a collar around the neck or chest for the duration of pregnancy) was

common in the EU for several decades, until it was banned from 2006 under the 1991 Pigs Directive. In the lead up, a longitudinal assessment of skin lesions in stall-housed sows throughout the production cycle and a cross-sectional study of the same lesions in tethered and stall-housed pregnant sows were conducted on 25 commercial pig farms (Boyle *et al.*, 1999). In general, there was a high prevalence of lesions to the hind limbs, reflecting the difficulty for sows of manoeuvring in close confinement and the unforgiving nature of the flooring used. Boyle *et al.* (1998) also determined that high culling rates in the early parities for reproductive failure, locomotor problems, disease and injury reflected major challenges to gilts' ability to adapt to close confinement on entering the breeding herd.

Given these issues it was not surprising that in 2008 the EU imposed a partial ban on sow stalls (Council Directive 2008/120/EC), which came into force on 1 January 2013. This required sows to be group housed from 4 wk after service. However, aggression between sows at mixing, during competition for access to resources and due to hunger, is a major cause of stress and injury, and can have a negative impact on sow reproductive performance (Read *et al.*, 2020; Lagoda *et al.*, 2021). Research on group housing was already underway in Ireland prior to the EU ban (e.g. Boyle *et al.*, 2002a; O'Connell *et al.*, 2003, 2004; O'Connell, 2007) prompted by the demand from the UK which banned gestation stalls in 1998. Subsequent investigation of high-fibre diets and foraging substrates, both requirements of EU legislation (Stewart *et al.*, 2008, 2010, 2011), aided identification of strategies to improve welfare. Research comparing group and stall housing systems for pregnant sows confirmed the major problem of lameness in the former (Calderon Diaz *et al.*, 2014), and epidemiological research on lameness in all classes of pigs confirmed that the ubiquity of fully slatted concrete flooring on Irish pig farms was a major contributory factor (Quinn, 2014). On-farm research then found that rubber flooring had considerable benefits to sow welfare, locomotory ability, reproductive performance, etc. during pregnancy (Calderon Diaz *et al.*, 2013, 2014; Calderón-Díaz & Boyle, 2014a, 2014b; Lagoda *et al.*, 2021) although these did not carry over to during the farrowing/lactation period (Calderon Diaz & Boyle, 2014a).

On most Irish farms, gilts destined to enter the breeding herd are treated in the same way as finisher pigs, and fed diets designed for fast growth rates and lean meat deposition. However, Quinn (2014) confirmed hypothesised benefits of preferentially treating young replacement gilts in terms of diet and housing on farm. Furthermore, terminal line gilts fed a restricted diet formulated for fat rather than lean deposition and supplemented with minerals for optimal bone and joint development had improved locomotion scores likely associated with slower weight gain (Quinn *et al.*, 2015). More

recent work by Hartnett *et al.* (2019, 2020a) confirmed that integrating supplementary minerals into maternal line gilt diets improved joint health (i.e. less cartilage damage), reduced claw lesion severity and improved production performance throughout life (Hartnett *et al.*, 2020b).

Hartnett *et al.* (2020a) showed that keeping replacement gilts in all-female groups from weaning was likely responsible for the benefits described above, as gilts were exposed to less sexual and aggressive behaviour performed by the males. Ireland is one of few European countries that raises male pigs as entire boars. This offers welfare advantages to piglets as they are spared surgical castration in the first week of life (Llamas Moya *et al.*, 2006a, 2006b, 2008b, 2008c). However, pigs in entire male pig production systems suffer challenges to welfare later in life arising from intense aggressive and sexual behaviour during the finisher (Bjorklund & Boyle, 2006; Teixeira & Boyle, 2014) and pre-slaughter (van Staaveren *et al.*, 2015) stages.

Farrowing facilities

Sows are usually confined in crates for the farrowing and lactation period to protect piglets from crushing, and enable quick, safe and easy checking of the animals by the stockperson. Protection from crushing is ever-more important with the increases in litter size that occurred due to selection for higher sow productivity (Boyle *et al.*, 2021). Larger litters are also associated with increased competition between piglets for access to a teat and considerable fighting between piglets when trying to establish the “teat order” (Fraser & Thompson, 1991). Associated injuries to the sows’ teats and piglets’ faces are reduced by clipping the needle teeth; pilot work at Teagasc demonstrated that leaving these teeth intact results in facial lesions and reduced growth rate for piglets during the first three critical days of life (O’Driscoll & Schmitt, 2016). However, even when carried out for welfare reasons, teeth clipping can still cause immediate and long-term pain (Sinclair *et al.*, 2018), and as such is regulated under Council Directive 2008/120/EC. An alternative is grinding, which has benefits for sows and piglets (Lewis *et al.*, 2005a, 2005b, 2005c; Llamas Moya *et al.*, 2006a, 2006b). Providing piglets with shredded paper and ropes in the farrowing crate redirects their behaviour away from the sow and may also help to reduce lesions (Lewis *et al.*, 2006).

