A national framework for effective environmental enrichment for Australian livestock industries.

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Project leads

Dr Peta Taylor, The University of New England, Armidale, NSW 2350
Dr Caroline Lee CSIRO Armidale, NSW 2350

In collaboration with
Dr Peggy Schrobback, CSIRO
Dr Megan Verdon, University of Tasmania
Dr Mini Singh, The University of Sydney
Dr Ellen Jongman, University of Melbourne

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Executive summary

Background: The Australian public is becoming increasingly interested in how their food is produced, often with a focus on animal welfare. As such, industry can provide assurance of welfare standards with science-based evidence. Livestock industries are under increased scrutiny from welfare lobby groups, due to the perception that animals are restricted from expressing their full repertoire of natural behaviours. The provision of environmental enrichment has the potential to safeguard and improve welfare. However, the effectiveness of enrichment programs are often unknown or inconsistent, showing either positive, neutral or detrimental effects to welfare(Nicol, 1992; Gordon and Forbes, 2002; Taylor et al., 2015b; a). There is a need to understand the effectiveness of specific enrichments provided to all livestock species in an Australian context. We proposed the development of a National framework that outlines the characteristics of effective enrichments across a range of environments and livestock species in relation to the costs, benefits and practicalities of implementing such programs is required for evidence-based improvements and demonstrated commitments to animal welfare. To date, the focus of environmental enrichments has been mainly on the more classically intensive industries such as poultry and pig production, however, the beef and dairy cattle and wool and sheep meat systems also have intensive components such as feedlots and long-distance transport that would benefit from the development of a framework. We developed a literature review of farm animal welfare enrichments to identify effective enrichment practice; surveyed industry on the perceived benefits and costs associated with enrichment practices; and identified gaps in the literature and available data required to estimate the net social benefit of farm animal welfare to the Australian public. The review fed into a National framework for effective enrichment for Australian livestock industries.

Project Aims

i) Identify knowledge gaps, research priorities and opportunities for effective enrichment programs in Australian livestock industries.
ii) Investigate the private benefit-cost analysis of effective enrichments programs identified in the review.
iii) Develop a theoretical framework to identify and demonstrate practical and effective enrichment across intensive components of the livestock industries in an Australian context.

Methodology

Researchers with relevant expertise contributed to the review to ensure the relevant species and contexts were reported. The review considered effective enrichment as improvements to biological functioning, affective states, stress resilience and/or expression of behaviours. Importantly, the relationships between these aforementioned indicators will be taken into consideration.

The review considered

- Various types of enrichment (e.g. physical, social)
- Underlying characteristics (e.g. novelty or mimicking aspects of the natural environment)
- Major factors that may impact the effectiveness of enrichment, such as age/stage of development, density and availability of enrichment.
- Net-private benefit of effective enrichments
- Enrichment efficacy, including negative, positive and neutral impacts on animal welfare

Livestock industries included in the review and collaborators

- Gestating and farrowing sows, Dr Megan Verdon, University of Tasmania, Tasmania
- Meat chickens, Dr Peta Taylor, University of New England, Armidale
- Laying hens, Dr Mini Singh, The University of Sydney, Camden
- Feedlot cattle, Dr Caroline Lee, CSIRO, Armidale,
- Feedlot sheep, Dr Ellen Jongman, Animal Welfare Science Centre, University of Melbourne, Parkville

A review of the literature of effective environmental enrichments for Australia intensive livestock industries

Taylor, P.S. [1], Verdon, M.[2], Singh, M. [3], Jongman, E. [4], Lee, C. [5]

[1] Environmental and Rural Science, Faculty of Science, Agriculture, Business and Law, University of New England, Armidale, New South Wales, 2530, Australia.
[2] Tasmanian Institute of Agriculture, Faculty of Science, Engineering and Technology, University of Tasmania, Tasmania, 7320, Australia.
[3] Sydney School of Veterinary Science, Faculty of Science, The University of Sydney, Camden, NSW 2570, Australia.
[4] Animal Welfare Science Centre, Faculty of Veterinary and Agricultural Science, University of Melbourne, Parkville, VIC 3010, Australia.
[5] Agriculture and Food, Commonwealth Scientific and Industrial Research Organisation, Armidale, New South Wales, 2350, Australia.

Environmental enrichment has been utilised to increase complexity in barren environments (Maertens et al., 2004), improve productivity (Klont et al., 2001; Adeniji, 2012), reduce abnormal behaviours (Mason et al., 2007; Hartcher et al., 2015) and to meet community expectations (McPhee et al., 1998; Powell and Bullock, 2014). In this review we report the effectiveness of social, physical, sensory, cognitive and nutritional enrichments on the welfare of cattle, sheep, chickens and pigs housed in intensive systems. There are various definitions of environmental enrichment (Chamove, 1989; Newberry, 1995b; Boissy et al., 2007; van de Weerd and Day, 2009; Mills and Marchant-Forde, 2010). While the overarching principal of environmental enrichment is to improve animal welfare (Newberry, 1995b; Beattie et al., 2000a; Mason, 2008), often the impact of environmental enrichment on the state of the animal is not quantified (Mellen and Sevenich MacPhee, 2001). Consequently, the term environmental enrichment has been used to describe changes to a captive animal's environment, rather than relate to the actual impact on the animal *per se*. In this review, we use the term '*effective enrichment*' to describe a change to an animal's environment that *positively* impacts either the physical and/or mental state of an animal. This definition places the emphasis on the impact of the change, rather than the intent. Positive consequences of environmental enrichment may include a reduction of negative affect, experiences of positive affect, improvements to health and/or biological functioning and/or an increased expression of behaviours that an animal needs or wants to perform. Thus, we interpret the current scientific findings in light of three frameworks used to assess animal welfare; health and biological functioning, affective states and behavioural needs and wants.

As animals attempt to cope within a particular environment there are a number of biological responses that may be upregulated to return the animal to a state of homeostasis; such attempts can be quantified via behavioural, physiological and immunological assessments (Broom & Johnson, 1993; Moberg, 2000) and the success of such attempts to cope can be assessed by fitness characteristics (Broom, 1991; Newberry, 1995b). These assessments have been utilised to assess the impact of environmental enrichment programs (Newberry, 1995). However, effective enrichment programs assessed via the biological function framework may not provide evidence of environments that improve welfare beyond an animal's basic needs (Boissy 2007; Desire, Boissy, & Veissier, 2002). So equally, environmental enrichment programs must consider an animal's quality of life which goes beyond basic needs and promotes the provision of resources and opportunities that animal's value. We place an emphasis on both effective enrichment that meets the basic needs of animals but also those that provide beyond the basic needs. We acknowledge that some indicators of animal welfare are easier and more practical to quantify (e.g. health assessments) than others (e.g. positive affective states). Although, the rapid progress of animal welfare science has resulted in the development of valid indirect assessments of affective states (Mendl, Burman, Parker, & Paul, 2009; Forkman, Boissy, Meunier-Salaün, Canali, & Jones, 2007; Mellor, 2015a) permitting greater insight of animal welfare through the affective state framework. Furthermore, as affective states are critical evolutionary adaptations which motivate particular behaviours (Fraser and Duncan, 1998), the behavioural needs framework used to assess improvements to animal welfare is also advantageous. However, throughout this review we refrain from inferring that an increase in the expression of every natural behaviour, or providing a natural environment automatically results in positive implications for welfare and thus rely on additional assessments. For example, environments which mimic the natural environment, such as stimulus-rich, complex environments, likely permit the expression of important behaviours associated with positive affect such as exploration and play, we acknowledge this may be achieved by artificial means (e.g. novel biologically irrelevant objects) and thus remove the condition that enrichment must be natural.

The aforementioned frameworks to assess animal welfare have historically been seen as competing. But it is clear such approaches are not mutually exclusive, the dynamic interactions between affective states and biological processes are now widely recognised, particularly the association between emotion and the activation of the SAM and HPA axis (Hemsworth et al., 2015). As such, the dynamic interactions between affective states, biological functioning and behavioural needs is now recognised as fundamental to assessing and improving animal welfare. Therefore, throughout this review, greater weighting has been given to assessments of environmetnal enrichments when a comprehensive assessment of welfare is reported, e.g. more than one component such as immune function, body weight and behavioural indicators of fearfulness. Such comprehensive assessments are more likely to identify effective enrichments but additionally can highlight potential unacceptable trade-offs which are imperative to consider, for example the provision of an outdoor enrichment program may increase the expression of motivated behaviours but additionally may increase the risk of particular diseases and thus compromise health (van de Weerd et al., 2009).

Where possible, we have considered and prioritised the long-term implications of environmental enrichment programs reported in the literature, although this information was not always available. Long term implications can include positive epigenetic changes (Jensen, 2013; Bowling et al., 2018) and resilience (Zulkifli and Siegel, 1995).

This review focuses on enrichments provided to ***target natural behaviours***, enrichments that provide ***environmental complexity*** (defined here as enrichments that are constantly available, stable and not found in the natural environment or that mimic resources in the natural environment) and enrichments that increase ***novelty*** (defined here as enrichment that are replaced frequently (days – weekly) which may be biologically relevant or not). Enrichments included in this review include the provision of improvements to the quality of space however but we have not included the welfare implications of the provision of increased space nor have we included considerations for extensive housing systems.

Finally, in this review we include assessments of environmental enrichment programs only when valid and reliable Animal Based Measures (ABM) are available in the literature. ABM directly assess the outcome on the animal (e.g. indicators of thirst), compared to Resource Based Measures (RBM) (e.g. provision of water) which require the assumption that the resource provided will be utilised and have a positive impact on the animal (Appleby, Hughes, Mench, & Olson, 2011). Furthermore, ABM are preferred to RBM as the totality of the organism and environment are taken into account including genetics, age, experience and temperament (Fraser, 2008a) and focuses on the impact of the EE on the state of animal rather than the intent.

Method

Researchers with relevant expertise from the relevant Australian livestock industries reviewed the literature relevant to enrichment programs that targeted improvements to animal welfare; farrowing and gestating sows - Dr Megan Verdon; laying hens - Dr Mini Singh; meat chickens - Dr Peta Taylor; feedlot cattle - Dr Caroline Lee; feedlot sheep Dr Ellen Jongman.

Outcomes of each welfare indicator for each citation were collated in an excel spreadsheet and variables from each study were noted including; density of enrichment, characteristic of enrichment, if (and when) interaction with the enrichment was assessed, impact on productivity (where assessed) and various experimental conditions including if the study was Australian, research or commercial conditions, the number of treatments and replicates, age of the animals, duration of treatment, sex, stocking density, and previous experience. Specific welfare outcomes were listed in the spreadsheet (e.g., salivary cortisol) but were pooled in regard to their assessment of i) health and biological functioning, ii) affective states, iii) behavioural needs, or iv) behavioural wants (Table 1).

Only animal-based measures were included in the review. Enrichments did not include quantity of space only consideration to improvements to the quality of space and provision to an outdoor area or other more extensive housing systems were not considered.

Table 1. Assessment approach and associated indicators of animal welfare.

Assessment approach	**Welfare indicators**
Health and biological functioning	• Stress physiology (e.g., cortisol, ACTH) • Fitness characteristics (growth, morbidity/immune function and reproduction) • Injury (e.g., scratches, foot pad dermatitis)
Negative affective state	• Negative affect (e.g. fearfulness) • Abnormal and aggressive behaviours (e.g., feather pecking, tail biting)
Positive affective state	• Positive affect (e.g., serotonin) • Positive mood (e.g., cognitive bias)
Behavioural needs	• Behavioural that are necessary for life (e.g., drinking and eating) – Ultimate behavioural needs • Failure to express behaviours will result in increased distress - Proximate behavioural needs
Behavioural wants	• Behaviours that are expressed opportunistically • Behaviours that animals are motivated to express but do not show an increased stress response when the opportunity is not provided

The characteristics of the enrichment were noted for each study, including enrichments that target natural behaviours, increased environmental complexity or provided novelty; definitions of each characteristic are provided in the glossary in appendix 1. Additional characteristics included social, physical, sensory, cognitive and nutritional enrichments (Table 2).

Table 2. Characteristics of enrichments, physical, cognitive, nutritional, sensory and social and examples of specific enrichments that fall under each category. Of note, categories are not mutually exclusive, for example deep straw may be both physical and nutritional.

Physical	Cognitive	Nutritional	Sensory	Social
Substrates Perches Climbing structures Refuges Nest/Den Shade* Bedding*	Novel experiences Mental stimulation Novel Objects	Novel food items Puzzle feeders Scatter feeders Hidden food Hanging food	Odours Music Vocalisations Noise makers Mirror Lighting*	Conspecifics People and stockpersons

* only included when relevant for natural behaviours or novelty

Descriptive analysis of the available literature

Most of the available literature was from poultry (Figure 1). As expected more traditionally extensively housed species had few relevant citations (Figure 1).

