MEAT & LIVESTOCK AUSTRALIA

finalreport

Project code: B.FLT.0347

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Date published: January 2008

ISBN: 9781741918298

PUBLISHED BY
Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Animal welfare assessment in cattle feedlots – A Review

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Abstract

A review was undertaken to identify and critically evaluate the scientific knowledge currently available to underpin the key requirements of the welfare code relating to feedlot cattle. The review focused on key factors influencing the welfare of feedlot cattle (including shedded cattle), with particular reference to: pen stocking density, feed bunk access and space allowance, water trough access and allowance, feedlot pad conditions and cold stress. Although the research was limited, there was good alignment between current scientific knowledge and the resource requirements specified within the code. There were no obvious inconsistencies between the science and the current code requirements for these resource criteria. However, it was noted that the current code does not articulate welfare standards for animal health. Recommendations to address this and for the development of outcomes-based practical welfare measures were made. This could be achieved through a combined approach involving industry benchmarking and targeted research.

Executive Summary

The current Model Code of Practice for the Welfare of Cattle (the Code) is scheduled to be revised into the new format of Standards and Guidelines within the next 2-3 years. Many of the current code guidelines are based on industry practice and knowledge, but there may be relatively little science that exists to underpin these requirements. It is important that industry knows which practices are supported by current scientific knowledge, and which are not, before embarking on the development of new Standards and Guidelines.

This review was therefore undertaken to identify and critically evaluate the scientific knowledge currently available to underpin the key requirements for feedlot cattle in the welfare code. Further, a gap analysis was undertaken that identifies where additional research is required to support cattle feedlot welfare standards and to develop practical welfare measures for the feedlot industry.

The objectives of this project were:

1. Undertake a critical review of the global scientific knowledge pertaining to the welfare of feedlot cattle to:
    a. identify available scientific knowledge that underpins the requirements for feedlot cattle under the Model Code of Practice and;
    b. determine where there are gaps in the scientific knowledge needed to support objective animal welfare requirements for feedlot cattle in the development of new Australian Standards and Guidelines.
2. Provide recommendations for a program of research to address identified knowledge gaps, and validate easily applied measures that feedlot operators can use to demonstrate compliance with the animal welfare standards.

The review focused on key factors influencing the welfare of feedlot cattle (including shedded cattle), with particular reference to:

- Pen stocking density
- Feed bunk access and space allowance
- Water trough access and allowance
- Feedlot pad conditions
- Cold stress

From the review, it was concluded that although there was a paucity of direct evidence on resource requirements for feedlot cattle, there was sufficient evidence to assert that a defensible scientific basis exists for feedlot guidelines with respect to the primary resources requirements of pen stocking density, feed bunk access and space allowance, water trough access and allowance, feedlot pad conditions and protection from cold stress. There were no obvious knowledge gaps with respect to these requirements and therefore, no immediate requirement for research.

The lack of any specific animal health requirements within the current feedlot welfare code was viewed as a deficiency. It was recommended that the feedlot industry give consideration for the

need for animal health requirements, specifically, maximum thresholds for mortality and morbidity within the code. Two approaches to identify these thresholds were suggested.

There are very few practical welfare measures that could be applied by feedlot operators to demonstrate compliance with animal welfare standards. Of those that were considered, productivity measures should be evaluated. It was recognised that there may be other behavioural cues that experienced feedlot operators and staff rely on to identify a problem in individual or groups or animals and there would be value in exploring this further. In both instances, these measures or indicators will require validation and this could be achieved via a combination of industry benchmarking and targeted research experiments.

Finally, it was recommended that the feedlot industry consider the need to address potential criticisms of it in the future on the issue of animal contentment in confined or intensive husbandry systems. A strategy to address these challenges may include research examining whether there is equivalence (or a higher level) of animal contentment and other animal welfare outcomes in the feedlot environment compared with extensive environments.

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1 Background

The critical public and community concerns with regard to animal welfare in production animals can nominally be categorised into four key subject areas. Those associated with; (i) housing and farming conditions that restrict animal movement, (ii) surgical husbandry practices without analgesia, (iii) long distance transport of livestock for economic reasons, and (iv) problems and diseases that are induced by the production environment. Feedlot finishing of beef cattle has and will continue to cause some animal welfare concerns particularly in relation to the first and last of these subject areas.

In this context, there is a public perception that animal welfare is reduced under intensive animal farming systems compared with extensive or free range systems. As an example, there was a recent article “The Great Food Debate Basket Case” in the reputable news journal The Bulletin (22/5/07). This article was based on information from the group Voiceless and presented as fact, statements on feedlots such as “Scientific evidence points to considerable physical and psychological suffering of grainfed animals”. While we are unaware of such evidence, this raises a key point - there is a distinct lack of scientifically defensible evidence to either support or counter such claims.

The current Model Code of Practice for the Welfare of Cattle (the Code) is scheduled to be revised into the new format of Standards and Guidelines within the next 2-3 years. Many of the current code guidelines are based on industry practice and knowledge, but there may be relatively little science that exists to underpin these requirements. It is important that industry knows which practices are supported by current scientific knowledge, and which are not, before embarking on the development of new Standards and Guidelines.

This review was therefore undertaken to identify and critically evaluate the scientific knowledge currently available to underpin the key requirements for feedlot cattle in the welfare code. Further, a gap analysis was undertaken that identifies where additional research is required to support cattle feedlot welfare standards and to develop practical welfare measures for the feedlot industry.

2 Project objectives

Provide a sound basis for the development of scientifically defensible welfare standards for feedlot cattle in Australia by:

1. Undertaking a critical evaluation of the global scientific knowledge pertaining to the welfare of feedlot cattle to:
    a. identify available scientific knowledge that underpins the requirements for feedlot cattle under the Model Code of Practice and;
    b. determine where there are gaps in the scientific knowledge needed to support objective animal welfare requirements for feedlot cattle in the development of new Australian Standards and Guidelines.
2. Providing recommendations for a program of research to address identified knowledge gaps, and validate easily applied measures that feedlot operators can use to demonstrate compliance with the animal welfare standards.

3 Methodology

A literature review was undertaken of the published material, from Australia and overseas. A critical assessment of the published data and the relevance of the science to the specific requirements for feedlot cattle under the Model Code of Practice was conducted.

The review focused on key factors influencing the welfare of feedlot cattle (including shedded cattle), with particular reference to:

- Pen stocking density
- Feed bunk access and space allowance
- Water trough access and allowance
- Feedlot pad conditions
- Cold stress

The review did not encompass heat stress and its amelioration. This follows advice from industry that these issues have been well researched already in the Australian context, resulting in both scientifically defensible standards and practices, and practical welfare measures (e.g. panting score). Furthermore it did not include other animal health issues specific to feedlots.

Having reviewed the science, a gap analysis was performed to:

- Identify inconsistencies between the science and the current requirements for feedlot cattle in the Model Code of Practice.
- Identify where there is little or no scientific knowledge to underpin the current requirements for feedlot cattle in the Model Code of Practice.
- Make recommendations about future research to underpin the development of the new Standards and Guidelines as they apply to feedlot cattle.
- Make recommendations about potential practical welfare measures to demonstrate compliance with welfare codes.
- Make recommendations about future research to develop and/or validate such practical welfare measures.

