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The Gordon Memorial Lecture: Laying hen welfare

Professor Christine Nicol

Department of Pathobiology and Population Sciences, Royal Veterinary College, London, UK

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ABSTRACT
Preference tests remain a useful tool in the assessment of laying hen welfare and have been used to establish what types of resources and enrichments are most likely to meet the birds' needs. Evidence on the underlying structure of bird preference suggests that hens make stable and reliable choices across time and context. This means that their preferences can also be used as a benchmark in the validation of other welfare indicators. Hens have sophisticated cognitive abilities. They are quick to form associations between events and they are flexible in how they apply their knowledge in different contexts. However, they may not form expectations about the world in the same way as some mammalian species. Limited research in this area to date seems to show that hens judge situations in absolute terms rather than evaluating how a situation may be improving or deteriorating. The proportion of hens housed in cage-free systems is increasing globally, providing birds with greater behavioural freedom. Many of the problems associated with cage-free systems, such as keel bone fractures, mortality and injurious pecking, are slowly reducing due to improved experience and appropriate changes in rearing practices, diet, housing design and alignment of breeding goals. However, much remains to be done. The design and performance of veranda-based systems which provide hens with fresh air and natural light is a promising avenue for future research aimed at optimising hen welfare and improving sustainability.

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Laying hen; welfare; animal motivation; injurious pecking; animal sentience; preference tests

Introduction

It was an honour to present the Gordon Memorial Lecture in the spring of 2022. The lecture focussed on my research with laying hens, appropriate to the goals of the Memorial Trust. I have studied many other species, from mice to whales, but laying hens were my first research subjects – and there are still a great many questions unanswered.

I will start with a short account of how I became an animal welfare scientist before describing the types of research questions, methodologies and applications that have interested and occupied me during my career, providing illustrative examples where I can.

A consistent thread in my work has revolved around my interest in animals' motivations and preferences. I've frequently set out to obtain information from chickens using careful experiments to establish about what matters to them, what they want and what they would wish to avoid. In parallel, knowing something of the perceptual and cognitive abilities of chickens is important. We can only make judgements about animal welfare if we understand how animals perceive their environment and how they act in the world. There is also a moral dimension to this question as cognition may in some cases be related to the capacity to suffer or to experience pleasure; or we may decide to treat cognitively more complex animals in a different way to simpler creatures (or plants) for other reasons. So a related strand of work has examined chicken cognition, pain perception and ethical questions related to sentience.

Alongside these fundamental interests I have collaborated with many expert colleagues on specific and practical questions related to commercial housing and management of poultry. Epidemiologists have helped me make sense of some of the risk factors for complex and multi-factorial issues including injurious pecking, keel bone damage and smothering in laying hens and pullets. Social scientists have helped elucidate consumer and producer views about poultry welfare and to identify opportunities and barriers to change. My work has been used to provide evidence for policy reviews, legislative change, assurance scheme guidance and I have been fortunate sometimes to be able to contribute directly to policy discussions. We are witnessing a time of rapid and exciting global change in how laying hens are housed and managed. Some problems are solved but others arise, particularly questions about how to balance animal welfare with the need to reduce the effects of livestock production on the environment and on biodiversity.

Personal history

To the bemusement of my family, I grew up with a particularly strong empathy with animals and the obvious way to pursue this calling seemed to be to apply for a place at a veterinary school. In preparation for imagined University interviews I quickly acquired a Saturday job in a small animal practice in Cardiff. However, after two years of wiping tables, mopping floors, adding up the petty cash and disposing of dead bodies in bin bags I began think again. By that time I was reading the works of Jane Goodall and Dian Fossey, who were studying chimps and gorillas in Africa. My ambitions were realigned and I applied to do Zoology instead. By luck (or rather *that intersection where preparation meets opportunity)* the person who interviewed me after my

CONTACT Professor Christine Nicol cnicol@rvc.ac.uk Royal Veterinary College, Royal College Street, London NW1 0TU, UK