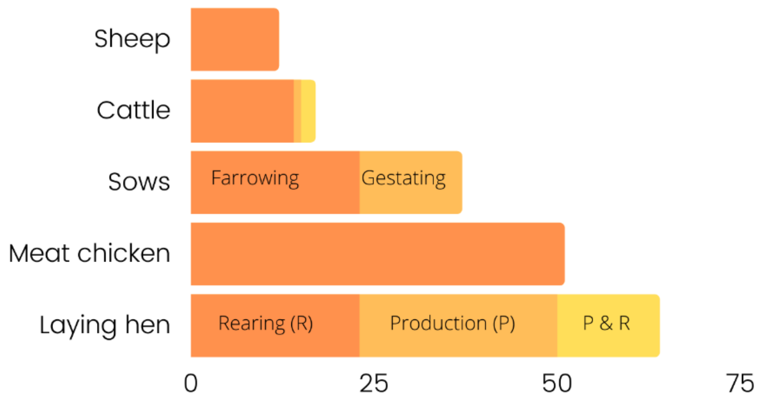

Figure 1. Number of relevant studied identified throughout the review of relevant literature by authors. Cattle; dark orange indicates feedlot beef cattle and includes one relevant dairy cow paper (light orange) and two dairy calf papers (yellow).

Few studies were conducted within Australia (Figure 2). Most of the research was conducted in research settings rather than in commercial conditions (Figure 3). Of note, 59.3% of studies in commercial conditions and 77.1% of studies in research conditions improved animal welfare.

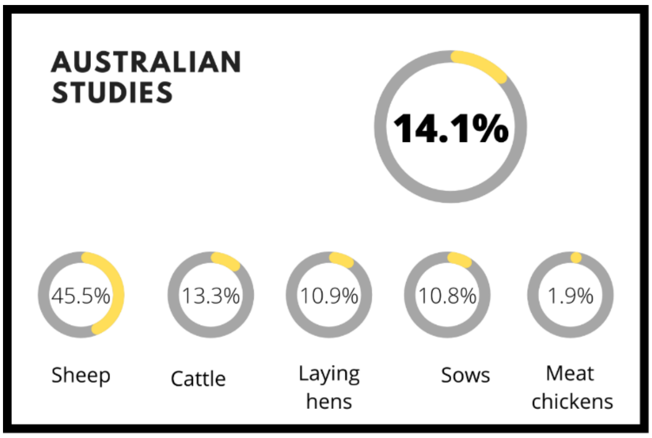

Figure 2. Percentage of studies identified in the literature that were conducted in Australia.

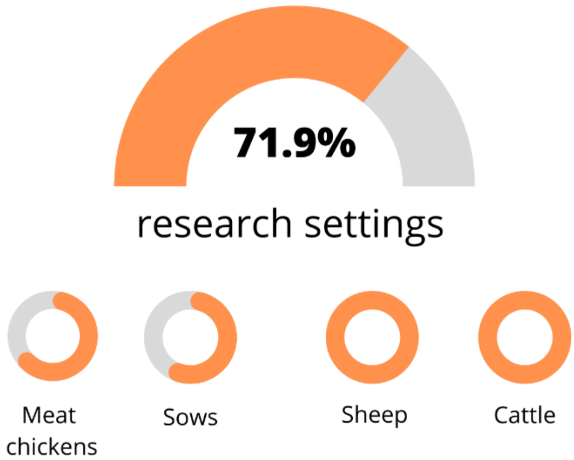

Figure 3. Percentage of studies identified in the literature that were in research settings (orange proportion of each image) relative to in commercial conditions (grey proportion of each image). Of note, this was not assessed for laying hens.

Characteristics of enrichment

Most of the enrichments provided targeted natural behaviours (70.0% of all citations), one quarter provided environmental complexity (25.4% of all citations) and few provided novelty (5.7% of all citations); see industry specific reports for industry specific reports (appendix 2). Furthermore, the majority of the enrichments were physical enrichments (71.3%), followed by nutritional (17.1%) and sensory (9.3%) enrichments. Few social (0.9%) or cognitive (1.4%) enrichments were investigated.

Assessments of enrichment

The most common welfare assessment was behaviour (80.8%; behavioural needs 47.7%; behavioural wants 33.2%) followed by health and biological functioning (56.4%). Negative affect was assessed in 34.2% of studies but few studies assessed positive affect (2.6 %). More than one third of all studies assessed the impact of enrichment on productivity, except for the laying hen literature where only 11.6% of studies assessed egg production and/or quality.

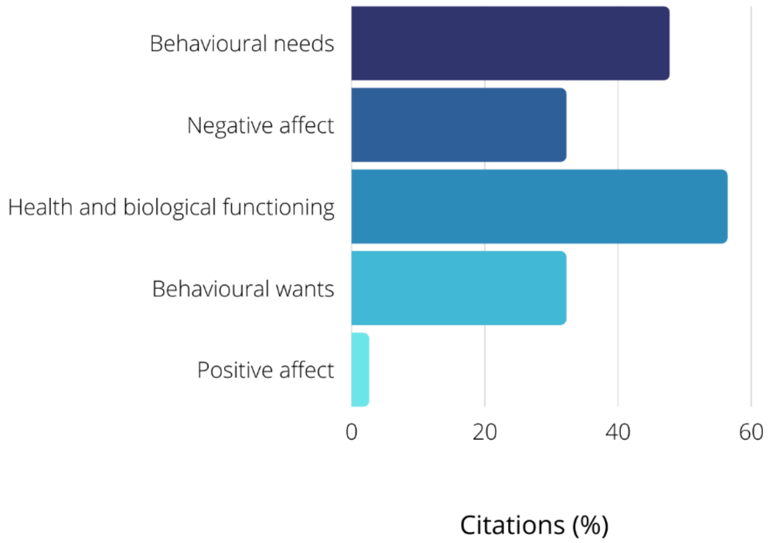

Figure 4. Proportion of relevant citations that assessed behaviour (needs and wants), affect (positive and negative) and/or health and biological functioning. Note: categories are not mutually exclusive (e.g. a citation may have assessed both health and negative affect)

Effective enrichments

More than half of all of the enrichments provided improved animal welfare (64.7% species data pooled; cattle 100%; laying hen 68.6%; meat chicken 50.6%; sheep 100%; sows 63.2%).

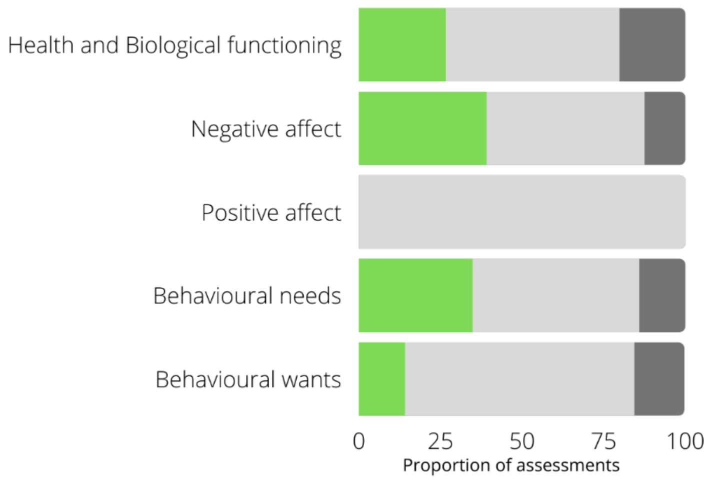

Figure 5. Proportion of assessments that were positive (green), neutral (light grey) or negative (dark grey) for welfare.

It is also critical to assess the potential negative impact that some enrichments may have on animal welfare. There were species differences (see appendix 2), however overall 20% of health indicators, 13.9% of mental health, 19.2% of natural behaviours were negatively impacted by enrichment.

Whilst not all studies quantified the impact on productivity, of those that did 72.2% of enrichments provided did not negatively impact productivity. However, of note only 22.2% led to improvements in productivity.

Effective enrichments for sows in the gestation environment

Enrichments that target the sow's natural behaviours

Nutritional enrichments that target natural behaviours

Nutritional enrichments make up 14 of the 16 studies reviewed. Straw is the most commonly provided ingestible substrate, either in a rack (Krause et al., 1997; Stewart et al., 2008; Elmore et al., 2011) or on the floor as bedding (Broom et al., 1995; Whittaker et al., 1999; Merlot et al., 2017; Merlot et al., 2019; Roy et al., 2019; Tatemoto et al., 2019), with fewer studies providing straw in a trough around feeding (Spoolder et al., 1995; 1996; Quesnel et al., 2019). Chronic feed restriction and the inability to express foraging behaviour are a major cause of the development of stereotypies in gestating sows (Lawrence and Terlouw, 1993). Activity levels and oral stereotypies are lower around feeding times when straw bedding is provided (Whittaker et al., 1999; Tatemoto et al., 2019), but straw is not reported to affect activity outside of feeding times (Whittaker et al., 1999; Stewart et al., 2008; Roy et al., 2019). Indeed, sows spend 47-72% of their time interacting with straw following feeding compared to 9% during non-feeding periods (Spoolder et al., 1995; Whittaker et al., 1999; Stewart et al., 2008; Elmore et al., 2011). The provision of fresh straw on the floor prior to a morning feeding reduces sow stereotypies up until early afternoon (1300 to 1500 h; Whittaker et al., 1999), but not into early evening (1730 to 1830 h; Tatemoto et al., 2019). Providing straw in a rack, however, has no effect on stereotypies over the course of a day (Stewart et al., 2008). There is no indication that straw enrichment effects sow weights or litter sizes (Spoolder et al., 1996; Merlot et al., 2017; Merlot et al., 2019; Quesnel et al., 2019), but recent research provides physiological evidence of reduced stress and improved immune function in sows housed on deep straw (Merlot et al., 2017; Merlot et al., 2019) suggesting that this type of enrichment may also offer non-nutritional benefits to sows.

Stewart et al. (2008) is the only study to report on the effect of straw on aggression after mixing unfamiliar sows. The authors found that straw in a rack increased aggression in large dynamic pens, although overall levels were low. The presentation of straw and method of feed delivery affect aggression levels around feeding (Verdon et al., 2015). For instance, providing straw in a rack increases sow and gilt aggression at the rack but reduces aggression at an electronic sow feeder, however, straw in a rack does not reduce aggression when gilts are fed simultaneously in feeding stalls (Krause et al., 1997; Stewart et al., 2008). Sow aggression around feeding is higher when straw is provided on the floor and sows are floor fed, compared to floor feeding without straw (Whittaker et al., 1999). Limited access to straw at a rack may create competition and consequently increase aggression, whereas straw on the pen floor may increase the likelihood of encounters between sows post-feeding as unsatiated animals use the straw to channel a persisting feeding motivation into foraging behaviour (Verdon et al., 2015).

The recently developed 'Sow Block' (Ridley Agriproducts™, Queensland, Australia) may present an alternative nutritional enrichment to foraging material provided to gestating sows. The product is best described as a nutritional lick block (27.6 × 26.0 × 23.4cm, 20 kg), mostly comprised of molasses (Jongman and Morrison, unpublished). There are no published data on the use of Sow Blocks as an enrichment for gestating sows. Unpublished reports suggest that the duration of time sows spend interacting with the blocks is higher than a wooden block of similar size, but not different to the duration interacting with Lucerne hay or straw enrichments, and less than the duration spent interacting with silage (Jongman and Morrison, unpublished). Published research in piglets reports that the frequency of contacts with a brick shaped nutritional block is 31% higher than a cube or wedge-shaped block (Winfield et al., 2017). We recommend caution when extrapolating research from young pigs to the sow, due to differences in physical and developmental states that may affect behavioural motivations. For example, Winfield et al. (2017) suggested the brick-shaped block provided a wider surface area that allowed piglets to simultaneous interact with the block in a similar way to a litter co-operatively massaging the sows udder prior to suckling bouts.

There is no evidence that the provision of Sow Blocks reduces the duration of foraging behaviour observed post-feeding, or aggression post-mixing and around floor-feeding (Muller et al., unpublished; Jongman and Morrison, unpublished). Their effects on skin injuries are less clear. Compared to sows housed under barren conditions, Muller et al. (unpublished) found reduced skin injuries at day 3 post-mixing when sows were provided with Sow Blocks, but Jongman and Morrison (unpublished) found no effect of the blocks on skin injuries until day 30 post-mixing. While neither study found effects of the Sow Block on productivity (liveweight, backfat, reproduction), Jongman and Morrison (unpublished) warned of a risk of nutritional scours if the Sow Block became wet. More research is required to fully elucidate the value of the Sow Block as a nutritional enrichment for gestating sows.