4 Results and Discussion

4.1 Introduction

All livestock industries operate under Model Codes of Practice (MCOP) for the Welfare of Animals. These codes are not legally binding but compliance with the requirements of the code can be used as a defence in a court of law. The aims of the specific code for cattle are:

- To promote humane and considerate treatment of cattle, and the use of good husbandry practices to improve the welfare of cattle in all types of cattle farming enterprises
- To inform all people responsible for the care and management of cattle about their responsibilities
- To set a minimum industry standard by defining acceptable cattle management practices

(PISC 2004)

A key objective of the Australian Animal Welfare Strategy is to redraft all existing MCOP into standards and guidelines. The new standards will be the minimum acceptable welfare requirements that must be met under law for livestock welfare purposes. The MCOP for cattle is likely to be redrafted within the next two years therefore, it is quite prescient that this review was undertaken.

4.2 Animal welfare input and output measures

In the assessment of animal welfare, there is firstly a need to differentiate between *input* measures and *output* measures. Input or resource measures are systemic or environmental requirements that are believed to result in good animal welfare. The key factors reviewed here would all be classed as input measures. Output measures directly relate to the animal's welfare and a good example here is panting score which is used to assess heat stress in feedlot cattle. Although input measures are sometimes criticised for not directly measuring the welfare of the animal, they may be the most practical and appropriate measure in a number of circumstances. In many instances, input measures may have been derived from studies of welfare outcomes of particular practices. In other instance they may be best guesses of adequate inputs. Furthermore, many of the input and outcome measures are qualitative not quantitative (e.g. provision of adequate feed for good health). Therefore, unless there is a direct correlation between input and output measures then specifying inputs will not fully capture the welfare status of animals. Moreover, input measures fail to take account of the considerable individual variation in ability to cope with challenges. Notwithstanding these points, input measures have and continue to serve their purpose in the context of animal welfare codes and standards. However, it is evident that there is an increasing requirement for more direct output measures of animal welfare.

4.3 Review of the current MCOP

The MCOP for the Welfare of Animals – Cattle (PISC 2004) exemplifies the input-based approach to assurance of animal welfare. Further, many specifications of the guidelines are qualitative rather than quantitative. The MCOP addresses all cattle production systems with few details specific to feedlots. Subsequently, the National Guidelines for Beef Cattle Feedlots in Australia (PISC 2003), hereafter referred to as the Feedlot Welfare Code, were developed to provide such details.

The Feedlot Welfare Code employs documentation in Standard Operating Procedures and an Animal Care Statement to establish the welfare standards of feedlot operations. Issues addressed include:

- Training of staff
- Cattle handling practices
- Dehorning
- Health inspection procedures
- Daily monitoring of stock
- Procedures for handling, feeding and accommodation of sick animals
- Health, morbidity and post-mortem records
- Feed management
- Feeding frequency
- Water quality
- Yard and pen design to minimise injury
- Stocking density
- Water trough space allowance
- Manure removal practices
- Protection from climatic extremes
- Carcase disposal
- Contingency plans

4.4 Pen stocking density

The Feedlot Welfare Code, specifies that the minimum space requirement is 9 m^2/animal in external pens and 2.5 m^2/animal for shedded cattle. The National Feedlot Accreditation Scheme recommends a stocking density range of 9 to 25 m^2/animal for feedlot pens. From some industry information, the space allowance in many large commercial feedlots is at the upper end of this range (15 - 20 m^2/animal) (http://www.agric.nsw.gov.au/reader/lotfeeding/lfestablish.htm). To the best of our knowledge, there are only two commercial feedlots that have facilities to finish cattle in sheds and the space allowance in these facilities (6 m^2/animal) exceeds the code minimum.

From an animal welfare perspective, the fundamental question here is what is the minimum space allowance that facilitates the expression of normal behaviour and function in cattle? However, there is a second issue that also needs to be considered. This issue resonates around the fact that feedlots, by their nature, require cattle to be kept in more confined conditions than what they would normally experience under pasture systems. Whilst there will be some exceptions here, the increased confinement and other associated environmental restrictions give rise to the perception within the general public and community that feedlots are a less “natural” production system and therefore, are more stressful to the animals. The feedlot industry will probably need to address this perception at some point in the future. In doing so it will require more than just the evidence that feedlots provide adequate resources for cattle and that this is reflected in their productivity. This evidence, whilst helpful, is unlikely to completely resolve these negative perceptions.

Returning to the initial question, there is reasonable body of published data that examines the impact on space allowance on behaviour, health and productivity in both beef and dairy cattle. However, very little of this research has direct relevance to the feedlot sector. It is also worth noting that this particular subject was recently covered in detail in another MLA review by Petherick and Phillips (2007).

In relation to the question of what space allowance do cattle prefer in order to maintain normal social interactions, the results from Kondo et al (1989) who conducted a series of studies on the behaviour of cattle at pasture are quite salient. These authors measured inter-individual distance and frequency of agonistic interaction among beef cattle at different space allowances. Above an average individual space allowance of 20 m^2, agonistic encounters declined rapidly with increasing space. Above 360 m^2 space allowance, there was no decrease in the frequency of agonistic interaction. The average inter-individual distance maintained by cattle also increased with increasing space allowance up to 360 m^2, but above that cattle preferred to maintain a distance of 10 to 12 m between themselves and the next nearest animal.

Most of the cattle research on space allowance relates to indoor housing systems (predominantly slatted floor) which are required during the northern hemisphere winter. From a behavioural perspective, this research has focused on the changes in lying and feeding behaviour and social interactions, particularly agonistic interactions. Andreae et al. (1980) examined the effects of space allowances of 2 and 3 m^2 on bulls (400 kg BW) housed in slatted-floored pens and observed no difference between space allowances in the length of time animals spent lying down. Kirchner (1986, 1989) housed bulls (approx. 580 kg BW) in groups of ten in slatted-floored pens at space allowances of 2.3 and 2.7 m^2. Bulls with less space spent less time lying down and had a reduced number of eating bouts. Wierenga (1987) maintained groups of bulls in pens from 6 to 16 mo of age at either 1.95 or 2.60 m^2 space allowance per animal. Bulls in smaller pens exhibited more aggression and had a greater incidence of interruption to resting behaviour, however, total resting time was not different. Muller et al. (1986) kept beef heifers (385 kg initial BW) at space allowances of 1.6 or 3.0 m^2 for a period of 4 mo in slatted-floored pens. There was no effect of treatment on time spent lying down, although lying behaviour was less synchronous at the lower space allowance. Muller et al. (1986) also recorded a higher incidence of head-resting behaviour among heifers housed at the lower space allowance, something that was not noted by the other authors, but which has been recorded in association with decreased cubicle availability in dairy cows (Wierenga, 1983). The results of three Irish studies (Fisher et al 1997[ab], Hickey et al 2003) examining the effects of different space allowances between 1.5 – 4 m^2/animal in beef cattle (470 – 560 kg mean liveweight) consistently showed a significant reduction in lying time at the highest density (1.5 m^2/animal). At space allowances of ≥ 2.0m^2/animal, there were no differences in lying time. Reductions in space allowance had no effect on the incidence of aggressive interactions (all three studies) but there was a significant reduction in the total number of social interactions in two of three studies (Fisher et al 1997[b], Hickey et al 2003). Feeding behaviour (time spent eating) was generally not affected by space allowance in all three studies.

