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Review

Welfare of beef cattle in Australian feedlots: a review of the risks and measures

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Abstract. The rising global demand for animal protein is leading to intensification of livestock production systems. At the same time, societal concerns about sustainability and animal welfare in intensive systems is increasing. This review examines the risks to welfare for beef cattle within commercial feedlots in Australia. Several aspects of the feedlot environment have the potential to compromise the physical and psychological welfare of cattle if not properly monitored and managed. These include, but are not limited to, animal factors such as the influence of genetics, temperament and prior health, as well as management factors such as diet, pen design, resource provision, pregnancy management, and stock-person attitudes and skills. While current industry and producer initiatives exist to address some of these issues, continuous improvements in welfare requires accurate, reliable and repeatable measures to allow quantification of current and future welfare states. Existing measures of welfare are explored as well as proxy indicators that may signal the presence of improved or reduced welfare. Finally, potential future measures of welfare that are currently under development are discussed and recommendations for future research are made.

Additional keywords: affective state, behaviour, health, stress, temperament.

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Introduction

Dramatic increases in global food demand have resulted in growing pressure on the agricultural sector to improve efficiency of production and to do so in an environmentally and ethically sustainable manner (Tilman *et al*. 2002). In coming years, it is predicted that livestock production will continue to intensify to support the increasing global demand for animal protein (Nardone *et al*. 2010; Henry *et al*. 2012). For many centuries, cattle husbandry in parts of northern Europe relied on housing and hand-feeding animals for extended periods of the year in habitations shared with humans or in barns, and it is a practice that continues today. Close confinement with intensive feeding of cattle in open air feedlots was developed as a method for raising cattle commercially in Australia in the 1960s (Gaughan and Sullivan 2014). Feedlots today are intensive beef-production systems designed to finish cattle on high-energy concentrate diets so as to meet various market specifications. Commercial feedlots can be found around the world and their scale and the proportion of the beef market they occupy varies considerably across countries. In Australia, there are ~400 accredited cattle feedlots, with an average capacity of 2793 cattle per feedlot (Australian Lot Feeders Association 2015). At any one time, ~1.2 million head are located within feedlots (~4% the total Australian cattle population), where they spend, on average, 95 days, equating to the last 10–15% of their lifespan (Australian Lot Feeders Association 2015). The increasing capacities of feedlots will result in increasing pressure on producers to monitor, maintain and improve the welfare of cattle in these systems.

Societal concerns regarding animal welfare are increasing, which is driving increased scrutiny of livestock industries (Wilson *et al*. 2002*a*; Eurobarometer 2007; Spain *et al*. 2018). Livestock producers tend to emphasise the importance of health and access to suitable resources such as food, water and shelter when considering welfare, while consumers place an additional emphasis on freedom to move and the ability to display natural behaviours (Vanhonacker *et al*. 2008; Phillips *et al*. 2009). The deviation of feedlots away from the more 'natural' environment offered by extensive systems may, therefore, lead to consumer concerns around the welfare of cattle within feedlots.

Since the emergence of animal welfare as an issue of importance (Brambell 1965) there have been considerable improvements in breeding, management, transport and slaughter practices in farm animals across most production systems (Fraser 2008; Farm Animal Welfare Council 2009). Outside of legislative enforcement, improvements in animal-welfare standards within a production system must rely on producer, industry or retailer drivers. Regardless of the impetus, an improvement in welfare within any system requires, first, an understanding of the potential issue and, then, a way of objectively measuring an outcome so as to determine the effectiveness of any intervention.

It is acknowledged that there are similar, but also different challenges to welfare for cattle in feedlots and pasture-based production systems. However, a direct comparison of the welfare risks presented by intensive versus extensive cattle production is not within the scope of the present review. For details of some of the welfare issues presented by risks inherent in extensive cattle production systems, see the review by Petherick (2005). It is also noteworthy that the feedlot environment may protect cattle against several welfare hazards experienced in other production systems, such as hunger, predation and some types of parasitism. Further, increased levels of monitoring achieved in feedlots enables many problems to be identified and treated earlier than some extensive systems allow. A discussion of these benefits over extensive systems is not included in the review as it will not assist in the development of plans to monitor and improve welfare in feedlots. Overall, it can be concluded that there are strengths and weaknesses of both extensive and intensive production systems, with one not necessarily superior to the other. Where insufficient research is available in beef cattle, research in dairy cattle is occasionally used, and is identified as such. For a review of the welfare issues affecting intensive beef production in the United States, see Tucker *et al*. (2015).

The present review aims to identify aspects of the Australian feedlot environment that may compromise both the physical and psychological welfare of beef cattle and that need to be carefully monitored and managed. Grandin (2016) described muddy conditions, heat stress and animal handling as the three major welfare concerns for outdoor feedlot cattle. While these are important factors, additional animal, resource and management factors may also affect cattle welfare (Colditz *et al*. 2014). In many areas, there are producer or industry plans in place to manage many of these risks, and research into methods of monitoring and improving welfare continues (for examples, see the Australian Lot Feeders Association website[1]). The present review aims to aid in the development of such plans and inform future research by providing a comprehensive overview of the main threats to animal welfare in feedlots. The review will focus on the Australian system and the identification of existing, practical welfare measures that may aid in continued improvement of welfare. Proxy indicators that are not direct measures of welfare, but which may imply the presence of improved or reduced welfare are also presented as well as new measures, which are currently limited to the experimental setting. Finally, future directions for research are suggested.

Factors affecting welfare in the feedlot

Several aspects of the feedlot environment have the potential to compromise physical and psychological welfare if not properly monitored and managed. The present review attempts to identify these aspects and outline the literature, which supports the conclusion that welfare may be affected.

Physical factors

Health

Injury and illness are well established causes of reduced welfare in cattle. While feedlot cattle are inspected daily, the identification of ill health by stockpersons remains challenging (Rezac *et al*. 2014). The effectiveness of stockperson training programs and observational skills in identifying sick or injured animals is, therefore, a predominant limiting factor to maintaining welfare (Weary *et al*. 2009; Daigle and Ridge 2018). Morbidities within feedlot enterprises tend to be associated with bovine respiratory disease (Sackett *et al*. 2006; Cusack *et al*. 2007; Edwards 2010), metabolic disorders, particularly acidosis (Galyean and Rivera 2003), and heat stress (Hahn and Mader 1997; Hahn 1999; Entwistle *et al*. 2000; Sackett *et al*. 2006). The incidence of ill health typically decreases as days spent in the feedlot increase (Snowder *et al*. 2006), although Vogel *et al*. (2015) found that the greatest percentage of mortalities occurred in the mid-feeding period (from 31 days on feed to 61 days before processing). A 2010 health survey of the Australian feedlot sector found that 84% of morbidities were related to respiratory issues, while 11% involved the musculoskeletal system and included, for example, lameness caused by foot and hoof injuries and septic arthritis (Perkins 2013).

The lifetime health history of cattle may also influence welfare within feedlots. Diagnosis and treatment of illnesses both before and after feedlot entry may have a lasting influence on the health status and overall performance of individual animals while in the feedlot (Brown-Brandl *et al*. 2006*a*). Cattle that had been clinically diagnosed and treated for illnesses before entering the feedlot spent 23% less time at the feed bunk than did cattle that had not been previously treated for health concerns (Sowell *et al*. 1997). Brown-Brandl *et al*. (2006*a*) reported that animals with a history of pneumonia had higher respiration rates (average 10.5% increase) and lower average daily gains (1.46 ± 0.04 kg/day versus 1.54 ± 0.02 kg/day) than did cattle that had no history of pneumonia. Similarly, Gardner *et al*. (1999) highlighted the differences in the average daily gain of steers with no (1.58 kg/day), inactive (1.43 kg/day) and active (1.17 kg/day) respiratory-tract lesions. Reinhardt *et al*. (2012) indicated that as the number of times that cattle were treated for any cause of morbidity increased, there was a linear decrease in average daily gains ($P < 0.01$). Therefore, identifying and treating sick or injured animals as well as understanding their health history

[1]http://www.feedlots.com.au [Verified 24 June 2020].

before feedlot entry, is important for improving not only the welfare but also the performance of feedlot cattle. In reality, accurate health-history records may not be feasible if cattle are purchased through the saleyards or have had multiple owners, so direct purchasing from producers who keep good health records is preferential. Improved health will reduce the cost of gain in meeting market specifications, while also minimising exposure to other aspects of the feedlot environment that may affect welfare.