Enrichments for sows that increase environmental complexity

Recent years have seen the emergence of research providing enrichment objects to gestating sows, such as ropes, sticks, disks, rubber mats, and wooden blocks (Elmore et al., 2011; Horback et al., 2016; Greenwood et al., 2019; Quesnel et al., 2019; Roy et al., 2019). Sows spend more time interacting with a hanging rope than a fixed wooden block and suspended rubber chew sticks, rubber mats, and plastic disks (Horback et al., 2016; Greenwood et al., 2019), but they spend more time interacting with straw than these enrichment objects (Elmore et al., 2011; Roy et al., 2019). These differences are stark; over the course of a day sows interacted with straw 35 times more often than with a rope, and 480 times more often in the period post-feeding (Elmore et al., 2011). Rotating enrichment objects can increase their utilisation (Roy et al., 2019), but there is no evidence that their provision positively affects sow welfare in terms of activity levels, skin injuries, explorative behaviour, cortisol concentrations, weight changes or reproduction (Horback et al., 2016; Greenwood et al., 2019; Roy et al., 2019), aside from one study that recorded increased play in enriched pens (Greenwood et al., 2019).

The preference of sows for straw over enrichment objects may be related to the ingestive qualities of straw and the fact that gestating sows are restrictively fed so likely to be experiencing hunger (discussed by Verdon et al., 2018). Elmore et al. (2012) found that feed restricted sows had a greater motivation to access feed compared to a rope, rubber mat or an empty trough. The finding of Roy et al. (2019) that occupation of enrichment objects was not affected by social status suggests these are not considered a priority resource. The opposite is true for straw provided in a rack (e.g., Stewart et al., 2008; Elmore et al., 2011). It is unclear whether the strong preference of sows for straw would be observed if they were not kept on a restricted diet.

Summary of effective enrichments for sows in the gestating environment

This review of the literature suggests that straw or similar substrates are the most effective enrichments for restrictively fed gestating sows in terms of reducing feelings of hunger and providing complexity to a barren environment. There is no evidence that point-source enrichment objects are either preferred by sows to straw or that they improve sow welfare. The presentation of straw can influence aggression levels around feeding with effects on sow welfare through fear, injuries, pain and stress (Verdon et al., 2015). Further research should focus on the accessibility and timing of substrate provision, as well as how these management decisions interact with feeding system, to ensure the resource does not become a source of competition and therefore primarily occupied by the dominant animals in the group.

Effective enrichments for sows in the farrowing environment

Enrichments that target the sow's natural behaviours

Physical enrichments that target natural behaviours

The primary aim of enrichments provided to sows around parturition is to facilitate the expression of highly motivated nesting behaviours. Sows start nestbuilding behaviour around 18 hours pre-partum and spend more time manipulating or interacting with enrichments in this period than during or post-parturition (Cronin et al., 1994; Thodberg et al., 1999; Damm et al., 2010; Bolhuis et al., 2018; Edwards et al., 2019). Of the 21 experiments reviewed here, 19 (90.5%) studied the effects of straw either as a single resource or in combination with other nesting materials. Sows provided with straw in farrowing crates spend 6% of their time budget interacting with the nesting material in the 18 hours leading up to parturition (Edwards et al., 2019). This increases to 16.5% if they are loose housed (Rosvold et al., 2018). The length of straw does not appear to affect nesting behaviour (Burri et al., 2009), but large amounts (15-20 kg) stimulate more nesting than small amounts (1-2 kg Westin et al., 2015a).

Straw increases the duration, frequency, and diversity of nest building behaviours compared to barren lactation housing (Cronin et al., 1994; Thodberg et al., 1999; Rosvold et al., 2018; Wang et al., 2020), but not compared to housing enriched with wood shavings (Damm et al., 2005; Swan et al., 2018) or sawdust (Damm et al., 2010; Chaloupková et al., 2011). Recent research shows that sows prefer to interact with a jute sack around parturition than with straw balls (Bolhuis et al., 2018), that sheets of newspaper are used more as a nesting material than wood shavings or straw (Swan et al., 2018), and that sows rarely interact with a manipulable and chewable object hanging in the farrowing crate (wooden device Valros et al., 2017; piece of leather Swan et al., 2018). These data suggest that an object does not need to have nutritional qualities to be suitable as nesting material for the periparturient sow, but the ability to manipulate and shape the substrate is important. Having said that, ingestible substrates such as straw may reduce oral stereotypies pre-partum (Westin et al., 2015b; Edwards et al., 2019), but further research is required to determine if this is also true for the lactation period (reduction in stereotypies reported by Cronin and Smith, 1992; no effect reported by Edwards et al., 2019).

Cortisol concentrations are lower and oxytocin concentrations higher in sows that farrow in pens enriched with straw compared to barren pens (days -1 to 35 relative to farrowing, Wang et al., 2020), and pre-partum oxytocin concentrations are higher when sows are provided with various nesting materials (sawdust, straw, tree branches, ropes) compared to one bucket of sawdust (Yun et al., 2013). Despite this, none of the 10 studies we examined found evidence that enrichment of the farrowing environment with nesting materials reduces the duration of parturition (Thodberg et al., 1999; Damm et al., 2005; Chaloupková et al., 2011; Cornou and Kristensen, 2014; Westin et al., 2015b; Yun et al., 2015; Bolhuis et al., 2018; Swan et al., 2018; Edwards et al., 2019). Evidence on the effect of enrichment on stillborn piglets is contradictory, with some studies reporting reduced stillbirths (Westin et al., 2015a; Edwards et al., 2019; Rosvold et al., 2019) and others reporting no effect (Cronin and Smith, 1992; Damm et al., 2005; Yun et al., 2015; Zhang et al., 2020). There is complexity and wide disparity in the housing design and the management of sows prior to and during parturition which may be contributing to contradictory results. Nonetheless, these data suggest that at worst the provision of nesting materials has no effect on stillborn piglets, and at best reduces stillbirths. Despite differences between studies in housing and nature of enrichments provided, there is wide consensus that enriching the farrowing environment does not affect maternal behaviours, such as positive interactions with piglets, postural changes during parturition and early lactation, frequency of nursing, or increases the risk of piglets being crushed (Cronin and Smith, 1992; Cronin et al., 1994; Herskin et al., 1999; Thodberg et al., 1999; Burri et al., 2009; Damm et al., 2010; Chaloupková et al., 2011; Yun et al., 2013; Cornou and Kristensen, 2014; Bolhuis et al., 2018; Edwards et al., 2019; Rosvold and Andersen, 2019; Rosvold et al., 2019; Zhang et al., 2020).

Summary of effective enrichments for sows in the farrowing environment

Enrichment substrates need to be provided to pregnant sows at least 18-hours prior to parturition if they are to effectively facilitate the expression of nesting behaviour. Substrates that sows can shape, such as a jute sack, wood shavings, sawdust and straw, result in the highest amounts of nest building. Features such as novelty and environmental complexity may be less important to this temporally and functionally targeted enrichment program. Emerging physiological evidence suggests that the provision of substrates to the peri parturient sow reduces stress around farrowing, and there is no evidence that enrichment negative effects productivity or maternal behaviour. Further research is required to inform the development of best practice enrichment programs for peri parturient sows (e.g., quantity, quality and frequency of replenishment of enrichment substrate). These programs may depend on the design of the farrowing environment, so the interaction between enrichment properties and the farrowing environment also requires investigation.

Effective enrichments for meat chickens

Research into environmental enrichment for meat chickens has historically focused on perches and bedding substrate, accounting for 48% and 44% of all welfare related environmental enrichment research in the last two decades respectively. Improvements to leg health has been the welfare focus of enrichment studies with assessments on gait, bone strength and common leg pathologies such as tibial dyschondroplasia. Targeted genetic selection throughout the 1990s has resulted in great improvements to leg health of meat chickens, therefore only literature from 2000 onward was considered for this review. Furthermore, only fast-growing meat chicken strains are included as this is the only relevant literature to Australian conditions.

Enrichments that target meat chicken natural behaviours

Physical enrichments that target natural behaviours

Chickens perch on elevated structures as an anti-predator tactic. However, despite some evidence that meat chickens are motivated to perch, and increased use over time, use of perches is typically low (8% of birds at one time Estevez et al. (2002); 10% of birds at one time Matković et al. (2019)). Evidence rejects the hypothesis that meat chickens want to perch at dusk (Martrenchar et al., 2000). Perches are used more by females than males (data not reported Martrenchar et al. (2000); 1.9% of females compared to 1.2% of males Estevez et al. (2002)), higher perches (15cm) are favoured more than lower perches (7cm; Estevez et al. (2002) and suspended platforms are favoured compared to more traditional perch designs (A frame, flat topped ramp, curved ramp, fixed wooden bar or suspended bar)(Bailie and O'Connell, 2016). However, evidence suggests that hay bales are the most favoured form of raised enrichment for sitting/perching (De Jong and Goërtz, 2017).

Perches can improve lying, standing, eating and sitting behaviours (Hongchao et al., 2014; Bailie and O'Connell, 2015), mild incidences of foot pad dermatitis (Karaarslan and Nazlıgül, 2018; Matković et al., 2019) and reduce the prevenance of severe hock burn (Simsek et al., 2009; Matković et al., 2019), a reduction of up to 10% when stocking density was low (Karaarslan and Nazlıgül, 2018), suggesting that time off litter is beneficial for meat chickens. Leg health has not been impacted by the provision of perches, which may reflect minimal use by meat chickens. Platforms are preferred by meat chickens (Bailie and O'Connell, 2016) evidenced by greater use (Norring et al., 2016) and have been shown to positively impact welfare by reducing the incidence and severity of foot pad dermatitis (Tahamtani et al., 2020) and fearfulness (Baxter et al., 2018a). Hay bales have been shown to lead to improvements in leg health, evident by improvements to gait scores (Bailie et al., 2013; Baxter et al., 2018a; Tahamtani et al., 2020) and shorter latency to lie (Bailie et al., 2013). There is no evidence that providing bales more than 1/44m^2 has any additional welfare benefits in terms of leg health (Bailie and O'Connell, 2014).

Strings and chains are provided to stimulate pecking behaviour of chickens. Bailie and O'Connell (2015) provided evidence that activity increases at 3 weeks of age when meat chickens are provided with string (24 × 60 mm string for 23,000 chickens) and subsequently gait score was improved. However, use of string decreased over time from 19.2 interactions in a 25 minute observation period at 3 weeks to 4.2 interactions at 5 weeks of age (Bailie and O'Connell, 2015) and Arnould et al. (2004) provided evidence that chickens show very little interest in string (less than 42 interactions with string over a 28 hour observation period). However, chickens in the Arnould et al. (2004) study were also provided with sand substrate for dustbathing which the chickens preferred and subsequently had little interest in string.

Bedding is thought to be an important resource to chickens and has been shown to improve the expression of natural behaviours. The type of substrate provided has different impacts on behaviour and welfare. Wood shaving bedding is most commonly used in Australia. The provision of clean wood shavings can increase activity immediately after distribution (Pichova et al., 2019), increase litter scratching, foraging and pecking (Baxter et al., 2018b; Pichova et al., 2019) and chickens have been shown to prefer clean wood shavings to oat hulls and straw pellets (Baxter et al., 2018b). Monckton et al. (2020) showed that meat chickens would not work for access to clean shavings suggesting that clean wood shavings is not important to meat chickens. Of note, the soiled treatment in the Monckton et al. (2020) study was minimal. Rice hulls increased resting and pecking (Villagrá et al., 2014) and improved gait score at 6 weeks of age(Çavuşoğlu et al., 2018). But has been shown to negatively impact food pad dermatitis, hock burn and plumage cleanliness (Çavuşoğlu et al., 2018) and negatively impact immune function at 18 days of age (Toghyani et al., 2010). Oat hulls are least favoured compared with straw pellets, peat and clean wood shavings but increase dustbathing, foraging, pecking (Baxter et al., 2018b). Hemp waste can reduce hock burn but worsen food pad dermatitis (Su et al., 2000). Straw is the meat chickens least favoured substrate, compared to sand, wood shavings and rice hulls (Villagrá et al., 2014) and has negative impacts on leg health, specifically foot pad dermatitis and gait scores even if the wheat straw is worked and refreshed (Su et al., 2000). Peat moss is preferred than oat hulls and straw pellets but no more preferred than clean wood shavings (Baxter et al., 2018b). The provision of peat moss increases dustbathing, foraging, pecking, sitting and preening (Baxter et al., 2018b). Sand is preferred for dustbathing, compared to rice hulls and wood shavings and meat chickens prefer to spend time on sand compared to rice hulls or recycled paper (Shields et al., 2004; Villagrá et al., 2014). Furthermore, behavioural repertoire is greater on sand than on wood shavings (Shields et al., 2005) and chickens forage, dustbathe, peck, preen and are more locomotive on sand when provided the choice between sand and wood shavings (Shields et al., 2005). Areas within the shed may be utilised to provide peat moss or sand as enrichments rather than bedding however Toghyani et al. (2010) found no welfare improvements when alternative substrates were provided (sand, rice hulls or recycled paper roll) compared to wood shavings.