A key point about the lowest space allowance (1.5 m^2/animal) used in the studies by Fisher at al (1997[ab]) and Hickey et al (2003) was that based on allometric calculations for the weight class of animal used, it should have been sufficient for all animals to lie down (sternal recumbency). However, as Fisher et al (1997[b]) observed, this rarely occurred and furthermore, they noted that there was increased disruption of lying at this space allowance. They concluded that this minimum allowance was insufficient and a higher space allowance (2.0 m^2/animal) would be necessary to accommodate more effective resting. This particular issue was also discussed in detail in the review by Petherick and Phillips (2007). They nicely highlighted that the minimum space allowance for an animal to either stand or lie in a sternal recumbent position was lower than that required for full recumbency (lying laterally with legs and head extended). Moreover, the space required for full recumbency would accommodate the additional space required during transitions between standing to lying. To estimate the area required for full recumbency the following allometric equation can be applied (Petherick and Phillips 2007).

$$Area = 0.047W^{0.66}$$

where

W = bodyweight (kg)

There is the potential for animals to experience increased psychological stress as a consequence of reduced space allowance. However, the results examining the physiological responses of groups of housed cattle to restricted space allowance in experiments have not been consistent. Although Andreae et al. (1980) measured higher basal plasma cortisol concentrations in bulls housed at 2 m^2 compared with 3 m^2 space allowance (7.0 vs 3.5 ng/ml), other studies have not recorded differences in basal cortisol concentrations (Beneke et al., 1984; Muller et al., 1986). The adrenal response to an exogenous ACTH challenge has also not reacted consistently in experiments examining space allowance in pens of cattle. Ladewig et al. (1985) recorded a reduced cortisol response to 1.98 i.u. ACTH/kg $BW^{0.75}$ among groups of heifers housed at 1.6 compared with 3.0 m^2 per animal. Beneke et al. (1984) also housed heifers in groups at space allowances of 1.6 and 3.0 m^2, used the same dose of ACTH, and reported only a tendency for crowding to reduce adrenal response. In contrast, Muller et al. (1986) reported no consistent effects of space allowance treatments of 1.6 and 3.0 m^2 for penned heifers (385 kg) on adrenal response to ACTH, having used 1.98 i.u. ACTH/kg $BW^{0.75}$. Fisher et al. (1997[a]) observed reduced basal cortisol levels and ACTH-mediated peak cortisol responses in cattle housed at 1.5 m^2 compared to 3.0 m^2 but there were no differences in their subsequent study (Fisher et al. 1997[b]) examining these stocking densities.

The impact of space allowance on animal productivity was reviewed in detail by Ingvartsen and Andersen (1993). They concluded that when the allowance was reduced from 4.7 to 1.5 m^2/animal there was a commensurate decrease in animal productivity measures including, feed intake, average daily gain and feed conversion ratio in bulls and steers (250 – 500 kg). This conclusion was further reinforced by the results of Fisher et al (1997[ab]) where beef heifers were housed at different space allowances between 1.5 – 3.0 m^2/animal. Cattle at the higher density of 1.5 m^2/animal had significantly lower average daily gains (25 – 31 % reduction) compared to those at 3.0 m^2/animal. This was confirmed by Hickey et al (2003) but the difference in averaged daily gain between the 1.5 m^2 and 3.0 m^2 treatments was even higher (51% reduction). From the studies of Morrison and Prokop (1982) and Fisher et al (1997[b]) it is evident that the reduced average daily gains in cattle housed at 1.5 m^2 is due largely to a reduction in feed conversion efficiency rather than feed intake. Fisher et al (1997[b]) further proposed that this in turn was probably due to the disruption in rest and increased demands associated with longer periods of standing. Although the conclusions of Ingvartsen and Andersen (1993) would imply that the relationship between space allowance (in the range 1.5 – 4.7 m^2) and productivity measures is linear, this is not the case. In general, the differences in productivity measures at different space allowances > 2 m^2 are generally quite small (eg. Arave et al 1974, Morrison and Prokop 1982, Fisher et al 1997[b] and Hickey et al 2003).

The above research, whilst important in the context of indoor housing systems lacks direct relevance to feedlot environments given that feedlot cattle are afforded much higher space allowances. To the best of our knowledge, there is only one study that specifically examines the effect of reduced space allowance in feedlot cattle. Fell and Wilson (1998) compared the behavioural and physiological responses in cattle on pasture and in a feedlot environment at two different stocking densities; 12 m^2 (normal) and 6 m^2 (stressed). The latter is below that recommended in the Feedlot Welfare Code (9 m^2). In addition to a reduced space allowance, the stressed feedlot treatment also included a reduced feed bunk space allowance (450 mm/animal compared to 900 mm/animal for the normal treatment) and the feedlot pad was continually kept wet. An experimental feedlot was used and the cattle were fed over a period of 42 days. The results are summarised in Table 1.

The combination of these resource constraints (ie. reductions in space and feed bunk allowance and dry areas for lying) in the stressed feedlot treatment would have been expected to elicit a significant difference. However, Fell and Wilson (1998) and Wilson et al (2002) found no differences in average daily gain, behaviour (lying time and social interactions) or any of the physiological measures between the two feedlot treatments. The authors concluded that the cattle had successfully adapted to the feedlot environments, despite the resource constraints, but they also expressed some caution about extrapolating the results to an industry feedlot context.

Table 1 - Summary of effects of dry and muddy feedlot pad conditions in comparison with cattle at pasture

	Dry Feedlot		Muddy Feedlot		Pasture		Significance Dry vs Muddy	Significance Feedlot vs Pasture
	Rep 1	Rep 2	Rep 1	Rep 2	Rep 1	Rep 2		
Lying (h/day)	13.0	11.5	12.2	11.8	9.8	10.6	NS	Not tested
ADG (kg/day)	1.60	1.55	1.62	1.44	-0.09	1.30	NS	0.01 / NS
Adrenal mass (g)	11.27		11.08		9.42		NS	0.01
Immune measures[1]:								
Total white blood cell count (x10^9/L)	8.3	8.1	6.6	8.9	6.1	7.9	NS	NS
Lymphocytes (%)	57.8	62.9	64.3	58.5	70.9	56.8	NS	NS
Neutrophils (%)	26.2	19.2	21.5	28.0	15.1	27.7	NS	NS
CD4+ T lymphocytes (%)	27.7	25.0	33.3	26.4	31.8	25.6	NS	NS
CD8+ T lymphocytes (%)	14.9	11.8	13.1	14.1	13.3	12.5	NS	NS
CD 4:8 ratio	2.0	2.2	2.6	1.9	2.4	2.2	NS	NS
CD5+ T lymphocytes (%)	51.7	41.2	55.0	49.7	54.0	40.9	NS	NS
WC1+ T lymphocytes (%)	18.4	9.8	15.9	12.6	19.5	15.9	NS	0.001
NK Cell assay (% cytotoxicity)	51.5	-	36.2	-	40.4	-	NS	NS
Neutrophil myeloperoxidase assay (iodination rate)	35.3	-	25.6	-	37.6	-	NS	NS
Lymphocyte proliferation- unstimulated (net count per million)	601	1160	231	990	376	1241	NS	NS
Lymphocyte proliferation- Con A stimulated (net count per million)	38400	53220	28860	50580	29080	56120	NS	NS
Lymphocyte proliferation- PHA stimulated (net count per million)	49330	39630	53450	25490	48.360	44380	NS	NS
Serum IgA (mg/100 ml)	21.4	31.8	25.1	23.7	52.4	49.4	NS	0.001
Serum IgG (mg/100 ml)	3982	3322	4217	3315	3643	4440	NS	NS