Even older research on farrowing facilities extends back to the mid-1990s when the injurious nature of floor types used in farrowing crates for piglet skin and feet as well as negative impacts on piglet behaviour were documented (Leonard *et al.*, 1996a, 1996b; O’Connell *et al.*, 1996). Early research also documented the injurious nature of confinement in farrowing crates for sows (Boyle *et al.*, 1999, 2000a, 2002a, 2002b). One of the first attempts to reduce injury and improve sow

comfort was through the use of RMs in the farrowing crate (Boyle *et al.*, 2000b).

The introduction of group housing during gestation posed yet another new challenge for gilts and sows; freedom during pregnancy (or most of their life to that point), followed by sudden confinement prior to farrowing, can act as a stressor (Boyle *et al.*, 2000a, 2002a; Baxter *et al.*, 2011). However, a strategy whereby sows are confined only from the initiation of milk let-down until 4 d post-farrowing (i.e. free lactation) could somewhat address this issue. Indeed sows in free lactation pens have improved locomotory ability at weaning relative to sows in crates, use all orientations in the pen and have less tear staining under the left eye (indicative of mental stress; DeBoer *et al.*, 2015) at weaning (Kinane, 2020). Most importantly, mortality was not higher than in standard crates; there was slightly more crushing in the free lactation pens after the crates were opened, but this was offset by fewer deaths from hunger and failure to thrive (Kinane *et al.*, 2021). Piglets from the free lactation pens also tended to perform less damaging behaviour, weighed more at weaning, were significantly heavier at slaughter and took fewer days to reach the target weight of 105 kg.

Tail biting

Irish producers recognise tail biting (a behavioural disorder which occurs when pigs experience a level of stress which is beyond their coping abilities) as a serious issue (Haigh & O’Driscoll, 2019), although over 99% of Irish pigs’ tails are docked to prevent biting, and about two-thirds of tails exhibit some evidence of damage (Harley *et al.*, 2012, 2014). Inability to perform natural behaviours and inadequate housing and management are the primary triggers (D’Eath *et al.*, 2014; Valros, 2018). Improving compliance with the ban on routine tail docking is currently one of the European Commission’s priorities in the area of animal welfare (Nalon & De Briyne, 2019). However, a significant challenge in Ireland is the physical structure of most pig facilities (e.g. fully slatted systems) which means that the recommended gold standard enrichment material, straw bedding on the floor of the pen (D’Eath *et al.*, 2014), cannot be provided.

Initial Irish research focused on a dietary solution. However, neither Mg supplementation nor a higher fibre level in the diet (both of which were hypothesised to have a calming effect) reduced biting or damage to tails (O’Driscoll *et al.*, 2013a, 2013b; Chou *et al.*, 2020a). Work conducted on commercial farms attempted to identify enrichment materials which could be attached to the walls; soft wood, such as spruce, was identified as being more favourable to pigs than harder wood (beech, larch and Scots pine; Chou *et al.*, 2018), or than compressed straw blocks (Haigh *et al.*, 2019). Indeed, soft wood and rubber are used more often by pigs than harder items (Chou *et al.*, 2020b). However, these materials were

insufficient alone to prevent biting outbreaks in undocked pigs (Chou *et al.*, 2020a). As such, Teagasc research moved on to investigating greater enrichment allowances, including racks of loose material (Chou *et al.*, 2019, 2020c; D'Alessio *et al.*, 2021; Misra *et al.*, 2021); grass was favoured by pigs over straw, paper and miscanthus (Chou *et al.*, 2019). Future work will aim to identify materials which are easily available, affordable, have a low biosecurity risk and can be stored without risk of degradation.

Link between pig welfare and pig health

On-farm research by Teagasc documented poor welfare arising from sub-optimal management and housing practices (Diana *et al.*, 2019a; da Costa *et al.*, 2021) and associated deficiencies in performance and health and increased mortality (Calderon Diaz *et al.*, 2017a, 2017b, 2018). Antibiotics are viewed by farmers as the most cost-effective way to address health and performance challenges, and thereby protect pig welfare (Diana *et al.*, 2021), but from January 2022 any prophylactic use is banned. However, Teagasc research found that by removing in-feed medication in current systems, and by employing good management and housing practices, there are no adverse effects on pig health, welfare or productivity (Diana *et al.*, 2017, 2019b).