Thermal comfort

All homeothermic animals have a thermoneutral zone where the animal experiences a thermal environment that supports optimal health and productivity (Ames 1980). Thermal comfort incorporates a lower critical temperature and an upper critical temperature (Yousef 1985), below and above which additional energy is required to maintain body homeostasis. When animals encounter climatic conditions outside their thermoneutral zone, the immediate response is self-preservation, where energy is diverted away from growth and shifted towards maintaining homeostasis and core body temperature (Baumgard and Rhoads 2012). However, it is important to recognise that core body temperature in cattle is not static and exhibits a circadian rhythm (Bitman *et al*. 1984; Robertshaw 1985; Lefcourt *et al*. 1999). These variations in core body temperature can be considered as the balance between heat energy produced or accumulated and heat energy dissipated from the body (Hahn 1999; Mader and Davis 2004; Gaughan *et al*. 2008*b*). This accumulation and dissipation of heat from the body is constantly adjusting; however, as heat load conditions increase, heat accumulation can become greater than dissipation, leading to accumulated heat load in cattle and an inability to regulate core body temperature (Mader *et al*. 2006; Gaughan *et al*. 2008*b*). Chronic exposure to heat load can be present in many regions throughout the world during the summer months and can be a major stressor for healthy feedlot cattle (Gaughan *et al*. 2013). Climatic conditions that influence the heat load placed on cattle include ambient temperature, relative humidity, solar radiation, wind speed and rainfall (Bond *et al*. 1967; Blackshaw and Blackshaw 1994; Brown-Brandl *et al*. 2006*b*).

Environmental conditions are not the only factors that influence thermal exchange in livestock. Genotype (e.g. *Bos indicus* content) and point of origin (e.g. tropical or temperate climate) influence the phenotype expressed by cattle, particularly coat characteristics (Belasco *et al*. 2015). For example, cattle with a short summer coat have a lower critical temperature of 15°C compared with –7.8°C for those with a long dense winter coat (Brandle *et al*. 1994). The selection of appropriate genetics for the production environment is, therefore, important for the continual improvement of animal welfare (Colditz *et al*. 2014). For feedlot cattle, other animal factors that influence thermal balance include the number of days on feed, body condition (fat coverage and deposition), growth rate, health status, and adaptation to the feedlot environment and local climate (Mader 2003; Maia *et al*. 2005; Gaughan *et al*. 2008*b*; Dikmen *et al*. 2012). The heat increment of feed provided, that is the increase in body temperature experienced after eating, may also influence the heat load placed on cattle. Fats, carbohydrates and protein have low heat increments, while fibre has a high heat increment (Gaughan and Sullivan 2014).

There are several strategies that feedlot managers may utilise to limit the impact of high heat loads on feedlot cattle. Restricting feed or changing the timing of feed delivery may help reduce the body temperature of cattle under high heat loads. However, this is also likely to affect growth and should be used as a short-term strategy only (Mader *et al*. 2002). Allowing animals to acclimate to the local climate may also help animals cope better with temperatures outside their thermoneutral zone (Young and Hall 1993). Traditionally, managing heat load in feedlots has emphasised the importance of providing shade to feedlot cattle. Numerous studies have identified that feedlot cattle will utilise shade where available (Clarke and Kelly 1996; Gaughan *et al*. 2004*b*; Brown-Brandl *et al*. 2005; Eigenberg *et al*. 2010; Sullivan *et al*. 2011). Lees *et al*. (2020) showed that as heat-load intensity increased, there was a corresponding increase in shade utilisation by both *Bos taurus* and *Bos indicus* steers. Mitlöhner *et al*. (2001) and Castaneda *et al*. (2004) indicated that unshaded cattle seek shade by placing their heads in the shade cast by feed bunks during the hot hours of the day. Similarly, Gaughan and Mader (2014) and Lees *et al*. (2020) described unshaded cattle utilising the shade of other animals, water troughs and fence posts. Numerous studies have highlighted that unshaded cattle have higher respiration rates (Mitlöhner *et al*. 2002; Gaughan *et al*. 2004*b*; Brown-Brandl *et al*. 2005) and body temperatures (Clarke and Kelly 1996; Gaughan *et al*. 2010; Mader *et al*. 2010; Lees *et al*. 2018*b*) than do their shaded counterparts. However, there is some conjecture in the literature regarding the amount of shade (m^2/animal) required to balance the impact of heat load (Clarke and Kelly 1996; Mitlöhner *et al*. 2002; Sullivan *et al*. 2011). Although shade structures can be beneficial for feedlot cattle under hot conditions, the reduction in solar radiation may be offset by a lack of air movement under the structure itself (Gaughan *et al*. 2004*b*). The design and functionality of the shade structure, as well as local climatic conditions, are, therefore, important considerations to enable adequate mitigation of high heat loads. Regardless, it is well established that shade availability is beneficial for feedlot cattle and an additional advantage is that the application is passive and reliant on voluntary use (Eigenberg *et al*. 2005).

Wetting cattle is another strategy that feedlot managers may employ to manage high heat loads. Studies utilising overhead water application for cooling feedlot cattle have predominantly focussed on reducing the impact of heat load on physiological responses such as increased body temperature, respiration rate and panting score (Davis *et al*. 2003; Gaughan *et al*. 2004*a*, 2008*a*; Mader *et al*. 2007; Brown-Brandl *et al*. 2010; Tresoldi *et al*. 2018). Morrison *et al*. (1973) found positive effects of sprinklers on feed intake and weight gain, but not feed efficiency in feedlot cattle. Cattle in the study by Morrison *et al*. (1973) were housed in a desert climate, on slatted floors, to avoid the issues of muddy pens developing as a result of the wetting process. Similar benefits were not found by Mitlöhner *et al*. 2001, who used misters on cattle housed in pens with partially slatted floors. The authors speculated that the finer droplet size generated by the misters may not have been as effective at cooling as are the larger droplets from sprinklers. Minimal production benefits have also been found when the pen surface rather than the cattle was wetted (Mader and Davis 2004). There is limited information regarding behavioural responses to sprinklers and their voluntary use. Mader *et al*. (2007) described feedlot cattle voluntarily using wetted areas during hot climatic conditions. More recently, Parola *et al*. (2012) concluded that beef cattle will voluntarily utilise overhead sprinklers during times of high heat load.

No studies have investigated the preference of cattle for sprinklers versus shade within feedlots. However, Schütz *et al*. (2011) described that dairy cattle prefer to use shade rather than sprinklers during summer. Utilising sprinklers to mitigate heat load has the potential to become a beneficial management tool (Mader *et al*. 2007), but there are some issues. At the cessation of wetting, cattle become suddenly exposed to hot conditions, to which they have not initiated physiological coping mechanisms, resulting in a rapid accumulation of heat (Gaughan *et al*. 2004*a*). Additionally, there is the potential for the application of water to increase humidity within the pen, reducing the efficiency of thermal-exchange mechanisms (Mader *et al*. 2007). Use of sprinklers may, therefore, be best suited to dry environments with limited humidity. Availability and access to adequate water in the Australian production environment may also prove challenging.

Animal comfort and productivity can also be compromised during exposure to cold, wet or windy conditions, as there is an increase in maintenance energy requirements (Belasco *et al*. 2015; Mader and Griffin 2015). Rainfall events have the potential to influence an animal's thermal-exchange mechanisms, where a wet hide reduces the insulation properties of the coat (Vandenheede *et al*. 1995). Grandin (2016) suggested that managing wet and muddy conditions becomes difficult when annual rainfall exceeds 500 mm per annum.

Housing

The conditions in which cattle are housed influence their comfort and welfare. Cattle are highly motivated to lie down, generally resting for 4 to 10 h a day (Kilgour 2012), and a reduction in lying time may lead to chronic stress (Fisher *et al*. 2002). Studies have shown that dairy cattle will conduct operant tasks or push heavy weights for lying-time rewards (Tucker *et al*. 2018). Dairy cattle also prioritise lying over eating when restricted from both resources or given limited time to utilise both resources (Munksgaard *et al*. 2005). A review of cattle preferences showed that dairy cattle prefer to lie on soft, dry surfaces (Schütz *et al*. 2018). Similarly, Wilson *et al*. (2005) found that the pattern of lying and feeding in feedlot cattle changed depending on pen conditions and stocking density. Uncomfortable surface conditions, such as mud, may, therefore, pose a welfare risk to feedlot cattle (Grandin 2016). Cattle housed in muddy pens also have a tendency to reduce feeding frequencies, and muddy coats can compromise thermoregulation (Mader 2011). However, a study by Lee *et al*. (2016*a*) found that under warm weather conditions, increasing mud depth did not influence beef cattle preference for a feedlot environment compared with pasture. Standing in mud may also cause breaches to the skin barrier, increasing the risk of infectious diseases such as digital dermatitis and foot rot and, therefore, increasing the incidence of lameness (Davis-Unger *et al*. 2019). The incidence of muddy pens is likely to be influenced by several factors, including bedding availability, climate, pen-surface conditions, pen maintenance, and overall pen design, including the slope of the pen.