Oxford entrance exam was Professor Marian Dawkins, herself a previous recipient of the Gordon Memorial medal. During summer vacations I helped Marian with some of her earliest preference tests with hens, but I was not considering a career in research at this time. Nor did it turn out to be feasible to head to Africa. All was not lost however, as Dr Marthe Kiley-Worthington agreed to take me on as a pupil, working with and studying her horses who were integrated into her ecologically-based farming system. Marthe took me to some of the first meetings of the Society for Veterinary Ethology (which later became the International Society for Applied Ethology), and showed me that research could be fun. So when I returned to Oxford and Marian asked if I wanted to do a PhD, I agreed with enthusiasm. Marian wrote to the Ministry of Agriculture, who granted funds for a project on the welfare of battery hens. That's how things were done in those days. I started with no more than a project title. Before completing the write-up of my PhD I read about a lectureship in animal welfare at the University of Bristol. Professor John Webster had obtained funding for this post and, because all the initially-preferred candidates declined the appointment, the lectureship became mine in December 1985. I stayed at Bristol, and enjoyed nurturing a supportive and innovative group of animal welfare scientists. It was a natural home for nearly 32 years. However, in 2017 it was time for a change and I took up a new role at the Royal Veterinary College in London, welcoming the chance to work with a new set of wonderful colleagues.

Hen motivations and preferences

My PhD was concerned with the question of whether the spatial confinement of a cage system had adverse effects on the hens. Activists assumed yes, but producers argued that the birds were well-fed and cared for and that they probably adapted to the spatial restrictions. Some basic information about what behaviours hens might be expected to perform was critical to making progress in this debate. Without this knowledge, how could we know what the hens were not doing?

The study of feral domestic animals that have escaped or been released from captivity and now live freely with little or no interference from human, is a useful starting point, as feral animals will be genetically similar to those that are still farmed. In a classic study, Ian Duncan, Chris Savory and David Wood-Gush released domestic chickens onto a small Scottish island and observed how they foraged, formed small, stable groups, roosted at night and selected extremely well-hidden nest sites (e.g. Wood-Gush et al. 1978). Such careful observational work has informed the modern chicken ethogram (a list of behaviours that chickens are able to perform under unrestricted conditions).

My first approach for my PhD was to use an ethogram to describe how behaviour changed when hens were provided with more or less spatial area or height (Nicol 1987a). Not surprisingly, behaviours that occupy a lot of space such as wing flapping or body shaking were performed less often in smaller enclosures, but the next question was how much this mattered to the birds. A second experiment suggested that these basic comfort behaviours were motivated by internal cues that increased in strength during periods when the behaviours were not being performed. Just as animals become hungrier, thirstier or more tired if they don't eat, drink or sleep, it seemed that the desire of hens to stretch or flap their wings continued to increase during periods when they movements were prevented. When released from confinement after 1 or 2 months, the hens showed exceptionally high 'rebound' levels of movement (Nicol 1987b). This rebound response is not observed for behaviours such as aggression, huddling or panting which depend far more on the current situation of the animal so it is always necessary to investigate the underlying motivation for any behaviour.

Parallel work showed that hens also tended to choose larger areas (e.g Dawkins 1983), independent of group size (Lindberg and Nicol 1996). Together these different strands of research provided compelling evidence that the extreme spatial restriction of the conventional battery cage did reduce the welfare of hens.

Choice tests are particularly valuable in other contexts, particularly in establishing the relative preferences of hens for resources such as foraging or dustbathing substrates, perching, roosting or nesting sites and ramp designs, or environmental factors such as light type and intensity or temperature. For example, Schrader and Muller (2009) asked how important it was for hens to grip a perch (wrapping their feet around a rod-type design) compared with roosting at height. A neat trade-off experiment showed that the preference for elevation was much stronger than the preference for foot-wrapping – hens chose high grids over low perches.