Poultry welfare

Most European citizens consider it is important to protect the welfare of farm animals (European Commission, 2016d), and there appears to be particular concern about the welfare of poultry (Clark *et al.*, 2016). The use of cages for laying hens is particularly contentious. While conventional or “battery” cages were prohibited under EU legislation from 2012, there is now increased momentum to move to cage-free systems entirely. This would invariably provide birds with more behavioural freedom, but is associated with increased mortality (Weeks *et al.*, 2016). In free-range systems, this mortality may result from a variety of causes including disease, smothering and predation (Elson, 2015; Rayner *et al.*, 2016; Bestman & Bikker-Ouwejan, 2020). Some of the welfare issues associated with cage-free production contributed to increased interest in the use of more “robust” breeds of hens that are better able to cope with these environments (e.g. Fernyhough *et al.*, 2019).

Concern over the use of cages means much of the public conversation about poultry welfare focused on the laying hen sector in recent years. This section will therefore focus on the broiler chicken sector, the scale and importance of which was outlined in the Introduction. There are different aspects of broiler production that could be discussed, including welfare during handling, transport and slaughter, and specifically of

broiler breeders. Our focus, however, will be on environmental enrichment strategies for broiler chickens in order to reflect a key research theme on the island of Ireland. The majority of broiler chickens are reared indoors over a 5–6-wk period in groups of more than 20,000 birds. The fact that they can reach slaughter weight in such a short time reflects, to a large extent, targeted genetic selection for production traits such as growth rate. This rapid growth is associated with health and welfare problems, including leg health issues and cardiovascular disease (see EFSA, 2010; Hartcher & Lum, 2019), and genetic selection strategies are associated with reduced activity levels (McLean *et al.*, 2002). Levels of activity often decline with age (Weeks *et al.*, 2000), and this inactivity can further add to health problems. While there is much focus on bird genetics, low levels of behavioural activity may also reflect lack of appropriate stimulation within housed systems. This is supported by the fact that increased activity is shown by fast-growing broilers in response to certain environmental enrichment (Riber *et al.*, 2018).

In order to address welfare concerns while also meeting global demand for chicken meat, there is increased interest in developing enhanced housing systems and using slower-growing breeds. This is evident in the commitments being made by many leading companies in the food supply chain (European Chicken Commitment, 2018). It is also evident in the enhanced housing systems already emerging from within the industry. Research into the use of slower-growing breed types gathered pace in recent years, and studies show benefits including improved health and reduced mortality (Rayner *et al.*, 2020) and improved gait (Dixon, 2020). Continued evaluation of the welfare outcomes of different slower-growing breed types reared under commercial conditions would be beneficial. Enhanced housing systems typically involve provision of environmental enrichment items, natural light and additional space. These systems emerged as part of voluntary initiatives or quality assurance schemes, and there is significant progress in recent years in capturing actual welfare outcomes of these strategies on commercial farms. This is essential to ensuring that these policies have a tangible effect on broiler welfare, and progress in relation to this area will be discussed in more detail below.

Environmental enrichment items

Environmental enrichment items in commercial broiler houses provide birds with an opportunity to engage in highly motivated behaviours, and may also stimulate general activity levels and consequently improve leg health. While there is a wealth of research into appropriate environmental enrichment for pigs, the same does not appear to apply with broiler chickens. This is perhaps reflected in the fact that provision of enrichment items to broiler chickens is not required under EU legislation. As mentioned, however, these items are often required as part

of quality assurance schemes or by others in the sector such as retailers. While this is a very positive step, it is important to ensure that what is provided meets the needs of the birds. The enrichment items typically provided on commercial farms include straw bales, pecking objects and perches, and research shows that these items are used by broilers. For example, research conducted in Northern Ireland by Baxter *et al.* (2018b) showed that an average of 30 birds clustered around straw bales on commercial farms, suggesting that they provide perceived protection. The birds also dismantle the bales over time on commercial farms, which helps to maintain litter quality, and also sometimes use them as perches. Research by this group also showed that pecking objects such as string and chains are used quite frequently by broiler chickens (Bailie & O'Connell, 2015; Baxter & O'Connell, 2019). For this type of enrichment item, more research is needed on optimum level of provision. Providing pecking objects such as string at minimum levels stipulated in some high welfare quality assurance schemes (e.g. 1 per 1,000 birds) does not appear to lead to sustained beneficial effects on general activity levels or leg health in commercial broilers (Bailie & O'Connell, 2015; Bailie *et al.*, 2018b). Similarly, research in commercial windowed houses showed limited benefits of providing 1.3 straw bales per 1,000 birds on general activity levels and leg health (Bailie *et al.*, 2013), and no additional benefits of increasing levels to 2 bales per 1,000 birds (Bailie & O'Connell, 2014).