The National Guidelines for Beef Cattle Feedlots in Australia (2012) indicate a minimum space allowance for feedlot cattle of 9 m^2/animal in open-air feedlots, a pen slope of 2–6% away from feed bunks and a pen-surface permeability of less than 1×10^{-9} m/s (National Guidelines for Beef Cattle Feedlots in Australia 2012). In the United States, mounds have been considered a useful addition to feedlot pens as they reduce mud problems during wet periods and can enhance airflow during hot conditions (Mader 2003). Mounds should be positioned perpendicular to the feedbunks, allowing water to easily run towards the drainage areas (Grandin 2016).

The negative impacts of muddy pens can be further negated by utilising bedding materials to absorb excess moisture from pen surfaces (Mader 2011; Grandin 2016). Several USA beef reports have outlined improvements in feed efficiency in open-air feedlot cattle provided with straw bedding under cold weather conditions (Birkelo and Lounsbery 1992; Mader and Colgan 2007). As feed intake did not increase, these gains may have been due to reduced maintenance-energy requirements. This suggests a potential for improved thermal comfort in these animals, although animal comfort and welfare were not directly measured in any study. In addition to straw, an Australian study compared other possible bedding materials, including woodchip, wood mulch, sawdust, timber off-cuts and building and construction waste. The suitability and effectiveness of these as bedding materials varies, as does their availability and economic viability (Watts *et al*. 2015). The potential for these beddings to contain sharp pieces or contaminants that may cause injury also needs to be considered. Good maintenance of pen surfaces may also reduce muddy conditions by allowing the surface to repel surplus water (Grandin 2016).

Feed and water

On entry to feedlots, cattle are typically transitioned from a roughage-based or grazing diet to a concentrate ration within a short period of time (<30 days). If not properly managed, this transition and the nature of the diet provided, can predispose animals to metabolic disorders such as acidosis (Galyean and Rivera 2003). From a survey of Australian feedlot producers, gastrointestinal-tract disorders were estimated to account for 8.6% of mortalities. The number of deaths peaked at about the third to fourth week on feed, before declining (Perkins 2013).

Susceptibility to acidosis may vary among individuals, and management should be tailored towards the most susceptible animals (Galyean and Rivera 2003; Bevans *et al*. 2005).

Feedlot rations are typically developed in conjunction with nutritionists to maximise growth, while ensuring that the basic biological requirements of cattle are met and the risk of metabolic disorders is reduced. Optimal-diet theory (reviewed by Sih and Christensen 2001) suggests that foragers will prefer to consume feedstuffs that provide the greatest energy for the least amount of work and there is evidence that cattle will preferentially consume the most palatable portion of the ration (reviewed by Schütz *et al*. 2018). This is supported by Lee *et al*. (2013) who found that when given free access to both feedlot and pasture environments, cattle chose to obtain most of their daily nutrition requirements from the concentrate ration offered in the feedlot. Further, when a cost was added to their choice, cattle preferred a feedlot environment over pasture when feeding coincided with making a choice (Lee *et al*. 2013). However, when the feedlot diet was available *ad libitum* and a cost was added, no clear preferences were shown due to individual differences among cattle (Lee *et al*. 2016*a*).

Evidence also exists to suggest that cattle may shift their preferences to suit their physiological state. For example, cattle experiencing bouts of ruminal acidosis have been shown to shift their preference to favour the fibre component of the diet (DeVries *et al*. 2014). Van Os *et al*. (2017*a*) found that, in a motivation test, beef cattle on a high-grain feedlot diet would push nearly half their bodyweight to gain access to hay. They also found that cattle fed a hay diet would push similar weights to access additional hay, albeit with less urgency. In a similar study, Van Os *et al*. (2017*b*) found that there was no difference in the motivation of cattle fed hay to access a concentrate ration compared with accessing additional hay. While preference studies have limitations (see section *Measures of preference and motivation to express behaviours and access resources*), these findings raise interesting questions around an animal's desire to satisfy its nutritional requirements in the easiest way possible versus the ability to search for different feeds (foraging). Additional research into the motivation of cattle to access additional concentrates if already fed a concentrate diet will help identify the value of the grazing and foraging processes, if any, as distinct from the satisfaction of basic nutritional requirements.

The use of in-feed antimicrobials may also have an impact on the welfare of feedlot cattle. While use of antimicrobials generally improves the health and, therefore, welfare of treated cattle, there is a risk that over-use will lead to development of resistance, reducing the efficacy of this treatment into the future (Badger *et al*. 2020). A survey of Australian feedlots suggested that in-feed antimicrobial use is not widespread and that antimicrobials are, generally, used strategically in at-risk pens to prevent gastrointestinal disorders (Badger *et al*. 2020).

Quantity as well as quality of water is another important welfare consideration in feedlots. Daily water intake is influenced by several bodily functions, including, but not limited to, regulation of core body temperature, growth, digestion and metabolism, and hydrolysis of proteins, fats and carbohydrates (National Research Council 2000; Arias and Mader 2011). However, daily water intake appears to be primarily driven by dry-matter intake, including the level of intake (kg/day) and the type of ration offered, i.e. concentrates versus roughage (McDowell and Weldy 1967). Feeding protocols may also play a role, with Ahlberg *et al*. (2018) finding that cattle fed *ad libitum* drank significantly more than did those that were not. Assessment of water requirements for cattle should consider both daily requirements and total annual requirement, flow rates needed for peak or short-term demand and design factors to prevent temperature build-up (Animal Health Australia 2014). There appears to be very little research on optimal space allowances at the water trough for feedlot cattle. However, even if sufficient space is provided, an additional welfare risk may occur in hot weather if cattle stand over the trough to cool themselves, reducing access for subordinate cattle (Castaneda *et al*. 2004).

For feedlots, it is important to ensure that appropriate water supplies can be met at all times of the year. Arias and Mader (2011) reported that feedlot cattle in the United States consumed 87.3% more water in summer than in winter (32.4 L/day versus 17.3 L/day, $P < 0.01$). The temperature of drinking water is an important factor influencing consumption; however, there is considerable variation within the literature as to the optimum temperature in relation to ambient conditions (Schütz *et al*. 2018). Regular cleaning of water troughs is also essential (Animal Health Australia 2014), especially where troughs are shared among pens, as this presents an increased disease-transfer risk (Hay *et al*. 2016).

The Australian Animal Welfare Standards and Guidelines for Cattle indicate that where water quality is known to be variable, water should be regularly monitored for harmful substances and managed so as to protect cattle welfare (Animal Health Australia 2014). The presence of salt, sulfates and faecal contamination may all result in reduced water intake and, subsequently, reduced feed consumption (Schütz *et al*. 2018).

Pregnancy management

The intake of pregnant females into feedlots is undesirable from both an economic and management perspective (Rademacher *et al*. 2015). Many cows will attempt to seek solitude and shelter when calving (Herring 2014), a process which may be hampered by the close confines of the feedlot environment. Frustration of this behavioural drive may cause additional stress on top of the calving process and represents a welfare concern for feedlot females. Other welfare concerns associated with feedlot pregnancies include calving dystocia, which may require a Caesarean, increased risk of mortality, as well as abortifacient induced morbidity (Buhman *et al*. 2003). Research from the United States regarding feedlot pregnancy management has generally focused on the identification of pregnant females and use of abortifacients (Buhman *et al*. 2003; Terrell *et al*. 2011; Rademacher *et al*. 2015). In Australia, the best-practice management guide for pregnant heifers (Bergman 2019) recommends a combination of strategies to reduce the risk of pregnant females calving on feed. Mainly, to reduce the number of pregnant females entering the feedlot by only purchasing steers or pregnancy-tested empty females, to determine the pregnancy status of high-risk females at arrival and to manage appropriately, and, finally, to monitor all females on feed for signs of impending parturition and remove them from the pen as soon as possible. Welfare of both the mother and calf need to be considered and managed in this situation. Further research into the incidence of this issue in Australia and the success of various management strategies is required to safeguard the welfare of pregnant females in the feedlot.

