

Key features of 'environmental fit' that promote good animal welfare in different husbandry systems

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Summary

In animal production there are two core dimensions to environmental fit, one that centres on the capacity of the environment to meet an animal's needs and the other concerns the capacity of the animal to match or 'fit' the environment. Efforts to increase capacity in both of these dimensions can contribute substantially to the continuous improvement of animal welfare within different livestock production systems. Achieving this will require an integrated approach that combines genetic, environmental and management strategies.

Keywords

Animal adaptability – Animal fitness – Animal welfare – Environmental fit – Extensive production system – Intensive production system.

Introduction

The term 'environmental fit' in the context of animal welfare could be defined as the capacity of the production environment to meet the animal's specific physiological, behavioural and emotional needs. Implicit in this definition is the premise that we have a good understanding of the needs of production animals. Whilst there are still gaps in our knowledge, significant advances continue to be made (1, 2, 3, 4, 5, 6).

Recognising the inherent needs of animals is central to the optimal design and management of animal production systems. However, this has often been overlooked, as exemplified in the design of some housing systems for livestock (e.g. dry sow stalls) and, indeed, also in some husbandry or management practices. As sentient creatures, animals would clearly prefer not to experience pain, yet surgical procedures are routinely performed on livestock without pain relief (7). Some procedures, such as tail docking in pigs and beak trimming in chickens, have been implemented to mitigate the harmful effects of specific social behaviours that can increase as a consequence of the production/housing system (8, 9). Many such areas require attention. Moreover, public interest in and concern about animal welfare are influencing the rate of change and

acceptance of the central argument that animal needs must be met in future farming enterprises.

The definition of 'environmental fit' provided above emphasises environments that optimise livestock production. However, there are two fundamental dimensions of environmental fit that are not primarily production-orientated; namely, the capacity of the environment to meet the animal's needs and the capacity of the animal to match or fit the environment. In the history of livestock production, there have been some notable failures due simply to the fact that the animals were not suited to the environment; for example, the unsuccessful attempts to introduce *Bos taurus* cattle breeds into sub-tropical northern Australia. Being of temperate origin, these breeds could not rapidly adapt to the harsher climatic, nutritional and parasitic (e.g. ticks) challenges in the sub-tropical environment. In stark contrast, when *Bos indicus* cattle were introduced, they thrived by virtue of their superior tropical adaptation characteristics (10).

It follows, then, that identifying and selecting animals that fit the production environment is equally as important as optimising the production environment for the genotype of the animal. An ongoing commitment to optimising both of these elements of environmental fit underpins the concept

of continuous improvement in animal welfare (Fig. 1). Often treated as independent, these components of environmental fit can also be seen as synergistic. Of relevance here is the question of how selection and breeding may alter the ranking of or priority attached to particular animal needs within a specific production environment.

The aim of this paper is to examine these dimensions of environmental fit in more detail and to discuss their relevance as strategies to advance animal welfare in farming systems.

Improving animal fitness and adaptability

'Fitness' in a general sense refers to the capacity of the organism to survive and pass on its genes to subsequent generations (11). However, as highlighted by Barker (11), there is no consensus about the specific definition as it varies depending on whether it is used to describe the genotype, individual or population. Fitness is similar to, but not synonymous with, the concept of adaptability, which Endler (12) defined as the degree to which an organism, population or species can remain or become adapted to a wider range of environments by physiological or genetic means. It would be reasonable to assume that, in this definition, ontogenic adaptive changes would also include those that are behavioural as well as physiological in origin. Thus we can see two timeframes for the expression of fitness: the first is the capacity of the individual to adapt to dynamic environmental conditions within its own lifetime, and the second, the capacity of a population to adapt to its environment over a number of generations through genetic change.