[1]Data from day 42 presented (end of experimental period)
Data from Fell and Wilson (1998); Wilson et al. (2002)

4.5 Feed bunk access and space allowance

The Feedlot Welfare Code recommends a minimum feed bunk space of 150 mm/animal for young cattle and 180 mm/animal for steers and bullocks (SCARM 1997). These minimum allowances are lower than the space allowances recommended by the feedlot industry and Government advisory groups (Table 2).

Table 2 - Recommended feed bunk space allowance

Fed once daily	Feed bunk space (mm)
Weaners	250 - 300
Yearlings	300 - 400
Adult stock	400 - 600

(Source: http://www.dpi.nsw.gov.au/agriculture/livestock/beef/feed/publications/lotfeeding)

A key factor in the context of feed bunk space allocation will be the feeding management practices such as the daily frequency of feeding and whether the cattle are fed *ad libitum* or on a restricted basis. Under restricted feeding it is likely that there will be increased competition at each feeding event and therefore feed space allowance becomes more critical. This was evident in the study by Keys et al (1978) where Holstein heifers were fed (restricted) for 90 days at four different feed bunk allowances (810, 410, 270 and 200 mm/head). With the reduction in bunk space, fewer cattle were eating at any one time and there was a reduction in the total time spent eating. The alterations in feeding behaviour with increasing competition were studied further by Olofsson (1999). When the competition at a single feeding station was increased from one to four dairy cows there were marked changes in feeding behaviour where there was a reduction in eating time and a commensurate increase in eating rate. As expected, the number of displacements at the station also increased.

Two separate reviews have been undertaken on the effects of feed bunk space allowance on productivity measures (Ingvartsen and Anderson 1983, Grant and Albright 2001). Grant and Albright (2001) reviewed five dairy cow studies and their summary of results is presented in Table 3. Ingvartsen and Anderson (1983) considered four beef cattle (bulls and steers) experiments, including the study by Keys et al (1978).

Table 3 - Effect of bunk space allowance on feeding behaviour and dry matter intake (DMI) in lactating dairy cows (Grant and Albright 2001)

Bunk space (mm)	Effect
< 200	Reduced eating time and DMI
200 – 510	Increased competition and variable effect on DMI
> 510 - 610	No measurable effect on DMI

There was some consensus in the conclusions from the two reviews in that (i) bunk space < 200 mm was likely to be detrimental to productivity and (ii) the differences in productivity measures at different space allowances > 200 mm were inconsistent. In a feedlot study, which was not included in these reviews, Zinn (1989) evaluated different feed bunk space allowances from 150 – 600 mm/animal in restricted fed crossbred steers (234 kg) fed for 76 days. He reported no effect on average daily gain, feed intake or feed conversion efficiency. In a more recent study by Gottardo et al. (2004), bunk space allowance (600 versus 800 mm/animal) was not found to influence daily gain or feed intake in housed bulls.

In summary, feed bunk allowances < 200 mm/animal are likely to be problematic from an animal production perspective for cattle > 300kg. It is interesting to note that this is marginally above the recommended minimum allowance with the code. However, anecdotal evidence would suggest that the bunk space allowance is well above this threshold in most commercial feedlots.

4.6 Water trough access and allowance

The only provision on water trough access within the Feedlot Welfare Code (SCARM 1997) is the statement: “Water troughs should be large enough and designed in such a way that cattle have easy access.”

Furthermore, we are not aware of any research that has specifically targeted the issue of water trough access and allowance. From a behavioural perspective, Hoffman and Self (1973) observed that feedlot cattle spend 12.2 – 17.4 minutes/day drinking and the variability was a function of season. In a comparison of feeding and watering behaviour in healthy and morbid feedlot cattle, Sowell et al. (1999) observed that the healthy cattle drank for 4 minutes/day during the initial four days after feedlot entry and this increased to 5.9 – 9.5 minutes/day after 32 days.

4.7 Feedlot pad conditions

For cattle in outdoor feedlots, the main potential welfare challenge in relation to pad condition is excessively muddy conditions. Such conditions may be caused by a combination of a high rainfall event, inadequate slope or drainage, and stocking density. The animal welfare challenge arises because cattle are reluctant to lie down in boggy conditions, and thus may become tired. This may be exacerbated by the increased difficulty in moving around. Prolonged wet conditions underfoot may also predispose cattle to foot health problems such as interdigital dermatitis and foot abscess. Generally, however, the animal comfort issue presents a welfare challenge before foot health becomes a problem.

Under Australian conditions, recommendations are that the risk of persistent mud can be minimised by siting feedlots in areas with less than 750 mm of annual rainfall, utilising a pen slope of 2.5 to 4%, and managing stocking density appropriately (Skerman, 2000). Higher rainfall areas may require higher standards of pen base construction and drainage systems.

There is only one study that has directly examined lying time and other measures of welfare in feedlot cattle kept in muddy or normal pad conditions. Interestingly, this experiment, conducted in Australia, failed to find any differences in lying time, stress physiology, immune function or daily gain between cattle kept under the two conditions. The study was reported by Fell and Wilson (1998) and published in journals by Wilson et al. (2002; 2005). The experimenters maintained cattle in a ‘normal’ feedlot pen at a density of $12m^2$ per animal, and with a dry, firm pad surface. In contrast, the other treatment group were kept at a density of $6m^2$ per animal, with reduced feed trough space, and the pad conditions were maintained in a wet and muddy state through artificial watering. A third group of cattle were maintained at pasture. There were 14 animals per treatment within replicate and there were two replicates, each of 42 days’ duration.

The results of the study are summarised in Table 1, however the key finding was that cattle in the normal pen lay down for 11.5 to 13 h/day, and the cattle in the muddy pen lay down for 11.8 to 12.2 h/day. These times represesent typical resting durations for cattle in feedlots. Hicks et al. (1989) recorded lying times of 13 h/day for feedlot cattle in the USA. Similarly, Hoffman and Self (1973) measured feedlot cattle lying for 12 h/day, also in the USA. The only difference in lying behaviour seen in the study by Wilson et al. (2005) was an alteration in the pattern of lying between the normal and muddy pens, as revealed by spectral analysis of the behaviour. However, given that overall rest was the same, this difference is more likely to represent an adaptive change in animal behaviour in response to the conditions, rather than a significant challenge to welfare.