Psychological factors

Social interactions

Cattle allocations to pens are a reflection of the management style within each feedlot. Cattle are allocated to pen cohorts at induction and cattle numbers within pens are based on pen size and design. In Australia, this typically ranges from 50 to 200 head (Watts *et al*. 2016). Group housing allows the choice of social partners and the expression of social behaviour to occur (Gutmann *et al*. 2015*b*). However, social stress may ensue, as there is a disruption to the animals' known social bonds, intermixing with new individuals and, ultimately, the establishment of a new social hierarchy (González *et al*. 2008). Agonistic behaviours often reduce as cattle become more familiar with their cohort and surroundings (McPhee *et al*. 1964; Tennessen *et al*. 1985), so the welfare risks associated with poor social interactions are predominantly concentrated at the beginning of the feedlot experience or each time animals are introduced into new groups. The physical implications of agonistic interactions may include injury and bruising and there is some evidence that the physiological stress of agonistic interactions may compound over time, particularly in subordinate animals (Mench *et al*. 1990). After initial mixing, pen cohorts typically remain together until the completion of the feeding period, unless required to be moved to a hospital or treatment pen. However, there are some instances where cattle that have not achieved market specifications remain at the feedlot and are regrouped until market specifications have been satisfied. Regrouping requires new dominance relationships to be established, resulting in an increase in agonistic interactions (Tennessen *et al*. 1985; Mounier *et al*. 2006; Jensen 2018). Regrouping within 2 weeks of slaughter may also have an impact on meat quality (Colditz *et al*. 2007). Boyland *et al*. (2016) suggested that, within a group of dairy cattle, keystone individuals may be particularly influential in maintaining the social structure. Therefore, understanding the social interactions among cattle within pen cohorts may also be an important consideration for feedlots. Abnormal social interactions such as Buller syndrome (repeated mounting of one steer by other steers; Brower and Kiracofe 1978; Edwards 1995) are an additional welfare risk above and beyond that associated with the normal establishment of social hierarchy and may lead to poor performance and increased risk of injury and death (Blackshaw *et al*. 1997). Steers subjected to repeated mounting may become exhausted and show evidence of trauma such as hair loss or swelling on the tail and rump (Tucker *et al*. 2015). The number of steers in a pen (but not stocking density), use of hormonal implants and method of mixing on feedlot entry have all been found to influence the incidence of Buller syndrome (Irwin *et al*. 1979).

Human–animal interactions

Humans are directly responsible for the emphasis placed on animal welfare and the living conditions provided to the animals within their care (Hansson and Lagerkvist 2014). Within the feedlot industry, stockpersons are directly responsible for the provision of food and water, maintaining health, identifying welfare issues and pen cleaning and maintenance. Therefore, there are numerous human–animal interactions that occur within a feedlot and it is important that stockpersons have sufficient training and experience in low-stress stock-handling techniques, as well as appropriate attitudes towards animals.

A stockperson's behaviour towards animals and their welfare is largely driven by the attitudes and beliefs that individuals and teams hold (Hemsworth *et al*. 1993). Human personality attributes, including self-esteem and job satisfaction, can also influence a stockperson's behaviour towards animals and welfare (Waiblinger *et al*. 2002; Boivin *et al*. 2003). In many instances, stockpersons do not have formal training and their attitudes are developed from observations of other stockpersons and personal experience (Hemsworth *et al*. 1993).

Numerous studies in other intensively managed species such as pigs and poultry have shown links between high levels of fear towards humans, stress and reduced productivity (reviewed by Hemsworth 2003). The use of cognitive-behavioural interventions with livestock handlers have also shown to improve both stockperson attitudes, animal behaviour and other job-related attributes, including staff-retention rates (Coleman *et al*. 2000). Research into the effects of human–animal interactions in beef cattle is less common, although a recent study confirmed that formal cattle-handling training has a positive outcome on stockpersons' attitudes, consistency of handling and the incidence of undesirable animal behaviour (Ceballos *et al*. 2018).

Affective state

Affective state is a concept used to describe the emotions or feelings of an animal and can incorporate both positive (pleasant) and negative (unpleasant) experiences (Mendl *et al*. 2010; Mellor and Beausoleil 2015). Dismissed for a long time as anthropomorphic, there is now increasing evidence that the brain structure, physiology and behaviour of animals are similar enough to those of humans to produce comparable emotional experiences (Boissy *et al*. 2007; Hemsworth *et al*. 2015). Understanding the affective state of cattle within the feedlot environment, and the factors that influence it, will contribute towards understanding how cattle perceive the feedlot and whether the experience is positive or negative. Negative affective experiences include emotions such as thirst, hunger, nausea, breathlessness, pain, fear and anxiety. Positive affective experiences include emotions such as satiety, contentment, companionship, curiosity, playfulness, anticipatory joy, sexual pleasure and exploration (Hemsworth *et al*. 2015). It has now been recognised that good welfare needs to be extended to include the presence of positive experiences and emotions (Boissy *et al*. 2007).

There is a perception that housing cattle in feedlots may negatively influence affective states due to the inability to express natural levels of activity, such as would occur during grazing, potentially resulting in 'boredom' (Fureix *et al*. 2015). However, this may not be an issue if the diets have adequate fibre to promote rumination and lying time. There has been limited research to identify which resources are important to feedlot cattle and the behavioural needs required by cattle to satisfy their emotional state. It could be anticipated that cattle desire access to pasture solely to satisfy the need to graze, a behaviour that may be restricted by the feedlot environment if insufficient roughage is provided (Rutter 2010). However, when given a choice between a pasture and feedlot environment, cattle showed a preference for the pasture during the night where they spent 90% of the time lying down, and preferred the feedlot during the day where they consumed the majority of their daily nutritional requirements regardless of the quantity of pasture on offer (Lee *et al*. 2013). Similarly, Lee *et al*. (2013) found that while cattle generally preferred pasture when given free choice, they would still regularly choose to enter the feedlot environment even when there was a cost associated with their choice (being confined to the feedlot for between 8 and 16 h; Lee *et al*. 2016*a*). The authors also indicated that, in warmer temperatures, the choice to enter the feedlot continued regardless of mud depth (Lee *et al*. 2016*a*). These findings suggest that cattle may view the feedlot environment as a good place to find high-quality feed but as a less comfortable place for resting. This is supported by similar research in dairy cows showing preferences for pasture access at night (Charlton *et al*. 2013; Von Keyserlingk *et al*. 2017). Finally, Lee *et al*. (2016*a*) found that there was considerable individual variation in cattle preference towards the feedlot or pasture environment, suggesting that an underlying trait may influence an animal's affective experience of the feedlot environment.

The inability to express highly motivated behaviours can lead to a high level of frustration. Stereotypies are maladaptive behaviours, often repetitive and periodic in nature, which are considered to arise from prolonged frustration (Williams and Randle 2017). Their role appears to be to reduce arousal in high-arousal situations. This is supported by the lowering of heart rates in beef calves performing stereotypies (Seo *et al*. 1998) and the complete suppression of stereotypies in adult beef breeder cows when a dopamine receptor antagonist is given, which eliminates the brain's positive feedback mechanism in response to the behaviour (Sato *et al*. 1994). In non-tethered feedlot cattle, it has been suggested that oral behaviours such as tongue-playing are demonstrated as an alternative oral behaviour when time spent feeding is reduced, rather than a true stereotypy (Ishiwata *et al*. 2008; Daigle *et al*. 2017). Further research is required to identify the incidence and implications of oral stereotypies in Australian feedlot cattle.

Temperament and coping style

Cattle vary in their behavioural response to stressful events and this is broadly defined as temperament (MacKay and Haskell 2015; Finkemeier *et al*. 2018). The behavioural response to a real or perceived threat is the first step in the stress response of an animal (Moberg 2000). Although these behavioural responses can be a biologically advantageous reaction to danger, extreme or reactive responses may lead to chronic stress and negatively affect welfare, productivity and stockperson safety (Rushen *et al*. 1999). Behavioural responses can be complex and are a combination of inherent and environmental factors (Grandin 1997). A major cause of the complexity in behavioural response is variation in the perception of a stressor by individual animals (Mason and Mendl 1993; Moberg 2000). There is also evidence in many species that individuals may consistently adopt either a passive (reactive) or active (proactive) coping style when dealing with fear-evoking stressors (Koolhaas *et al*. 1999), and there is some indication that variation in coping styles also exists in cattle (Van Reenen *et al*. 2005).

Training programs that include positive handling for young cattle reared in extensive production systems can result in the cattle being easier to handle in later life (Fordyce *et al*. 1985), having reduced fearfulness of humans (Petherick *et al*. 2009), and improved productivity within intensive systems (Walker *et al*. 2007). However, substantial variation in temperament remains, even with good handling practices (Burrow and Dillon 1997; Walker *et al*. 2007; Petherick *et al*. 2009). The welfare of cattle in the feedlot environment and how they experience stress may, therefore, be influenced by the animal's inherent temperament. The purchase of cattle with calmer or more appropriate temperaments is one method that may be utilised by feedlot management to improve the welfare and safety of both cattle and people. Evidence suggests that cattle with calmer temperaments can have improved productivity. However, the effects of temperament on economically important traits can be variable, and the biological basis for the effects is not fully understood (Ferguson *et al*. 2006; Kadel *et al*. 2006).

Established welfare measures

Improvements in animal welfare need to be based on managing measurable outcomes, allowing for the identification of risks and the implementation of effective management strategies (Lyles and Calvo-Lorenzo 2014). Identifying the success, or otherwise, of management strategies relies on sensitive, specific and repeatable measures of animal, resource and management factors that influence animal welfare. Therefore, understanding the role of quantitative data in identifying and improving animal management on farms has become a focal area in animal-welfare research (Sumner *et al*. 2018). There are several measures that already exist worldwide, or that could be practical and achievable measures of animal welfare within the Australian feedlot industry.