The results of preference tests are of course only useful if we are convinced that researchers have asked fair questions that take account of the animals' perceptual abilities, and that the preferences revealed are stable and reliable. This led to some work looking at the underlying structure of laying hen choices as revealed in preference tests. At Bristol, we tested whether repeated presentation of the same items revealed consistent choices. We presented individual hens with sets of complex environments differing in provision of foraging, perching and nesting resources (A vs B; B vs C; and A vs C). The first notable finding was that the hens were highly consistent within each set. Although different individual birds had different environmental preferences, they were likely to select their preferred environment at least 5 out of 6, and often on 6 out of 6 presentations and the chickens with the most consistent preferences also chose more quickly – they seemed very certain of what they wanted (Browne et al. 2010). However, the other question addressed in this paper was whether chickens made logically '*transitive*' choices, such that a bird that preferred A over B, and B over C, would choose A over C. Transitive choice suggests that birds are evaluating options according to a consistent underlying currency. This same experiment revealed that hens did make transitive choices significantly more often than expected by chance, even when the preference tests took place over a long period of time (Browne et al. 2010). This work provides us with confidence that there is a pattern to the choices made by hens, they are not choosing rashly or randomly.

A personal goal has been to establish how hens' preferences map onto other welfare indicators. Ultimately, only a hen can tell us what really matters and so her preference (a marker of 'valence', the extent to which an event is experienced as positive or negative) can be regarded as a gold standard in welfare assessment. Of course, preferences can not easily be assessed on farms but knowing which welfare indicators are reliable proxies for positive experiences, and which genuinely measure negative experience, is an important theoretical and applied goal. In a series of experiments we have found that preference is associated with calm behaviour particularly when being handled or exposed to novel objects, more preening, less head shaking, drier faeces, and lower levels of physiological stress (Nicol et al. 2009, 2011). Since this work was conducted, there has been an explosion of interest in a new method of assessing animal emotion or affective state – based on the idea that animals in a good welfare state will be more optimistic than animals in poor welfare – just as people with depression tend to make more negative cognitive judgements. So, more recently we also looked at the relationship between optimism and preference. Although some birds were consistently optimistic and others more pessimistic, these were individual traits not strongly linked to our preference measure of valence. The study did suggest however that living in less-preferred environments disrupted the stability of an individual's tendency to be optimistic or pessimistic (Paul et al. 2022). There is clearly much more to learn about how individual judgements about the world are related to other measures of welfare.

Hen cognition

Chicks start life with sophisticated and well-developed brains. Much of their perception and cognition is innate and does not require learning. For example, chicks can keep track of numbers up to five as shown in an experiment by Rugani et al. (2009) using the innate preference of chicks to stay with a larger group of companions or stimuli compared with a smaller group. When a set of five imprinted stimuli was split into a subset of three and a subset of two that were moved behind screens, the chicks would almost universally head for the screen covering the group of three. But when further stages were introduced (e.g. a stimulus moving between the screens) chicks were still able to keep track of the number of stimuli remaining in any given place. Chicks also possess an innate understanding of the structural possibilities of objects, preferring realistic 3-D images than Escher-like images that are structurally impossible (Regolin et al. 2011).

The ability to keep track of hidden objects helps chickens when foraging for moving insects, or in keeping track of moving companions. However, the way in which chicks are reared can influence these abilities. We found that rearing chicks with opaque barriers between the ages of 8 and 12 days was important in the development of their later ability to find hidden objects or to make spatial detours (Freire et al. 2004). More recently we found that providing chicks with ramps and barriers improved their later ability to find resources, navigate and switch away from unsuccessful strategies when trying to locate companions (Norman et al. 2019).

The navigational abilities of chickens are not dependent only on their spatial memory they can also use the sun as a cue to help them locate resources. In 2003, we designed an experiment where the sun was the only consistent cue available to solve an eight-armed maze problem. The maze was situated in an outdoor location and the birds had to find food placed in just one arm, using a compass direction that was consistent for any individual bird but which differed across the experimental subjects to avoid any confounding. Every day the maze was placed in a different location within the field, rotated and cleaned. On sunny days seven of eight birds tested consistently found food using a time-compensated estimate based on the sun's position at different times of day (Zimmerman et al. 2003).