Sensory enrichments for meat chickens that target natural behaviours

The provision of natural light has been shown to increase activity, standing, resting and ground pecking and subsequently improve leg health (gait scores and latency to lie) and had no negative impacts on body weight (Bailie et al., 2013). However, the impact of the differences in climate on the welfare of chickens exposed to natural light is unknown. Australia's regions with extremely hot climates may negatively impact bird welfare and the impact of natural light in Australian commercial conditions should be investigated. Lighting that mimics natural brooding conditions (dark periods at 40 minute intervals) has been shown to increase resting and reduce active behaviours but further implications for welfare are unknown (Malleau et al., 2007). Providing an environment that mimics specific components of the maternal environment may prove beneficial for meat chicken welfare as has been shown in laying hens (see Edgar et al. (2016)).

Nutritional enrichments for meat chickens that target natural behaviours

Whole wheat and maize roughage scattered on the litter has been proposed to improve activity and subsequently leg health. Although providing scattered whole wheat can increase activity (Pichova et al., 2019) there is no evidence that it can improve leg health (Bizeray et al., 2002b). The provision of maize roughage did not impact behaviour or welfare (Bach et al., 2019; Tahamtani et al., 2020). Scattering mealworms onto litter increased activity, litter pecking and scratching and food running but had no impact on fearfulness of chickens (Pichova et al., 2016).

The impact of enrichments that target natural behaviours on meat chicken productivity

Perches have been shown to improve meat quality (colour Aksit et al. (2017); protein, fat and cholesterol Simsek et al. (2009)). However, there have been negative impacts on body weight (Martrenchar et al., 2000; Su et al., 2000; Estevez et al., 2002; Aksit et al., 2017). However, the majority of studies report no impact on body weight or feed conversion ratio (LeVan et al., 2000; Martrenchar et al., 2000; Estevez et al., 2002; Heckert et al., 2002; Pettit-Riley et al., 2002; Tablante et al., 2003; Bench et al., 2016; Phibbs et al., 2019). The discrepancy is likely reflective of the variability in perch design and use between studies. Impact of platforms on productivity is unknown. Hay bales have no impact on productivity (Bailie et al., 2013; Bailie and O'Connell, 2014; Baxter et al., 2018a; Baxter and O'Connell, 2019).

There are no reported negative impacts on productivity when oat hulls or recycled paper roll is provided (Su et al., 2000; El-Lethey and Zaki, 2005; Toghyani et al., 2010; Kheravii et al., 2017; Baxter et al., 2018b). Of note, there are no production benefits of providing wood shaving bedding (Toghyani et al., 2010) however feed conversion ratio is improved when chickens are provided with pelleted straw compared with rice hulls or chopped straw (Kheravii et al., 2017).

Enrichments for meat chickens that increase environmental complexity

Physical enrichments that increase environmental complexity

The use of vertical panels has been shown to improve lying, resting, dustbathing, feeding (Bizeray et al., 2002a; b) and reduce aggression (Ventura et al., 2012) likely due to fewer disturbances (Cornetto and Estevez, 2001a) and a more uniform distribution of the pen space (Cornetto and Estevez, 2001b; Ventura et al., 2012). Vertical panels have been shown to improve leg health of meat chickens (Bizeray et al., 2002b). Vertical panels with mesh cover are more effective than frames (Cornetto and Estevez, 2001a) and providing vertical panels without mesh cover has been shown to increase fearfulness in meat chickens compared to panels provided with cover (Ventura et al., 2012). Of note, some behaviours are reduced when vertical panels are provided, such as foraging and standing (Cornetto and Estevez, 2001a; Ventura et al., 2012) and therefore may benefit from pairing with an additional enrichment to specifically target active behaviours.

There has been little investigation into the effects of providing access to a wintergarden for meat chickens. Bergmann et al. (2017) identified relationships between enrichments provided on commercial farms and welfare. Bergmann et al. (2017) found that use of wintergardens improved over time and birds were more active in the wintergarden compared to the shed. However, the wintergarden was also associated with a reduction in body weight. This investigation highlights the potential of wintergardens but reports only relationships, not causation. Further investigation is required about the benefits of wintergardens for meat chickens and specifically which characteristic of the environment is enriching.

Sensory enrichments that increase environmental complexity

Providing moving coloured lights for four 1 hour periods daily has been shown to increase eating and resting behaviours but negatively impacted leg health with no impact of negative affective states such as fearfulness or dermatitis (Bizeray et al., 2002a).

Enrichments for meat chickens that increase novelty

Physical enrichments that increase novelty

The provision of novel toys (plastic balls, plastic bottles, toys, mirrors changed every three days) has been shown to improve the welfare of meat chickens by reducing fearfulness, evidenced by shorter tonic immobility duration and improved immune function in response to heat, sound and crating stressors (Altan et al., 2013). This finding suggests that providing novelty in the meat chicken environment may increase stress resilience.

Sensory enrichments that increase novelty

The use of laser lights at intermittent intervals improved productivity but not injury or dermatitis. It may be that chickens developed stress resilience due to novelty subsequently reducing fear and positively impacting growth as observed with other enrichments that provide novelty (Altan et al., 2013). However, indicators of physiological stress and negative affect were not assessed and therefore the mechanism and impact on welfare is unknown.

Summary of effective enrichments for meat chickens

Hay bales are preferred by meat chickens than perches and platforms and have positive impacts for welfare. However, hay bales are expensive, a biosecurity risk and require additional labour and therefore may not be feasible for industry. Wood shavings litter is currently provided in all Australian chicken meat sheds and has good implications for welfare, providing access to small areas with preferred substrates such as sand and peat will likely increase behaviours associated with positive affect, such as dustbathing and foraging. Enrichments that have no biological function for meat chickens can be effective but only when replaced frequently. Such that, novelty can reduce fearfulness and may have consequence for experiences during unavoidable stressors such as catching and transportation. Vertical panels can improve use of space and improve welfare of meat chickens.

There has been some investigation into the effects of combining more than one enrichment (Baxter and O'Connell, 2019) the implications of providing enrichment in various combinations and densities may impact chicken welfare and requires further investigation. Whilst some enrichments have been shown to impact meat chicken welfare, interest in the enrichment decreases over time suggesting that the implications for welfare may not be long lasting. Some consideration for provision of some enrichments intermittently rather than constantly may assist to improve longer term interest and welfare outcomes (Meyer et al., 2019; Meyer et al., 2020).

Most of the research to date has focused on leg health and provision of physical enrichments. There is a scarcity of literature on the positive affective states of meat chickens. As natural behaviours are targeted with enrichments, preferences may be indicative of positive affective states but the implications for animal welfare requires further investigation.

Effective enrichments for laying hens

Enrichments that target laying hen natural behaviours

Physical enrichments that target natural behaviours

Under natural conditions, chickens make use of elevated structures in the environment (most often tree branches) to perch on during the day (Wood-Gush and Vestergaard, 1989) and to roost on at night (Blokhuis, 1984). Hens are highly motivated to perch (Olsson and Keeling, 2000), and will use perches for three main reasons: to reach resources, to roost at night as an anti-predator tactic (Duncan et al., 1992; Olsson and Keeling, 2000), and to escape unwanted attention from other birds (Gunnarsson and Valros, 2009). Perches can increase activity and improve welfare by reducing the incidence of feather pecking and cannibalism, increasing bone strength/volume (Duncan et al., 1992; Heikkilä et al., 2006; Barnett et al., 2009; Sandilands et al., 2009; Campbell et al., 2016b) and decreasing fearfulness (Ross et al., 2019).

Exploratory and foraging behaviour are integral parts of the laying hen's behavioural repertoire. Pecking and foraging in hens can be facilitated by either a substrate where ground pecking and scratching is possible or in the form of pecking devices (Dixon et al., 2010). Effective foraging substrates include straw (El-Lethey et al., 2000) that reduces feather pecking and increases egg production in comparison to no straw, but provision of grain showed better plumage condition as compared to straw although it reduced feed intake (Blokhuis and Van der Haar, 1992). Foraging substrates like straw, chick paper, peanut butter suet, seeds and cabbage leaves were more effective than dustbathing substrates such as sand, straw or peat moss in redirecting pecking and hence reducing feather pecking incidence (Huber-Eicher and Wechsler, 1997; Dixon et al., 2010; de Jong et al., 2013). Pecking enrichments, such as white strings (Jones et al., 2002; McAdie et al., 2005), paper substrate in rearing followed by hay bales in production (Tahamtani et al., 2016), aerated pecking blocks, polystyrene blocks (Huber-Eicher and Wechsler, 1997), porous concrete block (Holcman et al., 2008), pecking stones (Zepp et al., 2018; Liebers et al., 2019; Schreiter et al., 2020), stones on a wooden board (Moroki and Tanaka, 2016), hard-pressed alfalfa bales (Schreiter et al., 2020) and Lucerne bales (Zepp et al., 2018) all reduced feather pecking and improved plumage condition. Hens were observed to consistently peck at bunches of white polypropylene baling twine, probably as a natural stimulus to the resemblance to straw or worms (Jones et al., 2000). As well as pecking and pulling at the string, hens also drew the string through their beaks and teased the strands apart to mimic preening. The interest in string outlasted that in baubles, beads, tubing, lengths of chain, or feathers taken from other chicks (Jones and Carmichael, 1999) or other commercially available pecking devices (PECKA-BLOCKS, Breckland International Ltd., UK) (Jones et al., 2002). Provision of tassels and scratch pads (Frediani et al., 2019) increased locomotion and decreased antagonistic behavious. Sherwin (1995) found that brightly coloured spherical objects placed in the feed trough provided hens with a motivation to work for their feed while also redirecting pecks. The nature of the enrichment, and the amount of time and number of interactions, influence its effectiveness. Long-cut straw decreased feather pecking more than shredded straw or wood shavings (Huber-Eicher and Wechsler, 1997).

Nesting behaviour in a hen includes the behaviour patterns that lead to selecting a protected nest site and building a suitable nest. Hens are motivated to lay eggs when suitable nesting sites are available such a nest boxes (Duncan and Kite, 1989; Appleby et al., 1993). It has been suggested that nest building exercise is more important for the hen than the actual construction of the nest (Hughes et al., 1989). Thus, provision of loose material, a hollow enclosure, bean bags, etc. that can be identified as nests were found to be more beneficial in expressing nesting behaviour in hens (Duncan and Kite, 1989; Reed and Nicol, 1992).

The positive interactions seen may be due to the birds having more to occupy their time, leaving less time available for adverse behaviours, rather than due to the specific motivational properties of each of these enrichments.

Social enrichments for laying hens that target natural behaviours

Pullets do not have any maternal contact which may result in the development of fear responses to non-threatening stimuli or inappropriate reactions to potential threats when components of the maternal environment are not present (Edgar et al., 2013b; De Haas et al., 2014). Dark brooders which are warm, enclosed and can be used as dark areas for chicks to access in the absence of adult hens are seen to result in better plumage condition, fewer wounds during lay, lower mortality due to cannibalism, fewer floor eggs and had higher total egg production (Riber and Guzmán, 2017).

Sensory enrichments for laying hens that target natural behaviours

Sensory enrichment in the form of video images, diverse feeds, sounds and smells (Orihuela et al., 2018; Ross et al., 2020) can elicits natural behaviours. Hens showed appropriate response to televised images of predators and feeding, dustbathing or threatening conspecifics and altered their feeding behaviour when viewing video showing conspecifics feeding from a specific food dish or a predator-like stimulus (Keeling and Hurnik, 1993; Clarke and Jones, 2000; Dharmaretnam and Rogers, 2005), thus reducing fearfulness.

The sight of peat or powdered substrates (Petherick et al., 1995; Widowski and Duncan, 2000), and the presence of light or heat (Duncan et al., 1998) can stimulate dust bathing.

Nutritional enrichments for laying hens that target natural behaviours

Egg production was highest in hens supplement fed with either carrots or maize silage as compared to barley–pea silage, while severe feather pecking, and mortality was reduced with all three supplements as compared to no supplementation (Steenfeldt et al., 2007). Live insect feeding in the litter (Khan, 2018) can provide alternative source of protein to hens while satisfying their evolutionarily adapted natural behaviour of picking insects as a part of their diet. Coarser diets (Van Krimpen et al., 2009) and additional wholegrain (e.g., wheat, barley, oats) distributed in a way that interests the birds (e.g., scattered evenly or from a foraging device (e.g. pecking block)(Blokhuis and Van der Haar, 1992) improved feather condition. In case of perishable feeds like some forages, the health and safety implications may limit the practicality of their on-farm use (Steenfeldt and Nielsen, 2015).