Measures of health

Mortality can be considered an indicator of animal-welfare standards across animal agricultural industries (Ring *et al*. 2018). To date, information pertaining to mortality and morbidity has been largely overlooked as a measure of welfare (Colditz *et al*. 2014; Thomsen and Houe 2018). Mortalities should be considered as the worst-case outcome in regards to welfare management (Colditz *et al*. 2014). However, it is extraordinarily rare to find a livestock enterprise where mortalities do not occur. Therefore, while mortalities occur within all facets of animal agriculture, the cause and prevention of mortalities becomes an important factor for welfare assessment. Furthermore, information pertaining to the number of animals found dead versus the number euthanised may provide a valuable indicator of monitoring and intervention protocols (Colditz *et al*. 2014). The method of euthanasia used may also become an important welfare measure. The Australian Animal Welfare Standards and Guidelines for Cattle recommend the use of a close-range firearm or a captive bolt, to the brain, for the humane killing of adult cattle and calves (Animal Health Australia 2014).

Although blunt measures of animal welfare, data describing the cause and number of morbidities, treatments, and hospital-pen management may provide an understanding of the welfare performance of a livestock enterprise (Colditz *et al*. 2014; Fox 2015; Vogel *et al*. 2015). An understanding of the effect of days on feed and seasonal influence on the prevalence and incidence of morbidities may also assist producers in tailoring management practices accordingly (Perkins 2013).

Measures of thermal comfort

Changes in body temperature are considered to be a reliable indicator of thermal status; however, they can be difficult to measure in commercial environments (Mader *et al*. 2010; Gaughan and Mader 2014). Under field conditions, the assessment of panting score (Table 1) has been considered a viable alternative to measuring body temperature, to assess the heat-load status of cattle (Brown-Brandl *et al*. 2006*b*; Mader *et al*. 2006; Gaughan *et al*. 2008*b*; Gaughan and Mader 2014). Panting score provides a visual assessment of respiratory dynamics in cattle and assesses the breathing or panting condition that the animal is displaying (Young and Hall 1993). The presence of shade-seeking behaviour (if possible) may also be indicative of cattle that are uncomfortable with their thermal environment.

In addition to single measures of thermal comfort, indices combining multiple climatic factors provide a prediction of the impact of extreme climatic conditions on welfare and production. The heat-load index and the accumulated heat-load model were developed for feedlot cattle and can be adjusted for varying genotypic and management factors (Gaughan *et al*. 2008*b*). Further development of these models has led to a Cattle Heat Load Toolbox[2], which provides Australian feedlot producers with a 5-day heat-load forecasting service. Use of these tools not only allows feedlots to predict thermal comfort, but also to manage potential welfare risks associated with climatic extremes.

Resource measures

Measuring resources is generally a simple record of the quantity of a resource available or of the type or quality of the resource available. Determining the relevance of these resources to welfare and the required quantity for a positive welfare outcome is likely to be more difficult. For example, simple provision of water may not be adequate if the quality, temperature, flow rate and trough space per head is not suitable. Many of these factors will be highly specific to the feedlot and its location and will, therefore, need to be customised for individual feedlots.

Table 1. Assessment of panting score, including breathing condition and associated respiration rate (RR, breaths per minute)
Adapted from Brown-Brandl *et al*. (2006*a*), Mader *et al*. (2006) and Gaughan *et al*. (2008*b*)

Score	Breathing condition	RR
0	No panting	≤60
1	Slight panting, mouth closed, no drool, easy to see chest movement	60–90
2	Fast panting, drool present, no open mouth	90–120
2.5	As for 2, but occasional open-mouth panting, tongue not extended	90–120
3	Open-mouth and excessive drooling, neck extended	120–150
3.5	As for 3, but with tongue out slightly and occasionally fully extended for short periods	120–150
4	Open mouth with tongue fully extended for prolonged periods with excessive drooling. Neck extended and head up	≥160
4.5	As for 4, but head held down. Cattle 'breathe' from flank Drooling may cease	Variable RR may decrease

Measures of human–animal interactions

The quality of animal handling can be assessed by the US Beef Quality Assurance Feedyard Assessment model, which includes measurements of rate of electric prod use, improper catches in the crush, number of cattle vocalising following restraint in the crush but before procedure, cattle stumbling when exiting crush, cattle falling on exiting the crush, and number of cattle jumping or running when exiting the crush (Table 2; Beef Quality Assurance 2017). The advantage of these assessments is that the response is a yes or no, as they either do or do not occur during handling, making them easy to measure at the individual level. These individual scores can then be compiled to provide an overall incidence for the group, with thresholds set for acceptable occurrences of each measure (Beef Quality Assurance 2017).

Numerous questionnaires and personality tests have been used to attempt to qualify stockperson attitudes, although tailoring of the questions to the animal species of interest is generally necessary (Windschnurer *et al*. 2009). Avoidance distance at the feed bunk has also been suggested as a possible indicator of the human–animal relationship that has shown good inter-observer reliability (Windschnurer *et al*. 2009) and that does not appear to be influenced by the dominance or flightiness of other animals in the pen (Mazurek *et al*. 2011). The limitations of this and other tests designed to assess the human–animal relationship have been critically reviewed by Waiblinger *et al*. (2006).

[2]http://chlt.katestone.com.au/. [Verified 24 June 2020].

Table 2. Assessment of cattle behaviour during handling
Adapted from Beef Quality Assurance (2017), Simon *et al*. (2016) and Woiwode *et al*. (2016)

Category	Location	Measure	Definition
Cattle behaviour	Race	Balk	The route is clear in front of or behind the animal, but the animal refuses to move forward or backward within 4 s from being touched by a moving aid or electric prod.
		Run	The animal takes at least 2 strides at a gait faster than a trot once all 4 hooves touch the ground outside of the restraint on exiting.
		Back-up	The animal moves at least 1 step backward.
	Crush	Stumble	The animal's knee(s) or hock(s) contact the ground before the head gate is opened to release the animal.
		Fall	The animal's torso contacts the ground before the head gate is opened to release the animal.
	Crush exit	Stumble	The animal's knee(s) or hock(s) contact the ground after the head gate is opened to release the animal.
		Fall	The animal's torso contacts the ground after the head gate is opened to release the animal.
Vocalisation	Crush	Sound	Scored on a yes or no basis for any audible call or bellow made, while being restrained in the chute, but before any procedure being performed on that animal.

Measures of demeanour

An animal's demeanour or body language may provide important information about its physical and mental state. Qualitative Behavioural Assessment (QBA) is a technique used to identify subtle differences in behavioural expression that can then be converted to a numerical score. QBA forms part of the suite of welfare assessments for livestock administered in Europe by Welfare Quality (Welfare Quality 2009), and, in research, it has predominantly been used to assess the behaviour of beef cattle during transport (Stockman *et al*. 2011, 2013) and at slaughter (Stockman *et al*. 2012). Advantages of QBA are that they do not require specialised equipment and require limited training to conduct an assessment. Fleming *et al*. (2016) reviewed the use of QBA for assessing animal welfare, addressing key issues including reliability, sensitivity, versatility and feasibility. The resulting scores have been shown to have strong correlations with physiological indicators of stress, other quantitative measures of behaviour (Fleming *et al*. 2016), and measures of temperament (Sant'Anna and Paranhos da Costa 2013; Góis *et al*. 2016). Limitations to the technique have also been identified. For instance, observers shown footage of nervous animals in conjunction with the test footage subsequently scored the test-footage animals as more nervous (Fleming *et al*. 2015). Despite this difference, the overall ranking of animals did not change (Fleming *et al*. 2015). Furthermore, the time of day that video clips are scored may influence the outcome of QBA assessment (Gutmann *et al*. 2015*a*). Finally, the interpretation of QBA scores as an indicator of overall animal welfare requires experienced evaluation. Therefore, it has been suggested that QBA should be considered with other welfare assessments, rather than as a stand-alone measure of animal welfare (Fleming *et al*. 2016).

Measures of temperament and coping style

Numerous methods can be utilised to evaluate temperament using the escape and avoidance behaviours that cattle display when responding to stressors such as handling by humans, exposure to novel objects or social isolation (reviewed by Burrow 1997). These tests range from very simple objective or subjective measures to complex behavioural tests and assess various aspects of cattle behaviour in restrained and non-restrained situations. Wearable-sensor technology may also provide data on behavioural attributes such as activity levels in the home pen, which could be indicative of temperament or underlying coping styles (MacKay *et al*. 2013).