The findings of Fell and Wilson (1998) Wilson et al. (2002; 2005) are in contrast to the results of studies investigating the effects of boggy conditions on the lying behaviour of dairy cattle. In a controlled, experimental study, Fisher et al. (2003) found that non-lactating cows on a well-drained pad lay down for 11.9 h/day, in contrast to cows kept in mud (5.7 to 6.9 h/day). On farm behavioural observations of non-lactating cows by Stewart et al. (2002) yielded similar findings, with cows on well-drained pads lying for 11.3 h/day in comparison with cows in muddy laneways lying for just 4.1 h/day. Cows confined to earthen pads during a temperate winter by Muller at al. (1996) lay down for only 3.6 h/day on a smaller pad that became very muddy, in comparison with 8.6 h/day on a larger, drier pad.

In general, it is thought that cattle prefer to lie down for 10 to 12 h/day, and that values of less than 8 h/day represent a welfare challenge. Studies of cows at pasture have shown that they typically lie down for 9.6 to 11.8 hours per day (Singh et al., 1993; Krohn and Munksgaard, 1993; Ketelaar-de Lauwere et al., 1999). A reduction in cow lying time to 4 h/day was associated with alterations in the stress-responsive hypothalamic-pituitary-adrenal axis (Fisher et al., 2002).

Although these other studies were with dairy cows, there is little reason to presume that the lying requirements of feedlot beef cattle would be greatly different, given that body weights would be similar, if not greater, for the beef cattle. Beyond lying time, mud in feedlots can significantly impact on animal performance (reviewed by Elam, 1971 and DeRouchey et al., 2005). It was reported by Bond et al. (1970) that persistent mud had a greater detrimental effect on feedlot performance than either wind or rain, and that daily gains could be reduced by as much as 25 to 37%.

It is thought that there is an interaction between the deleterious effects of mud and the prevailing climatic conditions (Elam, 1971). An animal lying in wet and muddy terrain will lose much more body heat than an animal lying on dry ground, and this effect is more of a problem in cold, wet and windy conditions. This is supported by data indicating that under cold conditions, a muddy lying surface is particularly detrimental to cattle productivity and thermal comfort (Bond et al., 1970). It is likely that the animal's reluctance to lie down in mud is influenced by the perceived coldness causing discomfort.

This effect may explain the apparent discrepancy in lying time results between the experiment of Fell and Wilson (1998) and the other studies reviewed. The experiment of Fell and Wilson (1998) was conducted at Camden NSW during April-May (replicate 1) and October-November (replicate 2), and although the weather is not reported, it is possible that observation days did not coincide with particularly inclement weather. Certainly, the additional lack of effect on daily gain would suggest that the mud did not present a thermal challenge to the animals when they did lie down. Data and estimates from the USA predict that mud under inclement weather conditions can increase maintenance energy requirements for cattle by as much as 30% (Table 4). Recent published estimates for the effects of mud depth on animal performance are for temperatures between -6 and 4ºC (Table 5), although model estimates developed by Rayburn and Fox (1990) indicated that mud may be deleterious at a range of temperatures (Table 6).

In summary, although not supported by the one Australian study on the topic, it is generally thought that prolonged wet and muddy conditions are detrimental to the comfort and welfare of feedlot cattle. As recognised by the Australian Code of Practice, feedlot operators are expected to design and manage their facilities to minimise the risk of an inclement weather period resulting in persistent mud throughout feedlot pens. Similar guidelines are published elsewhere. For example, Grandin (2007) lists excessive mud as one of the three most important critical control points for the welfare of feedlot cattle, stating "*Mud that goes over the top of the hoof is a welfare concern and reduces cattle weight gain. Muddy cattle are a food safety issue*".

Table 4 - Estimated effect of mud on net energy needed for maintenance requirements in feedlot cattle

Feedlot pad conditions	Multiplier for Net Energy for Maintenance
Outside lot with frequent deep mud	1.30
Outside lot, no mud, inclement weather (cold stress)	1.10
No mud, no cold stress	1.00

DeRouchey et al. (2005), using data from Smith (1971)

Table 5 - Estimated reduction in daily gain for various mud depths at ambient temperatures from -6 to 4ºC

Mud depth	Reduction in average daily gain (%)
No mud	0
Dewclaw deep	7
Shin deep	14
Below hock	21
Hock deep	28
Belly deep	35

DeRouchey et al. (2005)

Table 6 - Estimated effects of mud on feed intake, daily gain and feed conversion ratio

Mud depth (cm)	Daily feed intake (kg)	Daily gain (kg)	Feed conversion ratio
0	6.86	1.37	5.02
4	5.83	1.08	5.41
8	5.32	0.93	5.73
12	4.80	0.77	6.22

Rayburn and Fox (1990)

4.7.1 Flooring conditions for shedded cattle

The published studies on the effects of flooring conditions on the welfare of housed cattle are from Europe and North America. This reflects the much greater frequency of the housing of cattle in those regions compared with Australia.

In Australia, discussions with feedlot operators indicate that where shedding of cattle does occur, it is usually for a defined period at the end of the finishing period and is aimed at presenting cattle in a clean state for slaughter. Such sheds are typically open-sided, and bedded with soft material such as sawdust or similar. Sometimes, cattle need to be de-dagged before entering the shed, with the removal of mud and dung lumps from the underside of the animal's body. This process, which may involve hosing, scraping and clipping the dags off the animal, is both labour-intensive and likely to be somewhat stressful to the animal, although this has not been measured. Clearly, aiming to maintain the outdoor pen conditions as dry and clean as possible minimises the amount of dags that have to be removed.

The type and condition of flooring has the potential to affect the comfort and health of cattle. The three most important factors are hardness, slipperiness and cleanliness. As a general rule, harder flooring surfaces, such as concrete, represent a greater challenge for adaptation for cattle than softer, bedded surfaces. In cattle housing, solid concrete flooors may be used in combination with bedded resting areas, or “slatted” concrete floors may be used throughout the pen surface.

Andreae and Smidt (1982) observed the lying down movements of bulls kept either on deep litter or on a concrete slatted floor (Table 7). Bulls on slatted floors were more hesitant about lying down and were more likely to lie down via the “dog-sitting” position. Graf (1979) also recorded a higher incidence of abnormal lying down movements among bulls on slatted concrete floors, but only at low space allowances. There was no difference in lying down movements between bulls housed on straw and those on slats with a large space allowance. In a study conducted by Pougin et al. (1983), cattle housed on slatted floors for 3 or 6 months adjusted well, with the only behavioural difference being that they lay down abnormally 5% of the time.