The impact of enrichments that target natural behaviours on laying hen productivity

Forage material such as maize silage and carrots showed an increase in the number of eggs produced, egg mass, rate of lay, and reduction in feed intake as compared to no forage or barley-peas silage, while mortality was reduced with all three foraging supplements (Steenfeldt et al., 2007). Although perches allow chickens to express their natural perching instinct, comparisons between chickens that always had perches with controls that never had perches showed similar performance relative to egg production, cracked eggs, egg weight, shell weight, % shell, and shell thickness (Hester et al., 2013b). Feed usage increased resulting in poorer feed efficiency in hens with perch exposure during the pullet phase with no effect during egg laying (Hester et al., 2013b). The opportunity to explore and forage reduced the risk of injurious pecking (Aerni et al., 2000). Husbandry practices that involve enriching the environments with suitable litter, pecking enrichments and forages reduced injurious pecking, thereby improving feather cover and reducing mortality (Huber-Eicher and Wechsler, 1997; McAdie et al., 2005; de Jong et al., 2013; Rodenburg et al., 2013; Daigle et al., 2014; De Haas et al., 2014; Janczak and Riber, 2015; Tahamtani et al., 2016).

Enrichments for laying hens that increase environmental complexity

Environmental complexity in laying hen's environment is achieved by using different structures and materials, shapes, sizes, varied temperatures and colours of enrichment materials, images, sounds etc, either individually or as a combination of few. Interacting with them provide hens with opportunities to move, exercise, learn and observe.

Physical enrichments that increase environmental complexity

Installation of perches apart from targeting natural behaviour is also a physical measure to enrich hens' environments structurally and offer them complexity. It is believed that perches alter the spatial configuration, which in turn may affect the hen's perception, use of space, and ultimately, social dynamics (Gunnarsson and Valros, 2009; Daigle et al., 2014). Other physical enrichments like a wooden board with stones (Moroki and Tanaka, 2016) reduced feather pecking, abrasive claw shortening devices (Shi et al., 2019) improved foot health, reduced feather pecking, mortality and fearfulness, and beak blunting boards reduced bird to bird pecks (Morrissey et al., 2016). Environmental complexity offered during rearing in the form of perches, aviary rearing, perch bars, plywood boards and plastic objects at rearing reduced fearfulness in hens (Reed et al., 1993; Janczak and Riber, 2015; Casey-Trott et al., 2017a; Guinebretière et al., 2020). Aviary rearing systems stimulate navigation and locomotor skills of the birds and improve spatial performance and short-term spatial memory as adults (Tahamtani et al., 2016) which may last until peak lay for avoiding collisions and until mid-lay for perch height preference (Casey-Trott et al., 2017a; Pullin et al., 2020). Hens reared in aviaries jumped and flew more accurately and had a preference for upper levels helping them to access higher nests and finding feed (Colson et al., 2008), especially when provided with ramps between tiers (Heerkens et al., 2016).

Social enrichments that increase environmental complexity

Environmental enrichments should provide positive social interactions between conspecifics and constructive human interaction. Increased human contact by handling in the first few weeks of life (Coleman and Hemsworth 2014) and regular visual contact (Edwards et al., 2013) reduces levels of fearfulness in hens (Reed et al., 1993; Edwards et al., 2013; Zulkifli, 2013).

Sensory enrichments that increase environmental complexity

Chickens have tetrachromatic vision, providing hens with the ability of colour preferences, with greater interest shown for white or yellow strings than green, blue or red ones (Jones et al., 2000; Dávila et al., 2011). Hens are strongly attracted to stationary bunches of plain white string and show a long-lasting interest in string-directed pecking observed at even 17 weeks post first exposure at day 1 (Jones et al., 2000). While string has the added advantages of low cost, ready availability and ease of installation, the precise breaking strain of the string and its nylon attachments needs to be considered to prevent breakage and possible ingestion (Ross et al., 2019). Although chicks have a propensity to peck small, spherical, shiny objects (Rogers, 1995), incorporating silver beads into bunches of white string reduced pecking (Jones et al., 2000)

Playing classical music stimulus (75 dB) to chickens helped reduce fearfulness compared to hens just exposed to background noise (65 dB) (Campo et al., 2005) and decreased the heterophil to lymphocyte ratio indicating reduced stress (Dávila et al., 2011).

Chickens exhibited less fear of novel environments when provided with a familiar odour and this effect was generalized to four odours (vanillin and the oils of orange, geranium and clove), four breeds and three methods of presentation (Jones, 2004).

The impact of enrichments that increase environmental complexity on laying hen productivity

Complex environments help hens to make choices and thus have more control over their movement. Hens are motivated to perch, increasing activity and resulting in welfare outcomes like decreased incidence of feather pecking and cannibalism (Huber-Eicher and Wechsler, 1997; Jones, 2005; McAdie et al., 2005; Rodenburg et al., 2013), and optimal skeletal development benefitting their bone health, preventing fractures, stimulating leg muscle deposition and increasing the mineral content of bones without causing a concomitant decrease in bone mineral density (Weeks and Nicol, 2006; Heerkens et al., 2016; Casey-Trott et al., 2017a; Casey-Trott et al., 2017b; Riber et al., 2018; Campbell et al., 2019). Structurally complex enrichments, although have many benefits, do come with a high rate of injuries such as keel fractures, which may suggest that the hen may not be physically capable of manoeuvring these structures optimally (Wilkins et al., 2011; Campbell et al., 2016a). A socially complex enrichment of human handling, presence, and voices reduced fear reactions in response to human catching procedures and fewer injuries during depopulation early in the lay cycle (Reed et al., 1993). The provision of appropriate visual, auditory and olfactory enrichment stimuli obtained by the routine incorporation of white string devices (Jones et al., 2002), classical music (Campo et al., 2005), familiar odorants (Jones, 2004), reduces fearfulness and tonic immobility, while increasing performance thereby improving the birds' welfare and productivity. However, the most effective type of enrichment can only be determined by comparing the provision within a group of birds that have had similar rearing and laying environments, experiences, and enrichment schedules.

Enrichments for laying hens that increase novelty

Jones and Waddington (1992) suggest that exposure to varied stimuli in the home environment enhances the animal's ability to adapt to novel situations and objects.

Physical enrichments that increase novelty

Jones and Waddington (1992) showed that hens showed reduced fear when provided with a variety of brightly coloured, and stimulating objects such as balls, buttons, thimbles, and drawings taped to the walls, from day 1 and changed every 3 d, as compared to constant availability or no availability of these resources. (McAdie et al., 2005) reared birds on litter and presented string enrichments at various days (on ages 1, 22, 52 days or never) and for different time periods (continuous or 4-hour periods from day 1) and found that the beneficial effects on feather condition were equally apparent regardless of whether the string devices had been provided continuously from 1 day of age, continuously from 16 weeks onwards, or for just 1 day every 4 weeks. (Dixon et al., 2010) found a reduction in feather pecking by providing alternate days of varied enrichment treatments that included a commercial wire bird-feeder suet filled with either peanut butter, seeds or cabbage leaves, flat wooden blocks covered by tin foil or tissue paper, or felt paper and dust baths filled with either peat moss, white sand or grey sand, while Campbell et al. (2020) used a novelty treatment (various novel objects were added/removed approximately weekly including balls, bottles, brooms, buckets, disks, ropes, chain, cinder blocks, containers, dog toys, milk jugs, plastic kids toys, pipes and strings) and found that hens offered this form of enrichment perched more, showed reduced fear, and greater use of nest boxes as compared to hens with perches or no enrichment.

Social enrichments that increase novelty

A combination of both novel objects (plastic bottles, balls, and rattles), human handling, human presence, and human voice via radio for the first 5 weeks of life, followed by housing in an area of high human activity until 24 weeks of age reduced fear reactions in response to human catching procedures and fewer injuries during depopulation early in the lay cycle (Reed et al., 1993).

Sensory enrichments that increase novelty

Chicks were increasingly attracted to videos of screensavers(Jones and Carmichael, 1998; Jones, 2004) prefer a familiar screensaver to a blank screen and a moderately novel one to the familiar image (Clarke and Jones, 2000). Chicks preferred bright to dull (38 versus 18 lux), moving to still, and coloured to grey tone versions of the Fish screensaver; they also preferred ‘Fish’ to a simple bouncing square (‘Square’), and a complex cartoon (‘The Simpsons’) to the ‘Fish’ video (Clarke and Jones, 2000). Such interest was then sustained for as long as 8 days and although it waned gradually thereafter it was fully restored when an unfamiliar video (“Doodles”) was presented on day 21 (Clarke and Jones, 2000).

Renewing of enrichment objects avoids boredom and lack of interest, and trains hens to be adaptable to unfamiliar environments (Campbell et al., 2019). Provision of novel and irregular enrichments can help in reducing fear, increasing activity and interaction with complex surroundings (Jones and Waddington, 1992; Jones et al., 2000; McAdie et al., 2005; Dixon et al., 2010; Campbell et al., 2020).

To provide novel enrichment stimulation throughout the rearing and growing period involves constant replenishing of novel objects, sounds, pictures and even structural re-arrangements, all of which are difficult to implement in a commercial farming environment as they involve added labour and time costs. The number of varied treatments and their presentation schedules make it difficult to tease out the benefits of any individual enrichment from the mix.

Summary of effective enrichments for laying hens

Environmental enrichment of hens is intended to expand the repertoire of desirable behaviours, improve musco-skeletal characteristics, sustain the animals' interest, and enable them to cope with challenges. Effective environmental enrichment can have an impact by increasing expression of natural behaviour, on adding perching, foraging and exploratory elements to the environment while reducing aggression and frustration and redirected foraging as pecking. Environmental complexity can be achieved either by the provision of structural arrangements or by offering a socially complex enrichment with visual, auditory, and olfactory stimuli, reducing fearfulness and neophobia. Novelty in enrichment objects provides birds with varied experiences training them to become adaptable to new environments and startle situations. To be effective and feasible for commercial poultry production, enrichments must be practically and economically viable.

Effective enrichments for beef cattle in a feedlot environment

Enrichments that target the natural behaviours of cattle

Physical enrichments that target natural behaviour

The most studied enrichment for feedlot cattle is a grooming brush that is provided within the pen to enable scratching/rubbing and self-grooming, natural behaviours for cattle. Positive effects of the use of brushes for environmental enrichment in feedlot pens have been reported with less stereotypic behaviours and fewer aggressive behaviours displayed. Park et al. (2020) reported that overall, there were fewer head butts, number of mounts, bar biting bouts, tongue rolling and allogrooming durations when compared with a control treatment with no enrichment.

Cattle did not habituate to the brush over the duration of the 64-day study in a feedlot (Park et al., 2020), indicating that they valued the ability to perform grooming behaviour using the brush. The physical brush was also shown to be preferred and well utilised in a study by Wilson et al. (2002) with an average of 75% utilisation by the herd that was maintained for the 22 days in feedlot cattle. Similarly, frequency of brush usage in a feedlot was maintained for the trial duration of more than 6 months in Japanese Black steers indicating that self-grooming is an important natural behaviour for cattle (Ninomiya, 2019). In contrast, brush use in younger Japanese Black calves was not maintained and reduced between day 3 and day 51 in a feedlot study (Ninomiya and Sato, 2009). This inconsistent finding may have been due to variation in age and breed of cattle and the testing facility design.

Improvements in carcass measures with the use of enrichments in feedlot environments have been reported. A drum can containing hay and a drum can with both hay and a grooming substrate was correlated with increased marbling score and increased belly fat yield in Japanese Black x Holstein steers (Ishiwata et al., 2006). The carcase improvements seen in the study were likely due to increased feeding from the drum cans. The use of enrichments that incorporate a feeding component may provide opportunities for productivity benefits.

From the few studies published, it appears that provision of enrichments to cattle kept in feedlots does not negatively impact on productivity and may improve some measures. Production metrics (ADG, G:F and weekly DMI) and carcase data were not affected by the provision of a cattle brush to feedlot steers in a US study (Park et al., 2019). Similarly, no differences in growth or carcase traits were reported with the provision of a brush to feedlot cattle (Park et al., 2020). In addition, average daily weight gain was not affected by the provision of a range of enrichments (brush, clean bedding and wooden partitions) to Japanese breed calves (Ninomiya and Sato, 2009).