Table 3. Assessment of crush score in cattle
Adapted from Grandin (1993), Cafe *et al*. (2011*a*) and Lee *et al*. (2018)

Score	Descriptor
1	Calm, standing still, head mostly still, slow calm movements
2	Slightly restless, looking around more quickly, moving feet, shifting weight
3	Restless, moving backward and forward, some slight movement of crush
4	Nervous, continuous vigorous movement backward and forward, snorting, some movement of crush
5	Very nervous, violent movements, rearing, attempting to jump out

Two tests that are simple and safe to measure, are moderately to highly heritable (Burrow 1997; Kadel *et al*. 2006) and are currently being used by the beef cattle industry to select for calmer temperaments are flight speed (Burrow *et al*. 1988) and crush score (Grandin 1993). Flight speed is the electronically recorded speed at which an animal exits the crush when released and is an objective measure of temperament. Crush score is a subjective assessment of the level of agitation an animal displays when confined in the crush (Table 3). Slower flight speeds and lower crush scores are associated with calmer temperaments. Temperament is a complex trait and the specific aspect of temperament being measured by these tests is a continuing field of research (Burrow 1997; Petherick *et al*. 2002, 2009; Kilgour *et al*. 2006; Müller and von Keyerslingk 2006; Lee *et al*. 2018). Regardless, higher scores on both crush score and flight speed have been associated with reduced productivity (Burrow and Dillon 1997; Voisinet *et al*. 1997*a*, 1997*b*; Petherick *et al*. 2002, 2009; Cafe *et al*. 2011*a*), lower meat quality (Fordyce *et al*. 1988; Voisinet *et al*. 1997*a*; King *et al*. 2006; Cafe *et al*. 2011*a*), increased stress responses (Curley *et al*. 2008; Cafe *et al*. 2011*b*), and reduced immune function (Fell *et al*. 1999; Hine *et al*. 2019).

Proxy indicators of welfare

Proxy indicators of animal welfare are indirect measures that can imply or be representative of improved or reduced welfare. These are usually used when a direct measure is not available, or when the cost, complexity or timeliness of data collection make the use of a direct measure impractical.

Production

Identifying production traits that can be utilised as direct indicators of cattle welfare may be difficult. Liveweights of animals, when entering the feedlot, are likely to be influenced by the type of cattle (breed and sex), point of origin (geographical and sale yard versus direct from producer), season, environmental conditions and target market specifications (domestic versus export markets). Production performance is also likely to have some variability across feedlot enterprises, which may be associated with differences in diet composition or diet ingredients as well as the genetic potential of cattle (Sowell *et al*. 1997; Gardner *et al*. 1999; Brown-Brandl *et al*. 2006*a*; Belasco *et al*. 2015). However, clinical and subclinical disease and other environmental stressors may influence the allocation of nutrients to production traits (Gardner *et al*. 1999; Galyean and Rivera 2003; Colditz 2004; Sackett *et al*. 2006). This has generated interest in using production data as a proxy indicator of welfare by representing how well individual animals are coping with their environment (Colditz and Hine 2016; Berghof *et al*. 2019). The capacity of an animal to maintain a production trajectory over time, such as growth rate or milk production, in the face of day-to-day fluctuations in environmental conditions, is termed resilience (Colditz and Hine 2016; Scheffer *et al*. 2018). Resilience of production traits provides an integrated measure of the impacts of the psychological and physical environment on the physiology of the animal (Colditz and Hine 2016; Scheffer *et al*. 2018).

Continuous electronic monitoring of livestock is increasing the availability of data suitable for estimating resilience. The main focus has been on analysing variables such as immune responsiveness, feed intake and milk yield in beef cattle, sheep, pigs and dairy cattle for estimating heritability of resilience for use in breeding programs (Elgersma *et al*. 2018; Putz *et al*. 2019; Hine *et al*. 2019). As well as the use of genetic selection to improve the resilience of progeny, it is recognised that resilience also provides a contemporary measure of the welfare of individual animals (Colditz and Hine 2016; Berghof *et al*. 2019; Elgersma *et al*. 2018). Development of resilience measures based on production variables, behaviours (e.g. feed intake) or physiological measures (e.g. body temperature, immune function) may provide new proxy measures of welfare of feedlot cattle.

Environmental enrichment

In many production systems, providing what is perceived as a completely 'natural' environment is not possible or may not result in improved welfare, for example, by increasing exposure to predators. Shortfalls in the ability to satisfy the behavioural needs of the animal may be fully or partially addressed using environmental enrichment. Environmental enrichment consists of providing animals with stimuli that promote the expression of normal, species-specific behavioural activities, potentially benefiting animal welfare through reduced stress and frustration (Ishiwata *et al*. 2006). The provision of environmental enrichment has been shown to improve behaviour, physiological responses and carcass characteristics for cattle (Wilson *et al*. 2002*b*; Ishiwata *et al*. 2006) and sheep (Aguayo-Ulloa *et al*. 2014) in feedlot environments. Ishiwata *et al*. (2006) found that average daily gain and marbling score were improved in cattle provided with a grooming and foraging device. Similarly, Aguayo-Ulloa *et al*. (2014) found that lambs given access to a feeding platform, straw forage and a ramp for play, had higher average daily gains, heavier carcasses and higher fat scores. The authors also reported reduced stereotypies, improved performance on a cognitive task, greater levels of immunocompetence and lower muscle pH at slaughter in enriched lambs (Aguayo-Ulloa *et al*. 2014). Furthermore, piglets reared in socially enriched environments were more tolerant of unfamiliar pigs when mixed at the growing phase (Li and Wang 2011). Further studies are required to determine the optimal type of enrichment and the length of exposure to sufficiently enhance the feedlot environment. Wilson *et al*. (2002*b*) investigated the value of different enrichment devices to feedlot cattle, concluding that grooming devices were well utilised, while scent devices held little interest beyond Day 2. Provision of environmental enrichment could provide an indicator of improved welfare; however, care would need to be taken that the type of enrichment utilised is species appropriate and addresses specific behavioural needs and that provision of the enrichment does not generate additional social stress or aggression over the device.

Coat cleanliness

Lying time is an accurate and reliable measure of animal comfort; however, behavioural sampling is time consuming and labour intensive, with measurements being required at least every 30 min to get an accurate assessment of lying duration (Mitlöhner *et al*. 2001). An alternative proxy indicator of animal comfort, as well as good pen maintenance and design, may be coat cleanliness score (Table 4; Grandin 2016). While coat cleanliness shows promise as a proxy measure, further research is needed to identify the relationship between lying time and coat cleanliness under different surface conditions.

Positive social interactions

Some behaviours are inherently rewarding in the longer term, without having an apparent immediate benefit to the animal. These behaviours tend to occur when other needs are satisfied and can, therefore, potentially be used as proxy indicators that the animal's primary needs are being met. Allogrooming and play are two such behaviours that may prove useful indicators of an overall positive affective state. Allogrooming in cattle has a role in the formation and maintenance of social bonds

Table 4. Assessment of coat-cleanliness score
Adapted from Grandin (2016)

Score	Description and assessment
0	Cattle are clean with no visible signs of dags or muddied areas on the body
1	Cattle have dags or mud on legs, otherwise there are very limited dags or muddied areas on the body
2	Cattle have dags or mud on legs and belly areas, otherwise there are limited dags or muddied areas on the body
3	Cattle have dags or mud on legs, belly areas and the sides of the animal
4	Cattle are completely covered with dags or muddied areas over the entire body

within social groups (Sato *et al*. 1993; Šárová *et al*. 2016). Although the presence of allogrooming suggests that, overall, the social harmony of the group will be improved in the long term, subordinate animals may find being groomed by a dominant animal stressful (Boissy *et al*. 2007). The immediate welfare benefits to the individual may vary; however, allogrooming could still be a useful indicator of improved welfare states within the group. Greater understanding of the relationship between time spent allogrooming and positive welfare outcomes is required. Durations vary considerably among studies, where allogrooming sessions have been reported to last between 1 and 814 s (Sato *et al*. 1991, 1993; Val-Laillet *et al*. 2009; Šárová *et al*. 2016).

Similarly, play behaviour may be a possible candidate for an animal-based measure of positive welfare (Winckler *et al*. 2003; Boissy *et al*. 2007; Held and Špinka 2011; Mellor 2015). The advantage of play behaviour as an indicator of positive emotions is that it can be easily interpreted by non-professional observers (Boissy *et al*. 2007). Furthermore, play behaviour incorporates elements of functional behaviour, including fleeing, fighting, sexual and predatory behaviours (Boissy *et al*. 2007). The use of allogrooming and play as indicators of positive welfare have so far been unsuccessful due to the intermittent occurrence of the behaviours and poor repeatability (Boissy *et al*. 2007; Knierim and Winckler 2009). Additionally, many of the studies on both allogrooming and play behaviour have focussed on dairy cattle; therefore, there is a need to quantify these behaviours in feedlot cattle.