Table 7 - Types of lying down movements performed by finishing bulls housed in straw-bedded or concrete slatted-floored pens

Type of lying down	Straw bed (% of observations)	Slatted floor (% of observations)
Lying down without hesitating	95.1	60.0
Lying down following hesitation		
- hesitating once	4.2	22.0
- hesitating 2 to 4 times	0.3	8.0
Lying down interrupted	0.1	1.7
Lying down via dog-sitting position	0.3	8.3

Andreae and Smidt (1982)

A series of experiments examining the flooring preferences of cattle were conducted by Irps (1983; 1987). In one trial (Ips, 1983) 15-mo-old cattle spent more time lying on a straw-covered area than on rubber-coated slats and spent the least time lying on uncovered concrete slats when they had access to all three areas. However, when lying times for fattening bulls were measured across three pens, one with rubber-coated concrete slats, one with 50% rubber-coated and 50% plain concrete slats and one with 100% plain concrete slats, there were no differences in lying times across the three systems (Irps, 1987). O’Connell et al. (1993) measured the occupancy rate of cubicles with and without rubber mats in an experiment examining the preferences of dairy heifers. In a free-choice environment, the daytime occupancy of cubicles with mats was 36%, compared with 8% occupancy of cubicles with no mats. It would appear that although cattle do not reduce their resting time with harder flooring, where they have a choice they prefer a softer lying surface.

Sometimes efforts to modify a housing surface in order to make it softer for cattle have reduced the apparent welfare of the animals. MacCormack et al. (1992) experimented with rubber coatings for concrete slatted floors and reported that cattle were dirtier on the rubber-coated slats using a scoring system, and that the surface appeared slippery for the cattle, with the experiment terminating when an animal slipped and was injured. In contrast, Smits et al. (1994), using a different compound, reported less slipping for bulls on rubber-coated compared with conventional slats.

The type of flooring can also have effects on the condition of the feet of cattle and have possible consequences for the incidence of lameness. Kirchner and Boxberger (1987) investigated the loading on the claws in relation to different types of slatted floors. Where the foot is placed partially over a space between the slats, the loading on the parts of the soles that are in solid contact is increased. Fattening bulls of 450 kg BW were measured to have a mean footing contact area of 53 cm^2, and by increasing the width of the slots in a slatted floor from 15 to 25 mm, the mean pressure on the soles of the claws rose from 2.36 to 3.02 Pa. It was estimated by Kirchner and Boxberger (1987) that for optimum claw health, the pressure should not exceed 2.5 Pa. Schlichting (1987) examined hoof growth and wear and behavioural adaptation of young cattle to different types of flooring. Calves were housed on a straw bed, on concrete slats with access to a strawed box, or on rubber-coated wooden slats also with access to a strawed box. Both hoof growth and wear were highest on the concrete, intermediate on the rubber-coated slats, and lowest on the fully-strawed bed. Schlichting (1987) reported that the abrasive effect of the concrete slatted floor led to an increase in the footing contact area, and that cattle behaviourally adapted to slatted floors had maintained this adaptation following a subsequent 3-mo period at pasture. An experiment by Murphy et al. (1987) measured the in-vitro abrasion on a wear-testing instrument of hoof horn samples of cattle in relation to breed and housing. The hoof horn of Friesian cattle was softer if they had been housed on slats rather than on straw, but there was no such effect in Hereford cattle.

Rowlands et al. (1983) conducted a survey of dairy cattle examining the effects of management system on the incidence and type of lameness. The overall incidence of leg and foot lesions was lower in cows housed in straw yards (0.71 cases per 100 cows per month) than in cows housed on concrete floors with cubicles (0.93 cases per 100 cows per month). A similar survey recording the incidence of lameness, and other health problems, among housed beef cattle was performed by Hannan and Murphy (1983). The incidence of lameness was 4.75% among steers housed on slatted floors compared with 2.43% for steers in straw yards. Septic traumatic pododermatitis following hoof penetration, and cellulitis of the limb were more prevalent among cattle on slats, while general necrotic lesions were more common in straw-bedded cattle. Among other conditions, skin and eye lesions had a higher incidence among cattle on slatted floors, while clinical parasitism was lower.

Essentially, the type of bedded flooring used for shedding of feedlot cattle in Australia does not represent a welfare risk, unless it is allowed to become too dirty and wet, or the stocking density is too high. In order to maintain surface quality, the stocking density of animals on bedded floors needs to be less than the density of animals on slatted floor systems. Data from Europe and North America suggests that whereas 2.5 m^2 for a finishing animal may be workable on solid slatted floors (e.g. Fisher et al., 1997), animals on a straw bed or similar typically require at least 3 m^2 per animal in order to most efficiently maintain bedding quality (Hickey et al., 2003). For more on this topic, see the section on stocking density.

4.8 Cold stress

Australian conditions are such that cold stress is not going to be an issue for shedded cattle. Work on cold stress in shedded cattle has been largely confined to Scandinavia, Canada and the higher latitudes of the USA, and has largely focussed on issues such as the production benefits of heating the drinking water, and on ventilation effects on the incidence of respiratory disease.

For cattle in outdoor feedlot pens in Australia, cold stress would only arise as a potential issue during sudden changes of cold, wet and windy weather, especially if there is no shelter from the wind. Cattle are remarkably resistant to prolonged cold conditions once they have adapted and provided that they are well-fed. Older, reasonably well-grown animals, such as those likely to be entering a feedlot, are more tolerant of cold weather than thinner, younger animals. This is partly due to increased muscle and fat, and a greater body volume: surface area ratio, which lessens heat loss to the environment.

Cattle are able to adapt to a wide range of temperatures with little or no threat to their welfare (Webster, 1988). The thermoneutral zone for animals is the range of temperatures below which the animal feels cold and has to divert extra energy for heat production, and above which it feels hot and reduces its heat production by decreasing feed intake (Wagner, 1988; Figure 1).

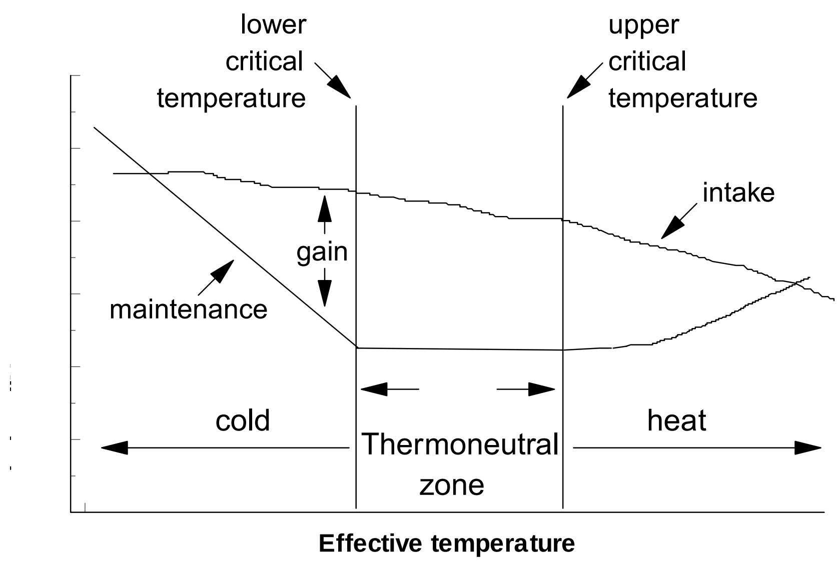

Figure 1 - Effect of temperature on intake, maintenance energy requirements and energy gain (Wagner, 1988)

The temperatures at which cattle are comfortable vary widely with breed (particularly *Bos taurus* compared with *Bos indicus*), age, physiological state and level of adaptation (Webster, 1983; Wagner, 1988; Alnaimy et al., 1992; Le Dividich et al., 1992). The bottom of the thermoneutral zone or lower critical temperature for beef cattle can vary from 15ºC down to -7ºC depending on the state of their hair coat and adaptation (Wagner, 1988). Webster et al. (1970) conducted a trial where 150-kg beef heifers were kept over a Canadian winter at either 20ºC in housing, outdoors with access to shelter or outdoors with no shelter. Even though the mean air temperature during January was -28ºC, heifers maintained outdoors with no shelter gained 90 kg between November and March compared with 102 kg for calves maintained at a temperature of 20ºC.