Providing physical barriers using wooden walls that aimed to enable calves to hide during feeding, reduced agnostic interactions in Japanese Black calves and increased affiliative behaviours in Japanese Shorthorn calves (Ninomiya and Sato, 2009). In the same study, higher levels of cleanliness of straw bedding provided to concrete flooring resulted in increased sternum lying and lying with the head touching the flank which has implications for the quality of rest (Ninomiya and Sato, 2009). Lying positions that support the head are important for sleep quality as rapid eye movement can only occur when the head is supported (Ternman et al., 2014). Provision of comfortable bedding may enhance the quality of rest and should be considered as an enrichment option if economically feasible.

Provision of shade appears to be an effective enrichment to feedlot cattle. Shade increased feeding by 1.7 % and decreased panting in beef steers over a 36-day period; for every 1 degree (C) increase in temperature, the proportion of standing and panting increased by 1.36 and 0.14% respectively, while lying and feeding decreased by 1.28 and 0.22 %. Shade decreased panting but had no effect on feeding or lying time (Blaine and Nsahlai 2011). Panting score has been demonstrated to be reduced with the use of shade (Gaughan et al., 2020; Lees et al., 2020) as has respiration rate (Mitlohner et al., 2002). Shade has positive effects on behaviours with reports of reduced agnostic interactions, reduced bulling behaviour and increased lying time in Angus and Charolais crossbred cattle (Mitlohner et al., 2002).

Shade appears to be valued by cattle as they have been reported to continuously use the shade during the day (Mitlohner et al., 2002), even when the average temperature was above relatively mild temperature of 23 °C (Blaine and Nsahlai 2011). Darker coat coloured cattle such as Angus were reported to use the shade more than lighter coloured cattle in an Australian study (Lees et al., 2020).

The most productivity benefits appear to be from providing shade to cattle in feedlots. Shaded animals were 6 kg heavier, had higher ADG and improved feed conversion efficiency (Blaine and Nsahlai 2011). Shade was also found to result in less dark cutters (Mitlohner et al., 2002), increased body weight and increased ADG and higher hot carcase weights (Gaughan et al., 2010).

Nutritional enrichments that target natural behaviour

Provision of a bale of straw that was replaced daily for 2 weeks was the most used by feedlot cattle when compared with a brush or salt and mineral licks, however the straw was also associated with increased aggression due to competition for the limited resource (Pelley et al., 1995). The cattle spent less time lying down and ruminating with the straw treatment when compared with the other enrichments (Pelley et al., 1995).

Drum cans either containing hay or covered in turf (for grooming) were used as enrichments in a study using Japanese Black x Holstein steers. The drum cans were used frequently for the 3 months study period and there was a higher frequency of eating from the drum can with the grooming device. Dopamine levels were higher with the drum can, which may indicate positive welfare (Ishiwata et al., 2006).

Enrichments for feedlot cattle that increases environmental complexity

Few studies have investigated environmental complexity for use as an enrichment in beef cattle feedlots.

Sensory enrichments for beef cattle that increase environmental complexity

A range of scented devices were investigated as possible enrichments in combination with a grooming brush in Charolais cross heifers over a 22-day period. The scented devices were less preferred than cattle brushes. The mean usage by the herd was highest on day 2 for the milk scent device (50%) and lower for the lavender (20%) and blank device (15%). Usage of the scent devices was low for the duration of the study, suggestion that scent devices are not highly valued by cattle and are not effective to use for enrichments in feedlot environments (Wilson et al., 2002). These findings do not support the use of scent devices as enrichments for feedlot cattle.

Summary of effective enrichments for beef cattle a feedlot environment

Consideration of access to enrichments by ensuring adequate supply or by manipulation of the stocking density to facilitate access to all animals within a group is required to reduce the negative effects of aggression from competition. For example, lowering stocking density has been shown to be effective at reducing aggression when feedlot cattle were provided with a grooming brush (Meneses et al., 2019).

The majority of enrichment studies published on feedlot cattle have been conducted overseas, where the differing systems and environment may result in the findings not being relevant to an Australian context. The main enrichments that were found to be effective in improving welfare for feedlot cattle while having no negative productivity impacts were brushes for grooming and the provision of shade. While providing shade in Australian feedlots has been shown to have both welfare and productivity benefits, further research in Australian feedlots, particularly in the provision of grooming devices, would be valuable.

Effective enrichments for sheep in a feedlot environment

Unlike most other livestock, sheep in Australia are almost exclusively housed outdoor on pasture, although they may be confined to smaller areas during part of the production cycle (feedlot or containment areas). Indoor production systems are extremely rare and have occasionally in the past been used for the production of superfine wool. Sheep used in research may at times be confined to indoor and individual housing. Therefore, environmental enrichment for sheep in Australia has rarely been considered and only limited research in this area has been published.

Enrichments that target the natural behaviours of sheep

Physical enrichments that target natural behaviour

Research on environmental enrichment for sheep has concentrated on physical features that target natural behaviours. Indoor feedlots are more common in Spain, and most of the research on environmental enrichment for sheep housed indoors has been conducted. Typically, the enrichment consisted of a complex environment of ramps, platforms and straw as bedding and forage (Aguayo-Ulloa et al, 2014a; 2014b). This enrichment has been shown to reduce chronic stress (decrease in stereotypic behaviour, non-esterified fatty acid and neutrophil/lymphocyte ratio) and resulted in positive effects on meat production (higher average daily gain, heavier carcasses and higher fattening scores, as well as lower pH_{ult}). In another study from the same research group, adding just straw to indoor pens as bedding and forage substrate was also found to be beneficial for sheep as it resulted in less stereotypic behaviour, although no effects on production measures were found (Teixeira et al, 2014). Additional research in individually housed lambs on the preferred properties of straw found that lambs preferred long straw over chopped straw, which resulted in reduced stereotypies and increased play (Aguayo-Ulloa et al, 2019). No difference was found between the use of wheat and barley straw and the provision of straw did not affect feed intake. These studies used the Rasa Aragonesa breed and included only a limited number of animals per treatment (8-30). These numbers may be insufficient to determine significant effects on production measures, and may not equally apply to merinos and merino crossbred sheep. An Australian study (Vasseur et al, 2006) looked at the effect of adding straw to the standard pelleted food on wool biting (a frequently seen stereotypic behaviour in indoor housed sheep) and wool damage. Not only did they find that the addition of 300g daily of barley straw was effective in reducing wool-biting, it also had a positive effect on growth rate. Straw can be added as supplemental feeding but can also be used as bedding. Positive effects of straw bedding however, appear to be related to straw consumption. Straw bedding was found to increase dry mater intake and average daily gain as well as feed efficiency (Jaborek et al, 2016). Therefore, the addition of straw, either as bedding or as supplemental feeding, could be a useful provision for sheep fed pellets and housed indoors individually or in groups, not only for production reasons but also for research purposes, such as for medical research.

Nearly all sheep in Australia are housed on pasture, which many would consider a 'natural environment' and thus not requiring environmental enrichment. However, there are some areas where pasture may be barren, with limited opportunity to find shade and shelter. While this may not be considered 'environmental enrichment', they are features in the environment that encourage natural behaviours and are biologically relevant (seeking shade and shelter under certain environmental conditions). However, the research on the benefits of providing shade and shelter provide mixed results.

Hypothermia due to cold and wet weather, is a known cause of mortality, particularly for newborn lambs. While protection from rain is rarely provided, wind breaks, particularly in the form of phalaris grass strips, have been shown to be effective in reducing wind speed (Lynch and Alexander, 1977) and therefore the wind chill factor. Shelter from wind may be naturally present as vegetation and undulation in paddocks, but can be provided as hedges of tall grass or artificial structures such as fencing of polyethylene garden mesh (Lynch and Alexander, 1977).

Pregnant ewes that are shorn before birth are more likely to use shelter than unshorn ewes (Taylor et al, 2011), and are more likely to lamb within two meters of shelter (Lynch and Alexander, 1976). However, area of placement of shelter within a paddock is an important determined of shelter use (Lynch and Alexander, 1977). For example, shelters near roads or human activity and at paddock ends were least preferred (Pollard and Littlejohn, 1999). It is recommended that shelter is impermeable or dense such as hedgerows, toe toe, flax, gorse, straw bales, humps, hollows and rocks (Palmer et al. (2003).

Provision of shelter resulted in lower lamb mortality, especially amongst twins (Lynch and Alexander, 1977), but this is highly dependent on the presence of inclement weather (Lynch and Alexander, 1976). Due to the variability in environmental conditions that are outside the control of the researchers and the high variability in biological responses of sheep, individual studies on the use of shelter are less informative, with not all sheep using shelter when it is provided and varying results on lamb mortality. However, when taking the results of several studies together, including those on lamb mortality and cold exposure per se, there does appear to be a benefit of providing shelter. Indeed, in an economic analysis, the addition of shelter was found to be profitability for those farms that lamb during the colder months from July to September in south east Australia, particularly in twin-bearing Merinos (Young et al, 2014).

While sheep can be susceptible to heat stress in some circumstances (such as on ship during live export; Carnovale and Phillips, 2020) they are generally able to respond to increased heat load with increased respiration rate without evident physiological consequences under paddock conditions in Australian climates (Srikadakumar et al, 2003). When observing use of shade by sheep in a paddock, a high degree of individual variation can be observed. A study investigating the sheep that voluntarily spent very little time in the shade during the day (<6%) compared to sheep that spent more time in the shade (>39%) found no differences in body temperature or respiration rate (Johnson, 1991). Individual differences in shade seeking behaviour within a flock of sheep could be due to differences in thermoregulatory capabilities, however, there may be some effect of dominance ranking (Sherwin and Johnson, 1987). However, shade-use does increase in hot weather and is correlated with radiation load and air temperature (Sherwin and Johnson, 1987). Shade may be more important in feedlots, where adult sheep in feedlots were found to spend more than 50% of time in the shade during hot days (Stockman, 2006).

While there is some research on the effect of heat stress on fertility (McCrabb et al, 1993) and growth rate (Cloete et al, 2000), there is surprisingly little research comparing sheep with and without access to shade. One example is a South African study, where lambs born in shaded paddocks tended to be heavier at birth and were 3.8 % heavier at weaning than lambs born in paddocks without shade (Cloete et al, 2000). Most research on heat stress is concentrated on sheep on ships for live export, where mortalities can be high due to heat stress. Nevertheless, voluntary shade use can be high on days with high temperatures and humidity, indicating that sheep do benefit from shade. Clearly more research is needed to determine the importance of shade to sheep welfare.

Summary of effective enrichments for sheep in intensive conditions

Housing of sheep indoors in is rarely done in Australia. There is limited research from other countries that under those conditions sheep clearly benefit from the addition of structural environmental enrichment, targeted at natural behaviour. The addition of straw, either as dietary supplement or as bedding has also been shown to be beneficial. While environmental enrichment is not normally associated with pasture systems, wind breaks and shade can be important provisions that potentially both benefit sheep welfare and production parameters. However, targeted research in this area is clearly lacking.

Recommendations and opportunities

It is clear that there is a lack of enrichment studies in an Australian context; 14.1% of studies identified throughout the literature review were conducted in Australia, this was particularly notable for the meat chicken industry (1.2% studies were Australian). It is likely that the effects of the enrichments will interact with Australian specific climates, breeds and feed and management programs.

Social enrichment was rarely investigated for any species. Perhaps this is due to the fact that conspecifics are typically in close contact physically or visibly. However, evidence from the laying hen literature suggests that social enrichment via human contact can indeed be an effective enrichment. This opportunity has further been supported elsewhere (Rault et al., 2020) and stockpersons as a source of enrichment could be considered.

Cognitive enrichment has had little attention, however current research (e.g. from rodents) suggest that changes to neurophysiology after provision of specific enrichments can aid animals to adapt to new environments, improve stress resilience and may have direct implications for immune function. This opportunity deserves further attention in the livestock sector.

Assessments of the impact on enrichment on productivity were included in most of the research reported from the pig (45.9%), meat chicken (47.5%), cattle (58.8%) and sheep (81.8%) literature. However, as economics play a large role in decision making regarding animal welfare this should be addressed in all papers. This is particularly a concern for the laying hen industry where only 11.5% of citations assessed productivity or product quality.

An effective enrichment framework for the continual improvement of animal welfare of livestock

Taylor, P.S., Schrobback, P., Verdon, M., Lee. C.

Introduction

The provision of environmental enrichments in captive animal housing is becoming increasingly prevalent, largely due to an increasing public awareness and concern for animal welfare (Grunert et al., 2018; Alonso et al., 2020) and the perception that enrichments improve animal welfare (Schütz et al., 2020). Indeed, recent years has seen the regulation of enrichment provision by welfare accreditation schemes, for example, RSPCA approved farming schemes (RSPCA Australia., 2021). Despite the good intentions of supplying enrichment, some enrichment programs have been shown to have no effect and, in some circumstances, can even negatively impact animal welfare (Nicol, 1992; Gordon and Forbes, 2002). As such, there is a risk that prescribing resource-based requirements to provide 'enrichment' may simply 'tick a box' rather than lead to actual animal welfare improvements. The consequences of this may lead to misleading consumers, cynicism from the public toward industry attempts to improve welfare and the development of negative perceptions surrounding the benefits of enrichment provision from producers. Further, the dichotomy of 'enriched' versus 'not enriched' does not encourage the incremental continual improvements to animal welfare, rather an all-or-none approach which may reduce industry uptake and subsequently genuine change for animal welfare.