Abnormal behaviours

The incidence of abnormal behaviours, such as stereotypies, may provide an indicator of reduced welfare within a feedlot. Oral stereotypies have been reported in dairy cattle (Redbo 1992) and, to a lesser extent, beef cattle (Sato *et al*. 1994), with approximately half of penned steers in one study showing some form of short-term (<20 min) tongue playing (Ishiwata *et al*. 2008). Daigle *et al*. (2017) found that the incidence of repeated animal–environment interactions such as tongue rolling, pica, navel or ear sucking increased the longer the weaned calves were confined in dry-lot pens, with ~15% of calves performing the behaviour by Week 5 of the observation period. Further research into the incidence of abnormal behaviours in feedlots and the implications for welfare is required.

Deviations from normal patterns of behaviour may also be indicative of health and welfare issues. Stockpersons who are responsible for monitoring cattle on a daily basis are best placed to identify deviations from normal behaviour; however, this is a subjective measure that relies on the skills of the stockperson and the effectiveness of any training programs. Several commercial and research options for wearable-sensor technology[3] offer the possibility of remotely monitoring behaviours such as lying and ruminating, so as to identify deviations as early as possible (Rahman *et al*. 2018). While predominantly focussed on the dairy industry, the technology has the potential to be easily transferred to other intensive systems, including feedlots.

Future directions for measuring welfare

Several methods exist within the research setting to measure some of the more complex indicators of welfare. Some of these tests are still in the development stage requiring further validation, while others are established measures that are currently too impractical or expensive to use in a commercial feedlot environment. While currently unable to be used by industry, these measures remain of interest as they may be able to inform the development of industry appropriate tests, or alternatively, advances in technology may make these measures more practical to apply.

Measures of preference and motivation to express behaviours and access resources

To assess the motivation of an animal to perform a behaviour or access a resource, it is important to understand the inherent significance of that behaviour or resource to the animal. One method of determining the significance of a behaviour or resource to an animal is to conduct a single-choice test (preference testing). These tests are appealing for their simplicity; however, several limitations to single-choice tests have been identified (Kirkden and Pajor 2006). Internal and external factors may influence preference or motivation for a particular resource (Legrand *et al*. 2011; Parola *et al*. 2012; Chen *et al*. 2013, 2016). Alternatively, preference may be affected by prior experience, with familiar resources being typically preferred over novel ones. Finally, it can be difficult to interpret findings when animals fail to exclusively choose a single resource and instead use both for varying amounts of time (Lee *et al*. 2013).

Motivation tests avoid some of these limitations by assessing how hard an animal is willing to work for a particular resource. For example, animals can be trained to push a weighted gate to gain access to a resource and the amount of weight is then slowly increased. The percentage of bodyweight willing to be pushed to access a resource can then

[3]https://www.allflex.global/ [Verified 24 June 2020]; http://www.icerobotics.com/ [Verified 24 June 2020]; https://www.dairymaster.com/products/moomonitor/ [Verified 24 June 2020] .

be taken as a measure of motivation. Alternatively, a cost may be associated with a choice, such as being limited to that resource for a period of time (Lee *et al*. 2016*a*). These methods may also have some limitations. Van Os *et al*. (2017*b*) found evidence of contrafreeloading in cattle where they were willing to work to access a resource that was simultaneously freely available to them. The authors speculated that the work may itself be rewarding, or allow the cattle to express control over their environment (Van Os *et al*. 2017*b*). These factors should be considered when assessing the importance of a resource using motivation tests. Finally, both preference or motivation tests tend to present limited options of choices, including, for example, a choice between two resources or the choice between working or not working to access a resource. The types of options provided are determined by the researcher and do not account for the possibility that an alternative resource may be of even greater value to the animal.

Measures of fearfulness

Fearfulness is a temperament trait indicative of an animal's tendency to display excessive fear in potentially threatening situations (Forkman *et al*. 2007). While some aspects of overall temperament can be assessed easily (see *Measures of temperament and coping style* section), measurements of fear and fearfulness are less established. Tests of fearfulness generally rely on the application of a sudden, unfamiliar or unpredictable stimulus to elicit a fear response (reviewed by Forkman *et al*. 2007). The most commonly utilised tests involve measuring the behavioural response to a novel area or object (Forkman *et al*. 2007). Repeatability and reliability of fear tests have been found to be low in most studies (Forkman *et al*. 2007; Meagher *et al*. 2016). Several issues have been identified with these tests. First, that calm, disinterested or ill animals will show a similar delay in approaching or exploring a novel stimulus as a fearful one (Meagher *et al*. 2016). Second, that there is likely to be a high level of habituation to novel stimuli and, therefore, the repeatability of tests is low (Forkman *et al*. 2007). However, the speed of habituation or how quickly an animal acclimates to a situation may also be indicative of temperament and coping style, although measuring this at an individual level is difficult (Monk *et al*. 2018*a*). Finally, individual variation in cognitive test results can be influenced by several outside factors that need to be considered when analysing results (Bushby *et al*. 2018).

Handling tests are less frequently used and vary considerably in methodologies. Such tests generally involve the presence of a human in conjunction with a husbandry procedure, such as restraint or separation (Forkman *et al*. 2007). Although there has been some correlation with handling tests and physiological parameters (Forkman *et al*. 2007), measures of repeatability have varied among studies (Welp *et al*. 2004; Turner *et al*. 2011). The relevance of current tests of fearfulness to the feedlot environment also needs to be considered. Feedlot animals would very rarely experience the social isolation frequently incorporated into these tests. The welfare implications for an animal showing high fearfulness in these tests may not eventuate in an environment in which they have companions to socially buffer their experiences.

Measures of affective state

Measures of affective state need to include measures of both positive and negative emotional valence. Research into positive affective states continues to emerge; however, measures of negative affective state remain more common and considerably more work on positive affective state is required. The complexity of most of these tests makes them currently unsuitable for industry-based measures of affective state for feedlot cattle. However, their use in the research setting may prove valuable to identify proxy indicators or to identify the types of resources required by cattle to promote a positive affective state.

Cognitive bias

It is known in both humans and animals that affective state can influence cognitive functioning, in particular, generating specific cognitive biases in attention, memory and judgement (Boissy *et al*. 2007; Mendl *et al*. 2010). Therefore, there is potential to utilise these biases to detect and quantify the effect of the feedlot environment on the underlying affective state and the emotional implications of providing or limiting access to particular resources.

Judgement bias has been assessed in several farm animal species (reviewed by Baciadonna and McElligott 2015). The assessment of judgement bias is based on the principle that the underlying emotional state influences the likelihood of a subject interpreting an ambiguous cue in a pessimistic or optimistic manner. Judgement bias is typically assessed through a go/no-go task in which animals are trained to respond one-way to a positively associated cue and another way to a negatively associated cue. The animal's response to an ambiguous cue is then assessed under the hypothesis that those in a negative affective state are more likely to interpret the ambiguous cue as predictive of the negative outcome. Negative judgement biases have been shown in dairy cattle in response to both physical (Neave *et al*. 2013) and psychological (Daros *et al*. 2014) stressors; however, only a few studies in other species have assessed positive judgement biases (Douglas *et al*. 2012; Verbeek *et al*. 2014). Disadvantages of this task are that it requires considerable training and may be confounded by low levels of motivation to complete one of the responses (Baciadonna and McElligott 2015). While judgement bias appears to be a valid measure of affective state, care must be taken to ensure that the emotional state of interest (positive or negative) is actually activated. Doyle *et al*. (2010) and Sanger *et al*. (2011) found that sheep exposed to an acute stressor, aimed at evoking a negative affective state, actually showed a positive judgement bias on release. It is also important for the validity of the results that animals are cognitively capable of distinguishing among the positive, negative and ambiguous cues, as well as distinguishing between the rewarding or punishing properties of a stimulus.

One of the main disadvantages of tests of judgement bias is the requirement for training. Tests of attention bias avoid this requirement, potentially providing a quicker and easier measure of an affective state (Monk *et al*. 2018*b*). Attention-bias tests are based on the idea that animals with a negative affective state will show greater attention towards threatening stimuli than do animals in a positive or neutral affective state (Lee *et al*. 2016*b*; Crump *et al*. 2018). In sheep, attention-bias paradigms have been well refined and pharmacologically validated (Monk *et al*. 2018*b*). A study has successfully extended the paradigm to cattle with similar pharmacological treatment responses (Lee *et al*. 2018). Recently, attention biases have been identified for depression, a longer-term negative affective state (Monk *et al*. 2018*c*). Further studies to determine whether attention bias can identify positive affective states are needed.