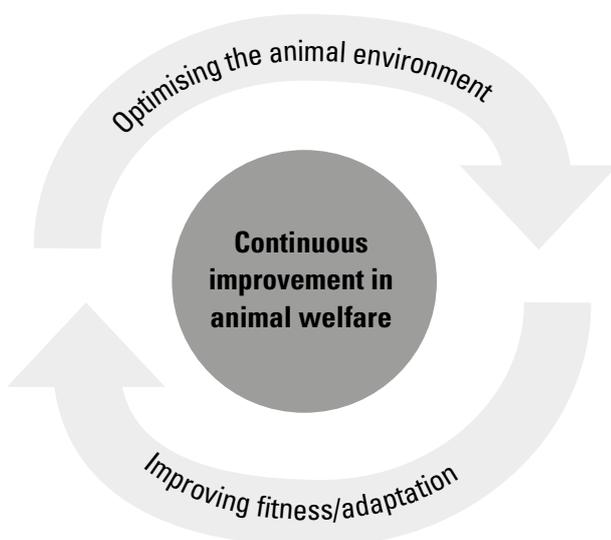


Fig. 1
Strategies to achieve continuous improvement in animal welfare

In general, fitness traits have generally been defined as those relating to either the survival (including longevity) or fertility of the individual (13). This of course encompasses a wide range of functional traits, including disease and parasite resistance, heat/cold tolerance, behavioural and metabolic adaptation to variations in food supply, fearfulness, fertility and fecundity (14, 15).

Historically, the most profound change in adaptation in livestock species occurred through the process of domestication, which enabled animals to adjust to captivity and regular human interaction (16). The early emphasis was on behavioural modification, particularly in relation to reduced fearfulness (16). However, as artificial selection gained momentum, the emphasis shifted to productivity and efficiency traits such as growth, feed conversion efficiency and product yield and quality. Tremendous genetic gains have been realised in these traits; however, these have come at a cost – in some cases to the fitness of the animal, as evidenced by some antagonistic associations between production and fitness traits (13, 17, 18, 19). Commonly cited examples include the negative genetic associations between milk yield and fertility in the dairy cow and the increased incidence of leg weakness, lameness and reduced activity as a consequence of intense selection for growth rate in broilers (13, 17, 18, 19). Consequently, over the last two decades, fresh attention has been given to fitness traits in livestock breeding programmes.

Fitness traits are now justifiably included in the breeding objectives or selection indices for some species. Notable examples include the measurement of longevity/survival and fertility phenotypes (e.g. conception rate, gestation length) in the dairy cow (20) and parasite resistance in sheep (21). Nevertheless, there is still a considerable way to go before this becomes the norm across all livestock species. Moreover, the rate of progress towards more balanced breeding objectives or selection indices that include both production and fitness traits is slow. This is because of a low or unknown heritability of some fitness traits and a paucity of practical phenotypic measures that enable high-throughput phenotype assessments of large numbers of animals (13, 20, 22).

There has also been considerable progress in the development of genetic approaches that aim to improve animal welfare directly. For example, D'Eath *et al.* (23) and Turner (9) have published comprehensive reviews on selection for behavioural change to reduce the expression of harmful social behaviours in pigs (e.g. aggression, tail-biting) and poultry (e.g. aggression, feather-pecking, cannibalism). More recently, Canario *et al.* (24) also reported on the genetic capacity for behavioural adaptation to acute and chronic physical and social challenges in pigs, poultry, cattle and fish. These authors emphasise that it is essential to consider responses to both acute and longer-

term stressors when quantifying an animal's capacity to behaviourally adapt, as their responses will be underpinned by different regulatory mechanisms. For example, in ruminants, the behavioural responses to human presence and handling (acute) will differ markedly from those expressed during chronic exposure to higher environmental temperatures. Whilst there are clear opportunities for improvement, the strategy of genetically modifying the behaviour of the animal has, not surprisingly, invoked some ethical concerns, even though it could be argued that it is an extension of the process of domestication. However, Sandoe *et al.* (17) and D'Eath *et al.* (23) contend that this approach is justified on utilitarian grounds if it results in improved welfare and quality of life and if it does not fundamentally alter the inherent nature or behaviour of the animal.