Perching is a highly motivated behaviour in chickens, but the type of perch provided on commercial farms is likely to have a significant impact on beneficial effects. Bailie & O'Connell (2015) did not find any significant benefits of providing standard bar perches in commercial broiler houses on activity levels and leg health. Subsequent research by Bailie *et al.* (2018a) demonstrated a preference among fast-growing birds for platform rather than bar perches, which corresponds with findings by Norring *et al.* (2016). This preference may be linked to the conformation of the bird, and further research will be needed to determine optimum perch type for slower-growing breed types. As with other types of enrichment items, more evidence is needed on optimum level of provision of perches. Recently, Baxter *et al.* (2020) investigated four different levels of platform perch provision (0, 0.5, 0.6 and 0.7 m²/1,000 birds) in commercial houses. They found evidence of reduced fearfulness among birds when platform perches were provided, and high levels of perch occupancy in all treatments (on average 11.5 birds/m²), but no significant differences between treatments in terms of average gait score or activity level.

It may also be important to design environmental enrichment strategies that facilitate other important behaviours in broiler chickens. These birds are motivated to perform dustbathing but litter in commercial houses may not always be suitable

for this type of behaviour. Research by Baxter *et al.* (2018a) investigated the preferences of broiler chickens for different dustbathing material (including peat, oat hulls, straw pellets, clean wood shavings and standard litter), and found more dustbathing behaviour in peat and oat hulls than in the other materials provided. Follow-on research investigated the effect of providing discrete dustbaths filled with oat hulls in commercial broiler houses and showed that they promoted more foraging behaviour than straw bales (Baxter *et al.*, 2018b). Importantly, the provision of dustbaths also led to a significant improvement in gait score at the end of the production cycle. This whole-house effect on this leg health measure demonstrates the potential benefits achievable with appropriate environmental enrichment. The engagement that the broilers showed with dustbaths led to further research to investigate if use of other types of enrichment such as pecking objects may be increased by placing them within "activity clusters" containing both dustbaths and straw bales (Baxter & O'Connell, 2019). There were no obvious beneficial effects on use of the enrichment items when they were clustered together rather than distributed separately throughout the house; however, further research on optimum placement of enrichment items within the house would be beneficial. This will be aided by developments in tracking technology (e.g. Baxter & O'Connell, 2020) which will enable long-term monitoring of the use of different parts of the house by broiler chickens.

Light and space

Under current EU legislation, broilers must be provided with at least 6 h of darkness in each 24-h period during much of the production cycle. Research by Schwan-Lardner *et al.* (2012, 2013) indicated that longer dark periods were beneficial for bird welfare. This might be particularly important at the start and the end of the production cycle when longer light periods are permitted. The quality of light provided also appears to have a significant impact on broiler welfare. Bailie *et al.* (2013) investigated the effects of providing commercially housed broilers in Northern Ireland with access to natural light through windows and found significant benefits in terms of activity levels and leg health. This and more recent research by De Jong & Gunnink (2019) appear to validate a requirement to provide natural light within enhanced housing. These effects may reflect the increased intensity of light and also the presence of ultraviolet (UV) wavelengths in windowed housing (Bailie *et al.*, 2013). Research evidence from commercial systems also supports the provision of additional space. In a study involving almost 2 million birds, Bailie *et al.* (2018b) showed increased severity of dermatitis lesions when stocking density increased from 30 to 34 or 36 kg/m². Dawkins *et al.* (2004) also showed evidence of poorer gait at higher stocking densities in a large on-farm trial that

evaluated space allowances of 30, 34, 38, 42 and 46 kg/m². Importantly, however, they also indicate that conditions on the farm (likely linked to litter and air quality) had a more important impact on broiler welfare than the space allowance provided.

Conclusions

The science of animal welfare has evolved considerably over the last 60 yr and with it the recognition that animals are sentient beings. This is partly due to changing attitudes towards animals and also to the increased intensification of animal production in western countries. Although this intensification greatly increased efficiency and levels of production from animal agriculture, it also brought new problems to be addressed by animal and veterinary scientists, as well as a questioning of many farming practices by the consuming public. The OECD (2020) acknowledged that animal welfare is an emerging trade issue, and the international conventions already in place and ongoing work with the OIE confirms this. Throughout this review, emphasis was placed on the scientific evidence informing three main aspects of livestock animal welfare: (i) physical health and well-being; (ii) naturalness, meaning that animals can express normal behaviour; and (iii) subjective states, in that animals experience positive states and that negative states (e.g. pain) are minimised.

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