Further complicating the matter, is the subjective nature of the term 'environmental enrichment', which may result in the expectations of various stakeholders not being met i.e. *how much improvement to animal welfare is required before an animal's environment can be considered enriched?* The term enrichment has been used to describe resources or environments that either prevent suffering (Newberry, 1995a), provide an environment beyond suffering (Boissy et al., 2007) or only refer to the gold standard species specific environment (Shepherdson, 1998). However put simply, the term enrichment refers to an 'improvement' in quality (Merriam-Webster, 2021). As such, improvements after the provision of enrichment must be measured and accurately labelled. This approach further encourages continual improvements to animal welfare through the provision of enrichments. Even as societal acceptance of current environments evolve and the quality of standard/baseline environments shift, terminology that defines enrichment as the relative improvements to animal welfare will remain relevant.

We propose a framework to redefine enrichment based on the outcomes on animal welfare. The proposed definitions of effective enrichment reflect the outcome of animal welfare improvements in a tiered structure that permits continual advancements to animal welfare, regardless of the baseline environment. Redefining the term enrichment in such a way will improve clarity, expectations and ultimately the impact of enrichment programs on animal welfare. The framework is based on Dawkins (2008) definition of welfare, on the statement by Newberry (1995a) that "*enrichment implies improvement*" and on the tiered approach to welfare assessments of Edgar et al. (2013a) and Fraser (2006).

We also argue, in addition to animal welfare outcomes, enrichment programs require other multi-stakeholder considerations before they are to be considered 'effective'. This is based on the premise that to truly be 'effective', an enrichment needs to not only improve animal welfare but must also be practical and economical for industries. Enrichments that do not meet these criteria will not be implemented, regardless of whether or not they improve animal welfare. This aligns with the theory first proposed by van de Weerd and Day (2009). For example, if an enrichment has a positive effect on animal welfare but there is no possible waste management solution (such is the case for straw in some commercial piggeries), it cannot feasibly be implemented and therefore will not be effective. Conversely, if an enrichment is practical and low in cost to implement but does not positively impact animal welfare it can also not be considered effective, i.e., the effectiveness of the enrichment is solely related to the *outcome* rather than the *intent*. Thus, the framework includes three components; animal welfare outcomes, practicality and economics. From this point on, the present paper uses the term 'effective enrichment' to encompass those enrichments that improve at least one aspect of animal welfare and are practical and economical to implement.

Methods

A literature review of enrichments and an industry survey regarding practicality of various enrichments formed the basis of the framework.

For the literature review, five intensively housed species were included; laying hens, meat chickens, farrowing and gestating sows, feedlot beef cattle and feedlot sheep. Welfare outcomes of each enrichment were recoded into a data file (see attached spreadsheet) including animal welfare outcomes (positive, negative or neutral) in relation to physical and mental health, abnormal and natural behaviours, impacts on production and animal preferences for, and utilisation of, enrichments. Enrichments that provided any evidence of improvements to animal welfare were included in an online industry survey aimed to assess the practicality of each enrichment.

A survey document to assess the practicality and economic feasibility of enrichments was developed and distributed through an online survey platform (Qualtrics XM, Provo, UT, USA). The online survey was distributed to stakeholders of the five livestock industries of intensively housed animals through the National Animal Welfare RD&E strategy. Collection of survey data was approved by the University of New England Human Ethics Committee (HE20-223). A total of 26 stakeholder responses from the five industries were recorded (n = 11 chicken meat; n = 2 cattle/dairy; n = 8 pork; n = 1 sheep; n = 4 egg). The survey included questions regarding the participant (i.e. stakeholder category; producer (n = 8); peak body representative (n = 2); welfare officer (n = 1); veterinarian (n = 5); non-government organisation (n = 2) other (n = 8)), if specific enrichments had been, or were, utilised, and whether implementation was practical.

Proposed framework

Practicality

For an enrichment to be effective it must be practical to implement. This includes providing an enrichment in a way that is effective, for example, ensuring enrichments are accessible to all animals (i.e. enrichment density) and/or provided at the appropriate time/age and frequency. The industry survey identified four main parameters regarding practicality of enrichments that must be considered for the enrichment to be effective (Table 3). The four main aspects of practicality included how the direct or indirect waste from enrichment could be removed, biosecurity risks, unmanageable interruptions to critical standard practices and the ability to source the enrichment in the quantity and location required. These perceived issues of practicality must be addressed and considered by researchers and regulatory bodies when designing, investigating or prescribing enrichment programs. Issues with practicality may be overcome with additional research and development (R&D), advances in technology or simply by providing scientific based evidence to eliminate perceived impracticalities.

Table 3. Four main themes reflecting the practicality of enrichment provision in Australian intensive livestock industries and industry specific quotations.

Practical consideration	**Quotations from industry survey**	**Industry**
Waste disposal method	*"Foreign objects entering the litter stream at clean out time"*	Chicken meat
	"Sand couldn't be composted"	Chicken meat
	"Won't work with effluent system"	Pork
Biosecurity standards	*"Difficult to clean between batches [of birds]"*	Chicken meat
	"Not practical as mites penetrate wood"	Egg
Obligatory management practices	*"…..impractical with very large broiler sheds – distributing and re-distributing for pickup"*	Chicken meat
	"risk for feed in crop at processing"	Chicken meat
	"may get floor eggs"	Egg
	"risk of unbalancing diet and risk of under-consuming anti-coccoidal medications"	Chicken meat
	"Block slats…."	Pork
Accessibility	*"Access to this substrate is a problem"*	Chicken meat
	"Rice hulls are increasingly difficult to source"	Pork

Animal Welfare Outcomes

For an enrichment to be effective it must improve animal welfare. Yet the nature of the improvement may be complex due to the variation in relative improvements, potential trade-offs and the method of welfare assessment. The optimal approach to assess animal welfare has been largely debated (Fraser et al., 1997; Duncan, 2005; Fraser, 2008b; Hemsworth and Coleman, 2010; 2011) but it is well accepted that there is not one single indicator of animal welfare and hence, welfare is best assessed using a combination of indicators. This framework utilises the simple, yet robust approach to assessing animal welfare proposed by Dawkins (2008); '*Are the animals physically healthy? And do they have what they want?*'. As such, we ask if the provision of a specific enrichment makes the animal healthier (evident by fewer injuries, less pre-clinical and clinical disease and normal biological functioning) and if the enrichment is something that the animal wants (evident by preference, behavioural demand and utilisation of enrichments). The indicators of health and what an animal wants must be considered together to inform the impact of enrichment on animal welfare outcomes; the proposed welfare outcomes are presented in Table 1.

In terms of animal welfare outcomes, health assessments are relatively straightforward and include assessments such as injury and lameness scores. However, health assessments also include indicators of biological functioning. A long-term disruption to biological functioning will be evident when biological fitness traits are compromised, such as morbidity, mortality, growth/body condition and reproduction (Broom and Johnson, 1993; Moberg, 2000; Hemsworth and Coleman, 2011). The long-term stress of specific environments can disrupt biological functioning (i.e. barren environments, or environments that do not contain a resource that the animal needs). When an animal is provided with an enrichment that it needs, the pro-longed stress responses and subsequent impacts on health will improve. As such, the question 'is the animal healthier after the provisions of an enrichment?' reflects both indicators of health and stress. This component of the framework asks the question *does the enrichment prevent, or ease, animal suffering?* Thus this question incorporates the Newberry (1995a) definition of enrichment; '*something provided to an animal that is biologically relevant and prevents suffering*'. Of note, here we consider only long-term assessments after the provision of an enrichment, as short term stress induced by enrichment provision (i.e. some novel objects) may provide positive effects on welfare in the long-term, such as increased resilience (Zulkifli and Siegel, 1995).

In agreement with the statement that enrichment should improve welfare beyond the absence of suffering (Boissy et al., 2007), the proposed framework also includes the question '*does the animal have want it wants?*'. This question provides insight into the positive experiences that enrichment can provide beyond meeting basic needs. Whether an enrichment is something that an animal wants is something that can be determined by assessing preferences for enrichments, motivation to access specific enrichments (behavioural demand) and utilisation/interaction with enrichment over time. Evidence suggests that the choices that an animal makes (i.e. to interact with an enrichment, or choose one enrichment over another) is associated with positive affective states (emotions), such as pleasure and reward (Fountain et al., 2020). Measuring what an animal wants therefore, provides indirect assessments of affective states that have evolved to motivate behaviour required for survival (Fraser and Duncan, 1998). Of note, the approach to infer affect from preferences, motivation and utilisation of an enrichment requires some consideration as animals often make choices based on proximal requirements which may change over time. For example, cattle prefer pasture rather than a feedlot environment in the evening but prefer a feedlot environment in the morning; preferences are related to lying and feeding behaviour respectively (Lee et al., 2013). Further, animals may become habituated to an enrichment over time (Guy et al., 2013) which would indicate that the enrichment is not effective and therefore assessments of utilisation must be over the entire timeframe of interest i.e. the whole production cycle or for the period of time that the enrichment is allocated in a suite of other enrichments.

Table 4. Welfare outcomes after the provision of enrichment related to changes in physical health and providing animals with what they want. Risks include possible negative impacts on health, such as an increased risk of contracting disease or possible injuries. Here, risks are considered something that can be controlled or minimised with increased/improved management.

Welfare outcome classification	**Is the animal healthier?**	**Is it something the animal wants?**
Improvements beyond basic needs, no/minimal risk	Yes ✓	Yes ✓
Improvements beyond basic needs, with risk	No ✕	Yes ✓
Improvements to meet basic needs	Yes ✓	No ✕
No improvement	No ✕	No ✕

Improvements beyond basic needs with minimal to no risk

Improvements to welfare outcomes ***beyond basic needs with minimal to no risk*** occurs when the enrichment provided improves health and provides the animal with something that it wants. This scenario results in the optimal welfare outcomes for effective enrichment with no suffering, minimal risk and the presence of positive experiences.

Improvements beyond basic needs with risk

A welfare outcome of improving welfare ***beyond basic needs with risk***, indicates that the enrichment is something that the animal wants but is associated with risk of negative implications for physical health (i.e., health *may* be compromised). While this may seem counter-intuitive, perhaps this is best demonstrated in circumstances where animals are provided with access to an outdoor range, as some individuals are highly motivated to access the outdoor range frequently, (Larsen et al., 2017) suggesting one or more components of the outdoor area is something that they want. However, there may also be negative consequences of range access such as the presence of predators and risks of disease. Rault et al. (2020) describes these positive but risky environments as providing the animal with a '*quality of life*'. This scenario requires additional management inputs to reduce the risks associated with enrichment provision and unless there is an economic return (e.g., premium price paid for free-range eggs) this enrichment may not be effective. This welfare outcome can also describe enrichments that may provide animals with something that they want, but the accessibility (i.e. density of enrichment) may cause additional stress or injury (i.e. through increased aggression). For example, sows provided with a point source of straw rather than distributed throughout the pen show increased competition, aggression and injury (Whittaker et al., 1999). Of note, some risks may be too great to consider regardless of the welfare outcomes, for example, dilution of medications due to nutritional enrichments or string causing necrosis after being caught on legs or tongues (Schlegel and Brash, 2015).

Improvements to meet basic needs

A welfare outcome classification that provides improvements to ***meets basic needs*** indicates that the enrichment improves physical health but does not provide an animal with something that it wants. Enrichments that improve basic needs provide the minimum standard of effective enrichments. As such, enrichments in this category may be prescribed as standards in legislation as part of a larger program that aims to protect animals from suffering. Of note, enrichments in this category may simply reduce boredom in a barren environment, rather than provide something specific that an animal needs and therefore, the outcome on animal welfare may not be directly transferable across production systems, enterprises or other environments.

No improvement

If an enrichment does not improve physical health and there is no evidence that it is wanted then the provision of the enrichment does not improve animal welfare and is not considered effective enrichment. Not only is the animal unable to engage in intrinsically valuable experiences but also the environment is lacking specific opportunities that may result in chronic stress. As such, any enrichment in this category must never be considered effective enrichment.