Accordingly, the appropriate consideration of cold stress for feedlot cattle in Australia needs to focus on sudden changes of cold weather, where the cattle have not previously adapted. Significant body heat loss in cattle is influenced most strongly by a combination of three factors- cold air temperature, rain and wind. Of these, rain and wind play the most important role, due to the rapid cooling effect of air movement on wet surfaces. The effective temperature and body heat retention are dramatically reduced by exposure to wind, especially if the animals are wet (Tables 8 and 9).

Table 8 - Estimated cattle heat loss and effective temperature for various wind speeds at an ambient temperature of -10ºC

Wind speed (km/h)	Heat loss (MJ/m^2 body surface area/day)	Equivalent temperature (ºC)
0	0.9	-10
5	1.4	-17
10	1.9	-22
15	2.2	-26
20	2.4	-29

Ames and Insley (1975)

Table 9 - Estimated cattle average daily gain (kg) for different combinations of temperature, wind and coat wetting

Temperature (ºC)	Dry coat		Wet coat	
	0 km/h wind	16 km/h wind	0 km/h wind	16 km/h wind
7	1.7	1.7	1.3	1.1
4	1.7	1.7	1.2	1.0
2	1.7	1.7	1.2	0.8
-1	1.7	1.7	1.0	0.7
-4	1.7	1.7	1.0	0.6
-7	1.7	1.6	0.9	0.5

Adapted from Hicks (2007) and NRC (2000). Calculations are for a 410-kg steer fed a diet 13.2 MJ/kg DM.

A feedlot study over 3 years was conducted by Mader et al. (1997) in Nebraska, USA. Cattle were lot fed in pens with either: 1) little protection against the prevailing winds; 2) wind protection on two sides; or 3) overhead protection and some wind protection. Despite an average of 29 winter days per year when the minimum daily temperature was less than 0 ºC, and 13 winter days per year when the maximum daily temperature was less than 0 ºC, there were no growth differences during winter between pen types. The mean temperature during winter was -4.2 ºC, and the mean wind velocity was 0.32 km/h. Interestingly, the authors found that the sheltered pens produced poorer productivity results during the summer, and concluded that although wind protection may be of some benefit during excessively cold conditions during winter, the relative resistance of feedlot cattle to cold stress combined with their relative susceptibility to heat stress, meant that wind shelter needed to be carefully used.

Coat length may also influence the risk of cold stress. Longer hair or winter coats provide cattle with additional protection against cold stress, unless the coat is wet, cancelling any benefits of coat length (Table 10).

Table 10 - Estimated lower critical temperatures for cattle fed a maintenance diet with different coat lengths and coat wetting

Coat length	Coat wetting	Lower critical temperature (ºC)
Summer	Dry	15
Medium short (0.8 cm)	Dry	7
Winter	Dry	0
Summer	Wet	15
Medium short (0.8 cm)	Wet	15
Winter	Wet	15

Adapted from Hicks (2007) and Ames (1987)

Although Australian topographical climate maps have been developed for the risk of heat stress in cattle (e.g. Davison et al. 1996), and prediction models have been developed for heat stress events, we are not aware of the same level of detail for cold stress. This is probably because of the relative resistance of feedlot cattle to cold stress, the typical siting of feedlots in central latitudes within the country, and the fact that local topographical features can greatly influence the most important component of cold stress- wind velocity. Furthermore, the level of cold stress for animals exposed to a certain combination of conditions then depends on animal condition, coat length, breed, diet and previous adaptation to cold conditions. Despite attempts to develop a cold stress index for cattle (e.g. Oklahoma Agweather, 2006; see Appendix 1), these have not been widely used, probably because these many additional factors limit their general practical application. Furthermore, the conditions for which they have been developed occur only infrequently in Australia, especially in cattle feedlot areas. Essentially, using the cold stress index developed by Oklahoma Agweather (2007), conditions of 7ºC, with a wind speed of 16 km/h and completely wet cattle would only just fall into the mild chill stress category.

It appears that feedlot designers and operators would be best advised to respond to their own specific locations, conditions and cattle types.

4.9 Gap Analysis

From the review of the published evidence about resource requirements for cattle in intensive production systems, it is worth reiterating that there has been very little research conducted under feedlot conditions, particularly those encountered in Australia. The majority of the literature is more pertinent to indoor cattle production systems in the northern hemisphere. Notwithstanding this point, this body of research can still be used to make a judgement about key requirements of the feedlot welfare code. In general, a defensible scientific basis exists for feedlot guidelines with respect to:

- Pen stocking density
- Feed bunk access and space allowance
- Water trough access and allowance
- Feedlot pad conditions
- Protection from cold stress

There were no obvious inconsistencies between the science and the current code requirements for these resource criteria. The current guidelines for these resource criteria should enable cattle to display the normal repertoire of behaviours. Further comparative behavioural research under Australian feedlot conditions would be of value to confirm this but this was not seen as a high priority. Apart from this, we do not see any immediate priority for any new research with regard to the current feedlot resource guidelines.

Need for animal health standards

The current feedlot welfare code does not include any guidelines with respect to cattle health. Intensive livestock systems can present higher risks with respect to disease, ill health and deaths than some pasture environments and the lack of appropriate guidelines is a cause for concern. It is recommended that the feedlot industry consider the development of additional guidelines or requirements for acceptable benchmarks of animal health in feedlots. Ideally, these should be developed with the view that they can be easily drafted into welfare standards when the current code undergoes transformation into standards and guidelines in the near future.

The logical animal health indicators to apply in the establishment of these benchmarks are the incidence of mortality and morbidity. Though a coarse indicator of welfare outcomes, the focus on morbidity and mortality data as indicators of standards for live export suggest comparable measures with appropriate targets will become the subject of attention for other sectors of the sheep and cattle industries in the future. The task of identifying acceptable mortality and morbidity targets could be approached a number of ways. One approach would be to undertake an industry benchmarking survey to create a database where the variance in mortality and morbidity was quantified. Statistical techniques would then be applied to identify unacceptable thresholds for these criteria. The creation of this database would also serve as a benchmark of industry performance and therefore be amenable to comparative evaluation in the future to assess the industry's progress towards reduced incidence of mortality and morbidity in feedlots. Once established, the mechanism for assessing compliance against these standards would be underpinned by the collection of individual feedlot records. An alternative approach would be to utilise the thresholds or trigger levels and reporting requirements for mortality and morbidity identified within the National Feedlot Accreditation Scheme (NFAS). New standards could be drafted around these existing NFAS requirements. The creation of specific animal health requirements for feedlots would ensure that feedlots not accredited under the NFAS would be legally bound by any new standards once the welfare code is rewritten and ratified by the various governmental jurisdictions.