The development of genetic tools that can be applied to avoid the need to perform surgical husbandry procedures on livestock represents another significant advance. In Australia, the procedure known as mulesing is performed on young lambs to reduce the risk of fly strike. This procedure involves surgically removing the wool-bearing skin around the breech and tail and causes significant pain and distress for up to 48 h after the procedure (25). As an alternative to mulesing, breeding for fly-strike resistance offers a viable long-term solution. To that end, Smith *et al.* (26) reported significant phenotypic correlations (0.22) between breech morphological characteristics (e.g. skin wrinkle, degree of accumulation of urine and faeces) and breech fly strike. This finding has provided the impetus for the generation of estimated breeding values (EBVs) for these breech traits, which are now available to sheep breeders, enabling them to use rams that are genetically less susceptible to fly strike (27). Dehorning and disbudding of cattle and calves is another painful husbandry procedure that is widely practised in both beef and dairy production (28). Breeding for polledness is the obvious long-term solution but this will take some time, particularly in some breeds (e.g. Holstein and Brahman), where the horned condition is the prevalent phenotype (29). However, the rate of genetic change may be accelerated through the use of gene marker technologies (30), which enable the identification of polled cattle for breeding at a much earlier age.

Optimising the production environment

The term 'environment' in this context is quite broad in scope as it encompasses the physical conditions and resources provided to the animal but also the quantitative and qualitative aspects of animal management. The intent here is not to cover all of these factors but to examine some specific advances and challenges relevant to the optimisation of the animal production environment.

Intensification of livestock production

The shift towards intensive pig, poultry and cattle production systems in the latter half of the last century yielded significant gains in production efficiency but has also evoked enormous debate and controversy. The key elements of intensification of livestock production have been the provision of a complete diet that meets the nutritional needs of the animal, a reduction in climatic variations through the provision of shelter and housing, a reduction in disease challenges through the creation of specific-pathogen-free systems by implementing quarantine practices, and a reduction in freedom of movement by physical restraint or crowding (2). Importantly, this standardisation of the production environment has itself enhanced the capacity to selectively breed animals for a uniform production environment. Thus, a broiler shed in North America has similar environmental conditions to broiler sheds in Australia and Europe, so that the one genetic selection programme can provide birds suited to all these regions.

In the mid-1960s, public concern was so great that the Government in the United Kingdom established the Brambell Committee to explore whether new animal welfare standards were required for intensive farming systems (31). Such public concern was not surprising, given the perceived large divide between conditions in intensive farming systems and the typical natural environments for these species. Indeed, opponents of 'factory farming', as it is often described, argue that it will never be possible to optimise these production systems simply because they are too far removed from the animals' natural circumstances. However, the future growth in the human population will require an estimated 60% global increase in agricultural productivity by 2050 (32). The total consumption of meat and milk is projected to rise by approximately 80% in developing countries by 2050, compared to estimated levels in 2015 (33). The projected rise is much more modest in developed countries, i.e. 13% for meat and 8% for milk. To service this growth in animal-derived foods, further intensification of animal production will occur, particularly in Asia (33). The question of whether this can be sustainably achieved is difficult to answer, given future constraints in natural resources (land and water), competition for cereals (human food versus animal feed) and the overarching effects of climate change on both of these factors. Furthermore, the animal welfare concerns about intensive livestock farming will remain an ongoing challenge. Whether these manifest themselves to the same degree in developing countries as has been witnessed in developed countries is also difficult to predict.

Unquestionably, the two most controversial housing elements of intensive systems have been the gestational sow stall or crate and the battery cage for chickens (34).

The central criticism of both is that the confined space limits movement and expression of normal behaviours. Behavioural expression in caged layers is further constrained through the lack of other resources, such as litter, nests and perches (35). As a consequence of the confined barren conditions, the animals experience boredom and frustration and this in turn can lead to the development and expression of abnormal behaviours, such as apparently purposeless, repetitive behaviours known as stereotypies (36).