Economics

Once an enrichment has been shown to be practical and has positive outcomes for animal welfare, it must also be considered economical. This relates to the nature of the welfare outcomes and cost of enrichment implementation (e.g., costs of material and labour). The cost of enrichment implementation will depend not only on the enrichment itself but also on the size of the enterprise, geographical location, and housing system and therefore will need to be calculated and considered for each application. We propose that the return on investment is reflected by the welfare outcome (discussed below) and should be considered when developing or revising minimum requirements for welfare policy and third-party quality assurance schemes.

Although production is not always associated with improvements to animal welfare, and vice versa, it is widely accepted that the physiological stress response can impact either product quality and product quantity (Roberts, 2004; Hemsworth and Coleman, 2011). We propose that enrichments that lead to improvements to the basic needs of an animal, will be more likely to have a positive economic return due to improvements to productivity. For example, enrichments that improve biological functioning and/or health will see impacts on fitness traits that are associated with increased productivity (i.e. reproduction and growth). However, to be profitable, the improvement to biological functioning (and productivity) must be sufficient to offset the cost of implementation (e.g., materials, labour for placement and maintenance and disposal). Enrichments that improve welfare beyond basic needs (i.e. no improvements to biological functioning but provision of positive experiences), may, but are unlikely to see associated improvements to productivity. For example, biological functioning is not expected to improve beyond 'normal' levels despite an animal experiencing positive affect. As such, the cost of implementation may outweigh the benefits unless the improvements to welfare are subsidised for the producer. This may be achieved by a premium price return as part of a third-party accreditation program. For such an approach to be viable, consumers may be required to pay a premium. However, it is unknown if consumers have knowledge regarding the concepts of 'basic needs' and 'beyond basic needs' for welfare or are willing to pay more for either or both. Further investigation into the public perception of 'basic needs' and 'beyond basic needs' (however the improvements are rephrased to the public) and the willingness to pay for such products is required to ensure that science-based improvements to animal welfare through the provision of enrichment is economically feasible for producers to implement.

An economic benefit-cost assessment of animal enrichment implementation should also consider the broader benefits for producers. For example, by implementing enrichments, businesses will likely gain access to a broader range of retailers in higher market segments which increasingly set private standards for animal health and welfare in the production process (Fraser, 2006; More et al., 2017). Furthermore, the adoption of effective enrichments can contribute to gaining/maintaining agri-businesses' social licence to operate which consumers are increasingly valuing (Martin and Williams, 2011). Lastly, livestock businesses may also be rewarded for their implementation of enrichments through easier access to finance, since financial institutions are increasingly basing their investment decision on sustainable production processes (Akomea-Frimpong et al., 2021) such as improved animal welfare for production animals.

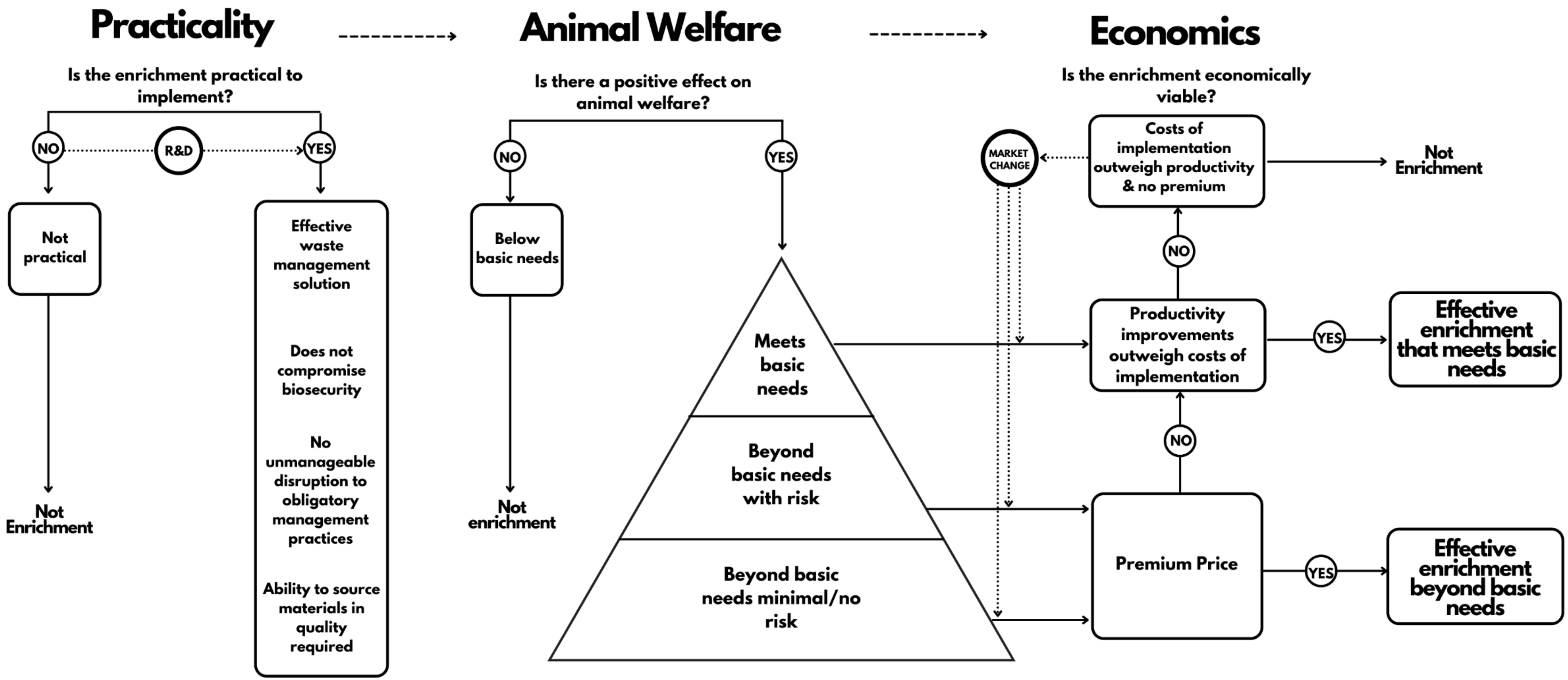

Figure 6. Framework for effective enrichment for Australian livestock species outlining three major components that must be considered; practicality, animal welfare outcomes and economics. R&D indicates the potential of innovation that may result in improvements in practicality over time. Market change indicates market dynamics (e.g., price, cost) that may lead to economic benefits outweighing the costs of implementing an enrichment.

Framework limitations and considerations

While the framework provides a guide for considering the effectivness of environmental enrichment to improve animal welfare, there are several limitations of this approach. The framework does not account for individual differences between animals and is aimed at welfare improvements at the group level. Utilisation (and therefore effectiveness) of enrichment may be related to individual differences caused by variation in previous experience, temperament, or genetics. For example, there is variation between individual laying hens in their motivation to access a dust bath (Widowski and Duncan, 2000).

Baseline environments are likely to affect the impact of enrichment provision on animal welfare. For example, if control animals are housed in barren environments they are likely to show a reduction in biolgical functioning (Beattie et al., 2000b) and a pessimistic mood (Douglas et al., 2012). However, this framework focuses on *improvements* to animal welfare after the provision of enrichment negating a 'one size fits all' enrichment. As continual improvements are made to the standard environments of intensively housed animals, this framework offers flexibility to assess the effectiveness of enrichments when they are added to the 'standard' or 'typical' housing environment. This framework does not dictate the standard intensive environment animals *ought* to be housed in, this has (and will likely continue) to change as social norms evolve. Rather we provide a framework to indicate the relative animal welfare *improvements* after the provision of enrichment that can be used to provide evidence, to consumers, regulatory bodies and producers. Therefore, this framework should be used to indicate the relative improvement from the 'industry standard' relative to time, place and market.

As prior experience can have an impact on an animal's response later in life, the impact of enrichment should be assessed across all of the housing conditions an animal may move through during its life/production system. For example, piglets reared in barren environments and are then weaned into enriched environments show evidence of improved welfare. However, piglets reared in enriched environments that are then weaned into barren environments have compromised welfare (i.e. less play and more belly nosing), even in comparison to piglets both reared and weaned in barren environments (Oostindjer et al., 2011). Similarly, hen welfare can be compromised if adult production environments contain specific enrichments (i.e. perches) that are not available in the rearing environment (Hester et al., 2013a).

Although not reported here (due to the low response), our survey data indicated that of the enrichments identified in the literature search that improved animal welfare (n = 67, appendix 1) only 33% on average were currently utilised by industry (6% pork industry; 34% egg industry; 56% chicken meat industry). This data suggests a disconnect between research and industry. This disconnect may be related to concerns with practicality (actual or perceived) or economics. Indeed, when surveyed the responses showed that industry's greatest perceived barrier to implementing enrichments was the associated costs (appendix 2). Our survey data revealed that an assessment of economic benefits and costs for effective and practical enrichments may not be straightforward. This can be due to the lack of familiarity with the enrichments as well as their implementation and maintenance costs (e.g., material). Furthermore, broader benefits from providing animal enrichments (e.g., access to retailers, gaining/maintaining social licence) may not generate an immediate economic return but may contribute to long run competitive advantage of a livestock production business which can be difficult to value in an economic benefits and costs assessment. This framework provides a structure to discuss the links between animal welfare outcomes and productivity improvements and premium price returns.

Conclusion

This paper proposes a framework to determine effective enrichments and incorporates four welfare outcome categories which are science based and may be utilised in a variety of contexts including, to inform on the development of animal welfare legislation, assurance programs, product differentiation and labelling. The impact of the enrichment is the focus rather than the intent and the tiered approach aims to ensure a continued improvement to captive animal welfare. The inclusion of practicality and economics ensures that researchers and regulatory bodies interact with industry to ensure that the proposed enrichments are industry relevant and feasible to implement. This framework can help stakeholders communicate the effects of their enrichment programs on animal welfare to the public and consumers and create genuine improvements to animal welfare.

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Appendix 1

Motives and barriers for implementation of animal enrichments (average rating) Rating scale from 1 for most important to 6 or 8 for indication least important motive or barrier, respectively. Results are reported as mean rank and standard deviation. A standard variation of zero and (*) indicates that only one response was recorded.

Motives	**Chicken meat**	**Pork**	**Egg**	**Feedlot cattle/dairy**	**Feedlot sheep**
To improve animal health and farm profitability	1.00 ± 0.0	3.25 ± 2.2	1.00 ± 0.0*	2.00 ± 0.0*	2.00 ± 0.0*
Increase the farm and/or industry's social license to operate	3.25 ± 1.3	1.50 ± 1.0	2.00 ± 0.0*	3.00 ± 0.0*	1.00 ± 0.0*
To meet the standards of accreditation agencies	3.00 ± 1.4	4.75 ± 1.7	3.00 ± 0.0*	8.00 ± 0.0*	6.00 ± 0.0*
Peer pressure	5.75 ± 1.3	5.50 ± 1.3	5.00 ± 0.0*	4.00 ± 0.0*	7.00 ± 0.0*
Pressure from consumers	5.00 ± 1.4	4.00 ± 1.2	6.00 ± 0.0*	5.00 ± 0.0*	4.00 ± 0.0*
Pressure from retail sectors	3.50 ± 1.3	3.00 ± 2.0	4.00 ± 0.0*	6.00 ± 0.0*	5.00 ± 0.0*
Pressure from lobby groups	6.50 ± 0.6	6.00 ± 1.4	7.00 ± 0.0*	7.00 ± 0.0*	3.00 ± 0.0*
Other	8.00 ± 0.0	8.00 ± 0.0*	8.00 ± 0.0*	1.00 ± 0.0*	8.00 ± 0.0*

Barriers	**Chicken meat**	**Pork**	**Egg**	**Feedlot cattle/dairy**	**Feedlot Sheep**
Costs of implementation, including time and communication	1.2 ± 0.5	1.25 ± 0.5	1.00 ± 0.0*	2.00 ± 0.0*	1.00 ± 0.0*
Pressure from stakeholders (e.g. consumers, retailers, lobby groups) is not high enough	3.8 ± 1.3	2.75 ± 1.5	5.00 ± 0.0*	5.00 ± 0.0*	4.00 ± 0.0*
Long term feasibility of enrichments is uncertain	3.4 ± 1.1	3.00 ± 0.0	4.00 ± 0.0*	6.00 ± 0.0*	2.00 ± 0.0*
No regulation that enforces adoption of enrichments	4.0 ± 1.2	4.75 ± 0.5	3.00 ± 0.0*	4.00 ± 0.0*	5.00 ± 0.0*
Lack of knowledge about the costs and benefits about enrichments that improve animal welfare	2.6 ± 1.1	3.25 ± 1.5	2.00 ± 0.0*	1.00 ± 0.0*	3.00 ± 0.0*
Other	6.0 ± 0.0*	6.00 ± 0.0*	6.00 ± 0.0*	3.00 ± 0.0*	6.00 ± 0.0*