Although many of these impressive cognitive abilities are innate, hens are also excellent learners, able to acquire new information individually and indirectly by observing their companions. Some of our earliest work on hen cognition showed that birds given the opportunity to watch a trained demonstrator discriminate between a pecking key of one colour that produced a food reward, and a non-functional pecking key of a second colour, were far faster to acquire the same skill than control birds without that same observational experience (Nicol and Pope 1992). It matters who the demonstrator is however. Hens learned more from watching dominant hens than they did from watching cockerels or subordinate females (Nicol and Pope 1994). More recently, research has shown that hens can identify and follow the most skilled demonstrators (Wichman 2018).

The ease with which hens can be trained to perform simple discrimination tasks has allowed us to probe other capacities, including their capacity for self-control. In one experiment we found that hens would generally ignore pecking a coloured key that provided 3s access to food after a very short delay of 2s in favour of a second key that provided 22s access to food but after a delay of 6s. Although the increase in waiting time that must be endured appears small, it is hard even for young children to control their impulsive responses to obtain a larger reward. This capacity for self control arises in children around the age of 4 or 5 and is also present in hens, provided the payoff for waiting is sufficiently large (Abeyesinghe et al. 2005).

A final example in this section relates to the cognitive flexibility of hens, and their capacity to take multiple factors into account before generating a response. In a key experiment (perhaps the favourite of my career) we allowed broody hens to live with their chicks except during feeding time. For feeding, the chicks were divided into two groups. One group were given daily exposure to palatable food dyed a particular colour (red, for example), and a second dish containing food that was bitter and coloured separately (yellow, for example, and sprayed with a harmless quinine solution). The second group received the opposing information about the association between food colour and bitterness. The actual colours were carefully counterbalanced across the experiment to avoid innate colour preferences influencing the results. Once hens and chicks had all learnt which colour of food to eat and which to avoid, hens were then allowed to watch each group of chicks separately. When the hens observed chicks with the same information as themselves, they remained calm but when a hen observed her chicks (apparently) eating food that she judged to be bitter, then she became agitated, increasing her rate of food calling, scratching and vocalisations. The key point in this experiment was that the hens were not responding to any cues from the chicks – both groups of chicks behaved in the same way. The hens were thus taking account of their own knowledge and applying it in an attempt to influence the behaviour of their brood (Nicol and Pope 1996). We subsequently used the same approach of presenting hens with identical or conflicting information about danger to examine hens' emotional responses towards their chicks (Edgar et al. 2011).

The studies outlined briefly above demonstrate that hens have impressive innate cognitive abilities, a strong capacity to learn individually and from each other, and the capacity to adjust their behaviour flexibly to take account of multiple contextual influences. But it is also worth thinking about what hens don't seem to manage, at least in relation to some other birds and mammals. For example, in the book H is for Hawk by Helen McDonald (McDonald 2014) there is a lovely description of her surprise when her goshawk, Mabel, starts to play with her 'eyes narrowed in bird-laughter'. Although chicks show locomotor and object play when young I've never seen such social-object play in a chicken – the type of play that involves setting up a new (and currently unnecessary problem) and then seeing if it can be solved. Nor do hens engage in the types of impressive tool building, tool selection, or co-operative tool use seen in some parrots and corvid species (Wimpenny et al. 2009; Rossler and Auersperg 2023). These complex capacities appear to have value for birds of prey and parrots, but provide no adaptive advantage for a ground-foraging bird.

Another interesting question is whether hens form expectations about the world and hence whether they can be disappointed or overjoyed if events fail to meet or exceed the outcome that was predicated. In one experiment we studied how hens that were familiar with obtaining palatable food in an experimental context reacted when their food was flavoured with an unpreferred taste. The birds responded immediately by consuming less, showing that they had detected the change. However, the pattern of their response was unusual compared with other species (Davies et al. 2015). Similar experiments with rats and other mammals consistently show that rats react to a devaluing of their food with a significant and substantial drop in consumption before they revert to a new steady-state (Ruiz-Salas et al. 2020). The chickens simply dropped to a new steady-state. So although rats appear to have expectations and show a disappointment effect, chickens appeared simply to adjust to a new reality.