Several alternative housing systems have been developed for both species, including group housing for sows and an array of alternatives for layer hens, such as larger furnished cages, barn and free-range systems. In comparative evaluations of these alternatives against either the conventional sow stall (37, 38) or battery cage (39, 40), scientific opinion has differed. Perhaps the best example of these differing opinions is the contrast between the conclusions of two comprehensive reviews on sow housing by Barnett *et al.* (37) and von Borell *et al.* (38). Barnett *et al.* (37) concluded that on balance the welfare needs of sows could be met by both individual stall and group housing systems whereas von Borell *et al.* (38) recommended that group housing was preferable on animal welfare grounds. The divergent opinions can, at least in part, be explained by the different weightings given to the conceptual frameworks (biological function, affective states and naturalness – see 41) used to assess animal welfare and underlying differences in the ethical values applied by the authors in their interpretations of the results (42). Differences in ethical values will always remain. However, in order to expedite the development of optimised environments for production animals, it will be necessary to reach a high degree of scientific consensus about the application of these different conceptual frameworks when assessing animal welfare. Conceptual convergence and therefore greater standardisation of welfare assessment methodologies is an obvious solution (43), and indeed there is emerging evidence of its application, such as the study by Nicol *et al.* (44), who combined behavioural, physiological and animal preference measures to determine welfare in hens under different housing environments.

Finally, the productivity and economic benefits for the public and the beneficial outcomes for major aspects of animal health and welfare provided by intensive systems are manifest. However, they appear to be either unknown, downplayed or ignored by the general public and those opposed to intensive farming. The controlled environmental conditions, standardised nutrition and improved hygiene have led to improvements in animal health and welfare relative to alternative husbandry systems (45). Balancing the trade-offs between the positive and negative aspects of intensive animal farming, demonstrating welfare improvements and conveying these to consumers will remain an ongoing challenge.

Enrichment

One strategy to expand behavioural expression and reduce harmful social behaviours in barren intensive confinements is to provide environmental enrichment. Enrichment can be achieved through the provision of, for example, alternative improved housing systems, flooring substrates such as straw, and novel objects (46). Van de Weerd and Day (46) have presented useful criteria to apply when drawing conclusions about the success or otherwise of enrichment strategies. Specifically, the enrichment should increase species-specific behaviour, maintain or improve health, provide economic benefits and be practical to implement.

For example, the simple provision of straw bedding to intensively raised pigs would appear to offer the greatest benefit, through reducing harmful redirected behaviours (e.g. 46, 47, 48). Furthermore, Douglas *et al.* (49) recently showed that enriched environments may elicit more positive affective states in pigs associated with more 'optimistic' judgement biases. However, there can be practical and economic constraints associated with the use of straw bedding, particularly in slatted systems, and lameness, specifically foot lesions, may be more prevalent in straw-based systems (46, 48). The provision of enrichment to livestock, particularly in intensive systems, would appear worthwhile, especially if the criteria identified by van de Weerd and Day (46) can be fulfilled.

Strategies to enhance adaptation to production environments

In addition to classical evolutionary adaptation, ontogenic adaptation within the life of the individual is also relevant to production animals. Thus, environmental and social conditions experienced early in life as the individual goes through critical periods of development influence its subsequent physiological, behavioural and emotional characteristics in ways that can modify its resilience and capacity to cope.

Manipulating early life experience as a targeted management strategy to aid increased adaptation to production environments and practices has perhaps not received the attention it deserves, as evidenced by the scarcity of literature on the subject (50). However, when it has been applied, it has proven to be a highly effective tool. One example centres on the use of social learning in the acceptance of novel feeds in ruminants. Previous exposure to a novel feed can expedite the acceptance of that food later in life (51). Furthermore, acceptance of an unfamiliar food can be significantly enhanced in the presence of social partners, particularly dams, which have prior experience with that feed (51, 52). This may also be applied to reduce feed neophobia during supplementary feeding (51, 52) or when ruminants are introduced into feedlots (53). These results

highlight the strength of social models in the transmission of feeding behaviour and food acceptance.