Potential practical welfare measures for feedlots

The development and application of panting score as an indicator of heat stress is perhaps one of the best examples of a practical, outcome-based welfare measure. On review, there are very few other measures with the potential for application in feedlots with the same degree of efficacy. The possible exceptions here are productivity measures. There is a view that productivity measures like growth rate are indicative of the welfare status of animals. Whilst there is some truth to this association there are exceptions to the rule and once again, the association has not been scientifically tested in feedlot cattle.

The productivity measures could be validated using an epidemiological approach where a database of records from several feedlots (similar to that described above) is analysed to examine the association between productivity and health indicators (mortality, morbidity, numbers of pulls) for instance. If robust associations are evident, then it would be advisable to validate these measures against more detailed behavioural and physiological measurements under experimental feedlot conditions. Ideally, it will be necessary to experimentally create variation in the animal responses. Accordingly, it is proposed that optimal versus sub-optimal feedlot conditions are imposed as treatments. The sub-optimal conditions could include reduced space allowance (pen and trough space). It would be desirable to validate these measures over the entire feedlot finishing phase as the impact of the sub-optimal conditions may be potentially higher during the more stressful induction phase compared to when the animals have adjusted to their feedlot environment.

From another angle, it is recognised that experienced feedlot managers and staff have developed skills that enable them to identify subtle changes in animals or pens of animals that are indicative of reduced health and/or productivity. These various behavioural cues could be quite informative in the context of animal welfare assessment and it would be valuable to initially identify the key indicators and determine whether these can be repeatably applied by experienced and inexperienced operators. If so, then the next stage would involve validation studies where these indicators were evaluated in cattle exposed to optimal versus sub-optimal feedlot conditions.

Community perception of feedlots

Intensive animal production systems will continue to receive increased scrutiny and criticism from animal welfare lobby groups. Statements, unsubstantiated or not, about the welfare standards of these productions systems have the potential to undermine community acceptance and consumer confidence of intensively produced animal products. This coupled with the perceived lack of naturalness of the feedlot environment, represents a real threat to the feedlot industry. To counter this risk, research that demonstrates equivalence (or a higher level) of animal contentment and other animal welfare outcomes in the feedlot environment versus extensive environments is required. The application of animal preference models would be a key element of such research examining for example, whether cattle prefer feedlot or pasture environments when given the choice. Furthermore, these models could also be used to investigate how specific environmental factors and enrichments influence this choice.

5 Success in achieving objectives

The project objectives have been successfully completed.

This review has critically evaluated current scientific knowledge pertaining to resource requirements and welfare of intensively housed cattle. Based on this and after consideration of the feedlot welfare code, recommendations were made to address identified knowledge gaps or deficiencies in code. The knowledge gap analysis concluded that there was generally a sound basis for the development of scientifically defensible welfare standards pertaining to resource criteria for feedlot cattle in Australia. In addition, recommendations were made with regard to the identification and validation of productivity indicators that have the potential to be easily applied by feedlot operators to demonstrate compliance with the animal welfare standards.

6 Impact on meat and livestock industry – now & in five years time

The results of this review should provide security to the feedlot industry in the knowledge that a defensible scientific basis exists for the welfare code guidelines pertaining to resource requirements for feedlots. This review should also help the industry to highlight knowledge gaps and undertake steps to address these. The main impact should occur in five years' time, when these knowledge gaps have been addressed, and the Industry is in an enhanced position to stand by its practices on animal welfare grounds.

7 Conclusions and Recommendations

It is concluded that although there was a paucity of direct evidence on resource requirements for feedlot cattle, there was sufficient evidence to assert that a defensible scientific basis exists for feedlot guidelines with respect to the primary resources requirements of pen stocking density, feed bunk access and space allowance, water trough access and allowance, feedlot pad conditions and protection from cold stress. There were no obvious knowledge gaps with respect to these requirements and therefore, no immediate requirement for research.

The lack of any specific animal health requirements within the current feedlot welfare code was viewed as a deficiency. It is recommended that the feedlot industry give consideration for the need for animal health requirements, specifically, maximum thresholds for mortality and morbidity within the code. Two approaches to identify these thresholds were suggested.

There are very few practical welfare measures that could be applied by feedlot operators to demonstrate compliance with animal welfare standards. Of those that were considered, productivity measures should be evaluated. It was recognised that there may be other behavioural cues that experienced feedlot operators and staff rely on to identify a problem in individual or groups or animals and there would be value in exploring this further. In both instances, these measures or indicators will require validation and this could be achieved via a combination of industry benchmarking and targeted research experiments.

Finally, it was recommended that the feedlot industry consider the need to address potential criticisms of it in the future on the issue of animal contentment in confined or intensive husbandry systems. A strategy to address these challenges may include research examining whether there is equivalence (or a higher level) of animal contentment and other animal welfare outcomes in the feedlot environment compared with extensive environments. This would provide objective evidence that may counter the subjective opinion of some animal interest groups that more intensive, confined systems result in animal psychological suffering and lower contentment than extensive environments that are perceived as more natural.

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9 Appendices

9.1 Appendix 1 - Oklahoma Agweather Cold Stress Index for cattle (developed by Oklahoma State University)

The following is the basic formula used to calculate the Cattle Cold Stress Index when temperatures fall below 45°F.

WCT = 0.0817*[(3.71*wind0.5)+(5.81-0.25 wind)]*[(tair-91.4)+91.4]

where WCT = Wind Chill Temperature (traditional formula)
tair = air temperature in farenheit
wind = wind speed in miles per hour

When temperatures are between 59°F and 46°F, the following formula is used.

CSI = [(tair-45F/14)] x tair + [(59F – tair)/14] x WCT

where CSI = Cold Stress Index
tair = air temperature in farenheit
WCT = Wind Chill Temperature (traditional formula)

The following table shows the Wind Chill Temperature ranges in farenheit where "Mild, Moderate, and Severe" cold stress is likely. Actual cattle stress will vary with location, cattle breed, stage of hair growth, and wind exposure.

Cattle Coat Impact on Wind Chill Temperature Stress Levels

Cattle Coat	Dates	Mild	Moderate	Severe
Dry heavy winter	January 1 – March 31	19-10	9-0	<0
Dry spring	April 1 – April 30	45-32	31-18	<18
Dry summer	May 1 – October 15	59-46	45-32	<32
Dry fall	October 16 – November 30	45-32	31-18	<18
Dry winter	December 1 – December 30	32-20	19-7	<7
Wet	Year-round	59-46	45-32	<32

Whenever 0.1 of an inch of rain occurs in the last hour, the calculated cold stress is the same as if the animal had a summer dry coat.

The forecast model will indicate an alert if 0.1 of an inch of rain is forecast during the 6-hour period covered by the forecast model.

Oklahoma Agweather OSU

http://agweather.mesonet.org/models/cattle/description.html