Lateralisation bias

There is evidence in humans and animals that emotional valence can be reflected in asymmetric brain activity that is determined by left or right hemisphere-dominant behaviour (Rogers 2010; Leliveld *et al*. 2013). It has been hypothesised that the right hemisphere is dominant in processing information when in a negative affective state and, therefore, results in an increased use of left visual and auditory fields and left motor responses (Rogers 2010; Leliveld *et al*. 2013). When presented with two bilaterally placed novel objects, dairy cattle that were more hesitant to approach the objects tended to explore the left object rather than the right one (Kappel *et al*. 2017). Similarly, when presented with a novel person walking through the herd, cattle tended to cross the person's path so as to be able to assess the experimenter with their left monocular field significantly more often than with their right field, and this pattern was reversed once the experimenter became familiar (Robins and Phillips 2010).

The use of lateralised presentation of stimuli for management purposes may also serve to reduce stress, such as, for example, by handling animals from the appropriate side (Robins *et al*. 2018). However, further studies are required to confirm these findings (Leliveld *et al*. 2013). The identification of the correct side may also incite production benefits. Rizhova and Kokorina (2005) found that dairy cows repeatedly presented with food from the left side had improved reproductive success. There was also an effect on milk production, where cows under poor feeding conditions improved milk yield when food was presented from the right, and cows under good feeding conditions increased yield when food was presented from the left (Rizhova and Kokorina 2005). Findings from the limited number of studies investigating affective state and lateralisation suggest that considerable research is required to understand the true nature of this relationship.

Eye whites

The amount of visible eye white has been suggested as a measure of both positive and negative emotional states. Increases in visible eye white in dairy cows have been demonstrated in response to waiting for feed (Sandem *et al*. 2006), offering inedible feeds (Lambert and Carder 2017), and depriving access to visible feed (Sandem *et al*. 2002). Decreases in visible eye white have been observed in response to stroking (Proctor and Carder 2015), and the provision of food (Sandem *et al*. 2002, 2006; Lambert and Carder 2017). Visible eye white has also been positively correlated with other indicators of frustration, including aggression and vocalisation (Sandem *et al*. 2002). Although these findings appear reliable and repeatable, Gómez *et al*. (2018) found no difference in visible eye white between a positive feeding experience and a negative hoof-trimming experience. They also found that visible eye white differed among dairy breeds (Gómez *et al*. 2018). Issues also occur around determining whether eye whites increase in response to arousal or changes in emotional state. Lambert and Carder (2017) found that visible eye whites in dairy cows were highest while eating concentrates (a supposedly positive experience), compared with pre- and post-feeding. The use of eye white measures as an indicator of affective state requires further research to determine its applicability to beef cattle and the feedlot environment.

Stress physiology

Affective experiences are not only a reflection of external influences but can also be seen as a response to the physiological inputs generated by the animal's internal state (Boissy *et al*. 2007; Hemsworth *et al*. 2015). Stress, pain and fear are examples of negative affective experiences resulting from physiological changes (Hemsworth *et al*. 2015). Physiology is a complex and detailed field and it is not the purpose of the present review to comprehensively describe every aspect of stress physiology. The focus herein is to provide an overview of the non-invasive physiological measures of affective state, which may, in the future, have practical applicability in the feedlot industry. Most physiological measures focus on the action of the hypothalamic–pituitary–adrenal (HPA) axis, known to be activated by stress, but which also regulates other biological processes such as reproduction and immune responses (Boissy *et al*. 2007). Increased HPA axis activity is known to be indicative of short-term stress; however, chronic stress may result in negative feedback regulation and HPA axis hypoactivity, and, so, careful interpretation of results is required.

Hair cortisol

Blood, urine and salivary cortisol concentrations are well established as measures of stress (Meyer and Novak 2012). However, the inherently stressful nature of sample collection, interference from circadian variation and short circulating half-life limit their applicability as a measure of chronic stress. Faecal cortisol metabolites can also be used to estimate stress in the previous 12–24 h, utilising less invasive sampling techniques. Limitations to faecal cortisol include potential modification of concentrations during gut transit and the need for samples to be frozen before testing (Tallo-Parra *et al*. 2015). Measurement of hair cortisol concentration has been suggested as an alternative measure of long-term cortisol accumulated over weeks and months (Meyer and Novak 2012). The mode of deposition of cortisol into the hair shaft is still unclear. However, it has been shown to be stable at room temperature for at least a year (Meyer and Novak 2012), and is relatively unaffected by environmental factors (Montillo *et al*. 2014). Moya *et al*. (2013) standardised a method of measuring hair cortisol concentration in cattle, which included clipping rather than plucking the hair and using hair from the tail switch to provide the best measure of cortisol concentration. Comin *et al*. (2013) found that hair cortisol differed between healthy dairy cows and those that had recently suffered a disease or that had been physiologically challenged by calving in the last month. Sensitivity and specificity of their nominated cut-off value was 62.4% and 69.3% respectively. Creutzinger *et al*. (2017) investigated hair cortisol and found a treatment effect of pain relief on surgically castrated beef cattle over 14 days, suggesting that hair cortisol may also be an appropriate measure of acute stress. Limitations include the possibility of diluting out the cortisol concentration by including portions of the hair shaft that grew before or after the stressor of interest. Clipping the area of interest to create a controlled baseline may avoid this issue.

Body temperature

In addition to the environmental factors affecting body temperature described in *Thermal comfort* section, changes to the regular circadian pattern of body temperature occur during infection and stress (Vinkers *et al*. 2009). During stress-induced hyperthermia, as seen for instance when cattle are subjected to an attention-bias test (Lee *et al*. 2018), activation of the sympathetic nervous system causes blood to be diverted away from the periphery and towards the vital organs in a fight–flight response (Bouwknecht *et al*. 2007; Proctor and Carder 2016). This causes a short-term increase in the core body temperature that can last as little as 20–30 min and a decrease in temperature in peripheral organs such as the eyes and nose. In contrast, cytokine-induced changes in body temperature (fever) during infection and immune activation can extend over days. Historically, measuring body temperature requires capture and handling to insert the temperature sensors into the tympanic membrane (Mader *et al*. 2010), abdominal cavity (Lefcourt and Adams 1996), rectum or vaginal cavity (Vickers *et al*. 2010; Lees *et al*. 2018*a*) or the rumen (Lees *et al*. 2018*b*). Methods of measuring peripheral temperature, such as infrared thermography, may provide a less invasive assessment of body temperature within the feedlot environment, although some limitations exist. Decreases in eye temperature have been found in response to aversive handling (Stewart *et al*. 2008), surgical castration (Stewart *et al*. 2010*a*) and epinephrine infusion (Stewart *et al*. 2010*b*). However, changes in eye temperature are potentially breed dependent (Gómez *et al*. 2018) and can be affected by environmental conditions (Church *et al*. 2014). Nasal temperature in dairy cows has been shown to decrease in response to both positive and negative emotional states (Proctor and Carder 2015; Proctor and Carder 2016), suggesting that changes in peripheral temperature may not just be a useful measure of stress but also of positive affective state. Further studies are required to quantify this relationship. Optimal conditions for imaging, including the avoidance of direct sunlight, high humidity, wind and temperature extremes may also be difficult to achieve in an outdoor feedlot environment (Okada *et al*. 2013).

Conclusions

Several factors may influence the welfare of cattle in the feedlot environment. These can become an issue when not properly monitored and managed. These include, but are not limited to, animal factors such as the inability of cattle to effectively respond to environmental extremes, inability to express their full range of natural behaviours such as grazing, and unsuitable temperaments, as well as management factors, such as stockperson skills in identifying morbidities, comfort of surface conditions for lying, stock-handling methods and yard design, identification and management of pregnancy and mixing of unfamiliar cattle. These issues, while significant, are not insurmountable, with several strategies already being employed within the feedlot industry to address them. Continuous improvements in these areas will require accurate, reliable and repeatable measures of welfare factors to allow quantification of current and future welfare states. Whereas measures of physical factors affecting welfare are well established, considerable work is still required to generate measures of psychological welfare that have practical applications in the feedlot industry.

It is important that future research focuses on developing a greater understanding of how the animal itself perceives the feedlot environment and which factors and resources are required to improve or maintain an overall positive affective state in animals confined to a feedlot. Research into the preferences and motivations of feedlot cattle is also needed, so as to identify which aspects from a pasture environment are required to satisfy the behavioural needs of cattle. The identification of these preferences will allow for the development of environmental enrichment and the provision of resources such as bedding and shade to ensure positive welfare outcomes for feedlot cattle. Further work assessing the affective state of cattle under various management conditions will clarify the effectiveness of any interventions in satisfying the psychological needs of feedlot cattle. Finally, a better understanding of the temperament types and coping styles that allow cattle to best adapt to the feedlot environment with minimal adverse physical and psychological consequences is required to maximise cattle welfare in feedlot enterprises. To help achieve these outcomes, and to monitor their success, it is also important that future research focuses on developing practical tools to accurately assess animal welfare in real time in a commercial feedlot setting.

Conflicts of interest

The authors declare no conflicts of interest.

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