Another management strategy designed to enhance cattle adaptation to feedlots is the practice known as yard weaning. It involves maintaining calves in yards after weaning at a relatively high density for five to ten days, with daily feeding (54). Yard-weaned calves display higher growth rates in the feedlot, a lower predisposition to disease and are easier to handle (54, 55). Yard weaning is now considered best practice in the Australian feedlot industry (56).

The compelling evidence of how both animal welfare and productivity in pigs and poultry can be improved through positive human interaction and stockmanship (4) is another good example of how adaptation to intensive systems can be enhanced through management strategies.

Challenges in extensive environments

In comparison to intensive systems, extensive grazing environments are considered to offer a more sustainable alternative production system for ruminants (57). They are often perceived as being more natural and therefore as posing fewer animal welfare problems (58). However, as highlighted by Petherick (58) and Dwyer (59), there is still considerable scope for animal welfare improvements in extensive grazing systems.

A key challenge in these systems is managing the interactions between climate, season and forage availability. Grazing systems also pose additional animal health issues, such as parasitism, and once again this can intersect with seasonal factors. Of real concern in the larger, more extensive pastoral systems, such as those in northern Australia, is the infrequent observation of the animals. The challenge of maximising animal health and welfare under these circumstances would appear to be extremely difficult, without additional labour and resources (58). It could also be argued that this is incongruent with the basic principles of animal husbandry. Remote automated animal monitoring

seems likely to offer a viable solution in this context and, indeed, considerable research effort is being expended on developing these monitoring technologies (60, 61).

Conclusions

Environmental fit can be defined as having two fundamental dimensions, one that centres on the capacity of the environment to meet the animal's needs and the other involving the capacity of the animal to match or fit the environment. Strategies that aim to increase the capacity in both these dimensions are central to the continuing improvement of animal welfare within livestock production systems. To that end, breeding livestock for improved adaptation and fitness is paramount, and functional or fitness traits should receive greater emphasis within the breeding objectives of genetic improvement programmes. The likely expansion in the intensification of livestock production to service the growing human demand for food will pose significant animal welfare challenges. The application of innovative management and housing solutions to enhance and enrich the lives of animals in these systems will be crucial in addressing these challenges. In extensive pastoral systems, there is likely to be a greater emphasis on animal monitoring to enable more informed and rapid decision-making about animal welfare.

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Les principales caractéristiques de l'aptitude d'adaptation environnementale et leurs effets sur un bon bien-être animal dans différents systèmes d'élevage

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Résumé

En production animale, l'aptitude d'adaptation environnementale comporte deux dimensions centrales : la première concerne la capacité d'un environnement donné à répondre aux besoins des animaux, la deuxième concerne l'aptitude d'un animal à s'intégrer dans son environnement. Les efforts visant à accroître les capacités de chacune de ces deux dimensions peuvent contribuer de manière substantielle à l'amélioration continue du bien-être animal au sein des différents systèmes de production animale. La réalisation de cet objectif passe par une approche intégrée associant des stratégies génétiques, environnementales et de gestion.

Mots-clés

Adaptation environnementale – Bien-être – Bien-être animal – Capacité d'adaptation de l'animal – Indice de reproduction animale – Système de production extensif – Système de production intensif.



Principales atributos de la «aptitud ambiental» que favorecen el bienestar animal en diferentes sistemas de producción

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Resumen

En producción animal hay dos dimensiones básicas de la aptitud ambiental, una que remite a la capacidad del medio para satisfacer las necesidades del animal y otra que tiene que ver con la capacidad del animal para encajar en el medio, o ser «apto» para él. Las medidas que favorezcan una mayor capacidad en estas dos dimensiones pueden contribuir sustancialmente a una continua mejora del bienestar de los animales en distintos sistemas de producción ganadera. Para lograrlo se precisa un planteamiento integrado, que combine estrategias genéticas, ambientales y zootécnicas.

Palabras clave

Adaptabilidad animal – Aptitud ambiental – Aptitud de los animales – Bienestar – Bienestar animal – Sistema de producción extensiva – Sistema de producción intensiva.



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