Continuing with the theme of animal expectations we have recently examined how *changes* in living conditions affect hens. Our question was whether a hen housed initially in relatively poor conditions (lack of enrichment, reduced space, intermittent loud noise) and then gradually exposed to improving and then good conditions (enrichment, more space, intermittent rewarding events) would show a greater appreciation and enjoyment of the good environment than a hen that had always been housed in that good environment. The converse question was whether a hen that transitioned from good to poor conditions would show more adverse responses than a hen that had always been housed in poor conditions. The welfare of the hens in the good conditions was better but evidence that the hens took account of their previous living conditions was not strong (Paul et al. 2023). Compared with rats and other mammals my tentative conclusion is that hens view the world in absolute rather than comparative terms.

Hen sentience

Information about hen cognition helps us to understand what sort of animals they are but doesn't directly tell us much about their sentience – their capacity to feel pleasure or pain. Yet although sentience is now enshrined within both EU and UK law there will no doubt be future debates about this issue. Lord Goldsmith commented that the UK's animal (sentience) bill '*recognises that animals are sentient and experience feelings in the same way humans do*'. Yet, it is far from certain that sentience is equally distributed across the animal kingdom (Mason and Lavery 2022).

In humans, the perception of pain involves more than a response to nociceptive input. The perception of pain is associated with other thoughts about the meaning of the injury, whether it is getting better or worse, the capacity for distraction and planning and decision-making around the pain (e.g. whether to take analgesics, make an appointment with a physiotherapist). These pain-related thoughts involve the cortical regions of the brain involved in planning and decision-making, alongside the older parts of the brain which process nociceptive stimuli.

So if hens can manage and make decisions around their pain (or pleasure) then this would provide evidence that cognitive processes are involved. In a study conducted at Bristol on hens that had sustained keel bone fractures we examined whether they could make decisions related to the onset of pain relief. Given a choice the hens with the keel fractures moved to hens moved to a clearly-marked location where they had on previous days experienced opioid analgesic drug administration. Despite the fact that opioids might be rewarding for other reasons, non-injured hens showed no such preference (Nasr et al. 2012). This work shows that hens do not simply respond to painful stimuli with simple reflexes but are able to appreciate that pain-relief is possible. Whether or not they have the self-awareness to add an 'I' to the 'I feel pain' sentence is another matter altogether. No-one has shown that hens pass self-recognition tests, or that they have signatures or names for themselves or their conspecifics. A hen may feel pain without being aware that she herself is doing the feeling.

Whatever their limitations, it is clear that laying hens are complex and sophisticated animals and their welfare is increasingly a matter of concern to a global human population.

Hen housing and welfare

The housing and management of laying hens has been a source of debate between producers and consumers for many years. Scientific evidence about the negative effects of cage systems, particularly spatial restriction and a lack of enrichment, has resulted in both legislative and voluntary changes in hen housing systems. In the European Union (EU) conventional (battery) cages with high stocking densities and a lack of enrichment were banned from the beginning of 2012 (Council Directive 1999/74/EC). In other countries, retailers have reached voluntary agreements with producers to phase out cage systems.

The two main alternatives to conventional cages are colony-cage systems or cage-free alternatives, including a variety of indoor barn or aviary systems, with or without veranda or outdoor free-range areas. In comparison with conventional cages, colony-cages provide hens with the opportunity to perform a broader behavioural repertoire by the inclusion of enrichments such as perches, scratch mats and nest boxes with hens housed in larger groups of around 80 birds at 750 cm^2 per bird (1999/74/EC), whilst retaining the economic advantages of conventional cages. Observational studies have confirmed that the behaviour of hens in colony cages is more varied and less restricted than in conventional cages (Appleby et al. 2002; Rodenburg et al. 2008; Li et al. 2016). This means there is ongoing consumer and activist pressure to move towards cage-free systems. In one study, we found that consumers favoured free-range eggs because they felt the hens were both happier (74%) and healthier (69%) (Pettersson et al. 2016).

The proportion of hens housed in cage-free systems has been steadily increasing in many countries. In the U.S.A, cage-free production has risen from 13% in 2017 to 24% in 2021 (USDA 2022). A rapid transition is also taking place in Europe where 55.1% of production was from in cage-free systems in 2021 and where a recent EFSA Scientific Opinion has recommended that all EU egg production should become cage-free to avoid welfare problems for hens.

For many producers and legislators, however, the decision to go cage-free is not straightforward. Cage-free systems can be more difficult to manage and can be associated with other welfare problems including higher mortality (Lay et al. 2011). Experience with managing cage-free systems can however, reduce these risks. Schuck-Paim et al. (2021) reported the outcome of a large meta-analysis of laying hen mortality from 6000 flocks across 16 countries. They concluded that mortality gradually drops as experience with each system evolves. Since 2000, there has been a 0.5% drop in cumulative mortality each year for cage-free systems and the authors argue that as management knowledge and genetics are optimised new entrants to cage-free farming will have faster downward trajectories.

However, for many producers the decision to switch to cage-free still remains finely balanced. Countries such as Canada, Australia and New Zealand that have banned (or announced plans to ban) conventional battery cages on welfare grounds view colony-cages as an acceptable alternative. Colony cages have often been reported to result in a lower prevalence of keel-bone damage for example. Our early work on this topic showed lower levels of keel damage in furnished cages and higher levels in non-cage systems where, despite increased bone strength, the risk of fractures due to collisions within the house is much greater (Sherwin et al. 2010). A quantitative survey found an average prevalence of 36% of keel fractures in furnished (or colony) cages compared with over 80% for hens kept in multi-tier systems (Wilkins et al. 2011). However, as with everything in the world of laying hen welfare, the situation is not static.

A recent meta-analysis by Rufenor and Makagon (2020), covering 49 independent studies also showed, contrary to expectation, that producers keeping hens in multi-tier aviary systems are now achieving lower fracture rates than many colony cage or single tier systems. So our intuitions are not always correct.

One reason for this improvement may be due to increased awareness of the risk of fractures and hence the implementation of changes in both rearing practices and the design of multi-tier systems. For example, rearing pullets with ramps encourages them to start using vertical structures at an earlier age, increasing their locomotor and their navigational abilities (Stratmann et al. 2022). In a study of 12 commercial flocks of pullets raised either with or without early ramp access, 52% of the ramp-reared birds later sustained keel-bone fractures compared with 65% of the control flocks. Of course these fracture levels are still too high. The risk of fractures in red junglefowl housed indoors is less than 10%. These JF birds have not been genetically selected for high egg production but I would argue that no more than 10% what we should be aiming for in cage-free systems. This is going to require a rethink of both management and breeding strategies, both of which are active areas of ongoing research (e.g. Malchow et al. 2022; Candelotto et al. 2020).

Injurious pecking is another welfare issue that can sometimes be worse in cage-free systems than in enriched, colony cages, as any bird that starts to peck others has an unlimited number of potential victims. Summarising studies that together have examined over 300 flocks the risk of being in a flock where SFP occurs is around 75% and the risk of being a victim rather than a perpetrator is 85%. One of the first applications of epidemiology to identify risk factors for behavioural welfare problems in poultry was conducted with my colleague Laura Green. A first cross-sectional analysis identified factors such as drinker type, use of the range, occurrence of disease as being associated with injurious pecking (Green et al. 2000). This work was followed by a series of case-control and longitudinal studies designed to investigate cause-effect relationships, rather than the simple associations resealed by a cross-sectional study (e.g. Nicol et al. 2003; Lambton et al. 2010; Gilani et al. 2013). Important risks identified include high numbers of diet changes, food provided in pelleted form rather than mash, and poor use of the range. But perhaps the most important conclusion from many years of work in this area is that there is no one solution and so multiple, practical, management strategies must be applied (Lambton et al. 2013; Pettersson et al. 2017). The damage caused by injurious pecking is somewhat reduced in birds that are beak-trimmed compared with hens with intact-beaks but the practice of beak-trimming itself raises welfare concerns. Future research may look more towards strategies whereby beaks are blunted during normal foraging activities. We recently looked at the effect of providing pullets with hard pecking materials. The top and side beak lengths of pullets exposed to pecking materials were significantly shorter between 6 and 12 weeks of age, though by 15 weeks the birds had lost interest in the materials (Baker et al. 2022). Further research on how to maintain interest in such pecking materials is needed. An alternative approach at an early stage of investigation may be to breed birds with beak shapes that cause less damage.

Hen genetics and welfare

Despite the best efforts of animal welfare scientists, farmers and assurance schemes to improve laying hen welfare via management changes, there are also genetic components to problems such as keel bone fractures, injurious pecking and (as mentioned above), beak shape. These are issues that it is hard for the public to engage with, information about genetics is much less salient than a photo of a hen in a cage. Breeding companies are producing birds for different markets and for producers who are understandably focussed on economics and productivity. This is not to say that welfare is not considered as a breeding goal, but the weight that is given to this is rarely made clear.

This problem was explored in a paper which brought together the perspectives of ethicists, breeding companies and animal welfare scientists (Fernyhough et al. 2020). One of the conclusions was that:

A level of transparency with regard to welfare traits (bone health, cannibalism, morbidity) concomitant with the current level of transparency with regard to productivity traits should be possible

After all, each of the major genetics companies is selecting on these traits and therefore must also be measuring them. Such data may be influenced by many factors, but the same can be said for the productivity measures that are already freely available on each company's website. Increased transparency about the genetic profiles of layer breeds would make it easier to apportion responsibility to the various actors within the supply chain. Producers, retailers and assurance schemes could begin to select, or require, the use of breeds based on welfare performance. In turn, these welfare measures become important points of difference, which could help to drive genetic improvements in welfare similar to those seen in egg production – but, crucially, only if there is sufficient retail and/or consumer demand for higher welfare traits.

In conclusion, the scale of research into poultry welfare is increasing rapidly and globally and many of the problems associated with keeping hens in non-cage systems may be solved by a combination of improved rearing practices, diet, house design and communication with breeding companies. Despite the prevalence of free-range systems in the UK I believe the welfare of hens is often better in cage-free systems that have access to protected areas with fresh air and natural light, but where birds are not exposed to predators, rain, cold and mud. The continuing risk posed by HPAI may also prompt a reassessment of whether veranda-based systems might provide a better and more sustainable solution for good hen welfare than an idealised view of free-range.

Conclusion

My career has been devoted to animal welfare, a subject that I still care about greatly. And yet I also recognise that people want safe, affordable, high quality animal-derived foods, produced in ways that protect rural livelihoods. How can we meet these aspirations and also get rid of the most negative impacts of livestock production on the environment and protect biodiversity? As the cost of inputs continues to rise against a background of pandemic and war, it will be a challenge for animal scientists to meet these intersecting demands. We should at least strive to identify areas of work that have simultaneous and beneficial effects on the diverse issues that concern people (Nicol 2021). In the context of laying hens, an example of a win-win solution would be the selection of birds with naturally blunter beaks which could reduce costs, wastage, pain from feather pecking and beak trimming. Where this is not possible we must identify, analyse and quantify points of opposition and goal divergence. Balmford et al. (2012) have convincingly argued that livestock production is more damaging to wild nature than any other human activity and they strongly advocate a Land Sparing approach, with intensification of food production per unit area. This may be another reason to favour veranda-based systems over free-range.

Disclosure statement

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