



Management of Bedding during the Livestock Export Process

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Abstract

The live export industry has identified improved bedding management as a priority to help support improved voyage outcomes. In this study, the management of bedding on livestock export ships was reviewed through a process of consultation with industry including exporters, ship owners, ship stockpersons and shipboard veterinarians. Current practices were evaluated against relevant existing literature from the intensive dairy, beef and equine industries in order to develop recommendations and guidelines for the management of bedding for cattle and sheep during the export of livestock by sea.

A well planned bedding management program should entail a review of bedding management as part of the daily meetings involving the captain, first officer, bosun (or equivalent), shipboard veterinarian and ship stockperson so as to ensure delivery of healthy, well conditioned stock. The provision of adequate and highly absorbent sawdust or shavings, together with a predetermined schedule of pen washing (for cattle) will result in substantial health and welfare benefits including: a reduction in the incidence of lameness and abrasions, improved visual and clinical hygiene, improved animal comfort and reduced emissions of ammonia. An important element of risk management is the application of bedding prior to loading to minimise feet and leg injuries before the commencement of the voyage. On vessels carrying cattle whose drains and pumps cannot cope with large amounts of effluent, the quantity of bedding used is limited by the ship's pumping capacity, and the risk of breakdowns. Cattle are reluctant to feed, drink and lie down when standing in large amounts of effluent and where feeding and watering is not automatic, the crew will be preoccupied with removing effluent from pens. The aim of managing the natural sheep manure pad is to maintain a dry, firm base to limit pugging, fleece contamination and minimise ammonia emissions.

A summary of recommendations which would assist in managing the numerous risk factors arising during the exporting process are listed in Figure 1 and Figure 2. These recommendations cover the areas of strategic, operational and tactical management. A number of recommendations are also made for further research including the development of a system to score bedding and related animal outcomes, the investigation of alternative ship pen flooring and lower protein / higher digestible fibre levels in ship rations.

1 Executive summary

Written standards for the management of bedding during live export by sea are limited. Some basic standards in relation to bedding management for cattle are given in the *Australian Standards for the Export of Livestock* (ASEL) Version 2.1. More details and practical advice are provided in the *Stockmen's Handbook, Transporting of Cattle by Sea – Long and Short Haul Voyages* (Ainsworth, 2008), however, these references do not provide extensive recommendations on the management of bedding to significantly improve animal health and welfare. Furthermore, there is no mention in these references of bedding management for sheep or goats. The purpose of this report is to provide more wide-ranging recommendations for bedding management to help improve the health and welfare of livestock on board ships.

Livestock prefer clean and dry bedding on ship pen floors while in transport. As cattle produce a larger amount of more fluid waste than sheep or goats, the most important quality of bedding for use with cattle is the level of absorbency. The bedding materials of choice for cattle in recent years have been kiln-dried sawdust and wood shavings. Currently bedding material is not widely used for sheep or goats.

The primary desired outcome from using bedding material on cattle ships is to minimise the incidence of lameness and skin abrasions at loading, during the voyage and during discharge. Bedding material when used in conjunction with routine pen washing will also:

- Help lower moisture in the air and lower pen wet bulb temperature;
- Minimise the amount of hide and hair contamination by faecal matter;
- Improve the comfort and ease of standing, walking, lying down and standing up by minimising pugging of the cattle bedding or sheep pad; and
- Maintain low levels of ammonia in the pen environment.

The natural sheep manure pad, while dry and intact, has been the preferred choice of bedding material for sheep during live export. However, problems can occur with the sheep pad if it becomes too moist or too dry.

The primary desired outcome of managing the sheep pad is to maintain a firm and dry base at all times. Management of the sheep pad aims to:

- Help lower moisture in the air and reduce the pen wet bulb temperature;
- Minimise the amount of skin and fleece contamination;
- Improve the comfort and ease of standing, walking, lying down and standing up by minimising pugging; and
- Maintain low levels of ammonia in the pen environment.

The impact of many of these bedding management effects is magnified by any external increase in deck wet-bulb temperatures, which can lead to:

- Heat stress in livestock complicated by a deteriorating manure pad coating the hair or wool;

- Deterioration of the manure pad resulting in decreased levels of hygiene and increased risks of infection associated with lameness and abrasions; and
- Increased ammonia emissions causing health risks to both livestock and crew.

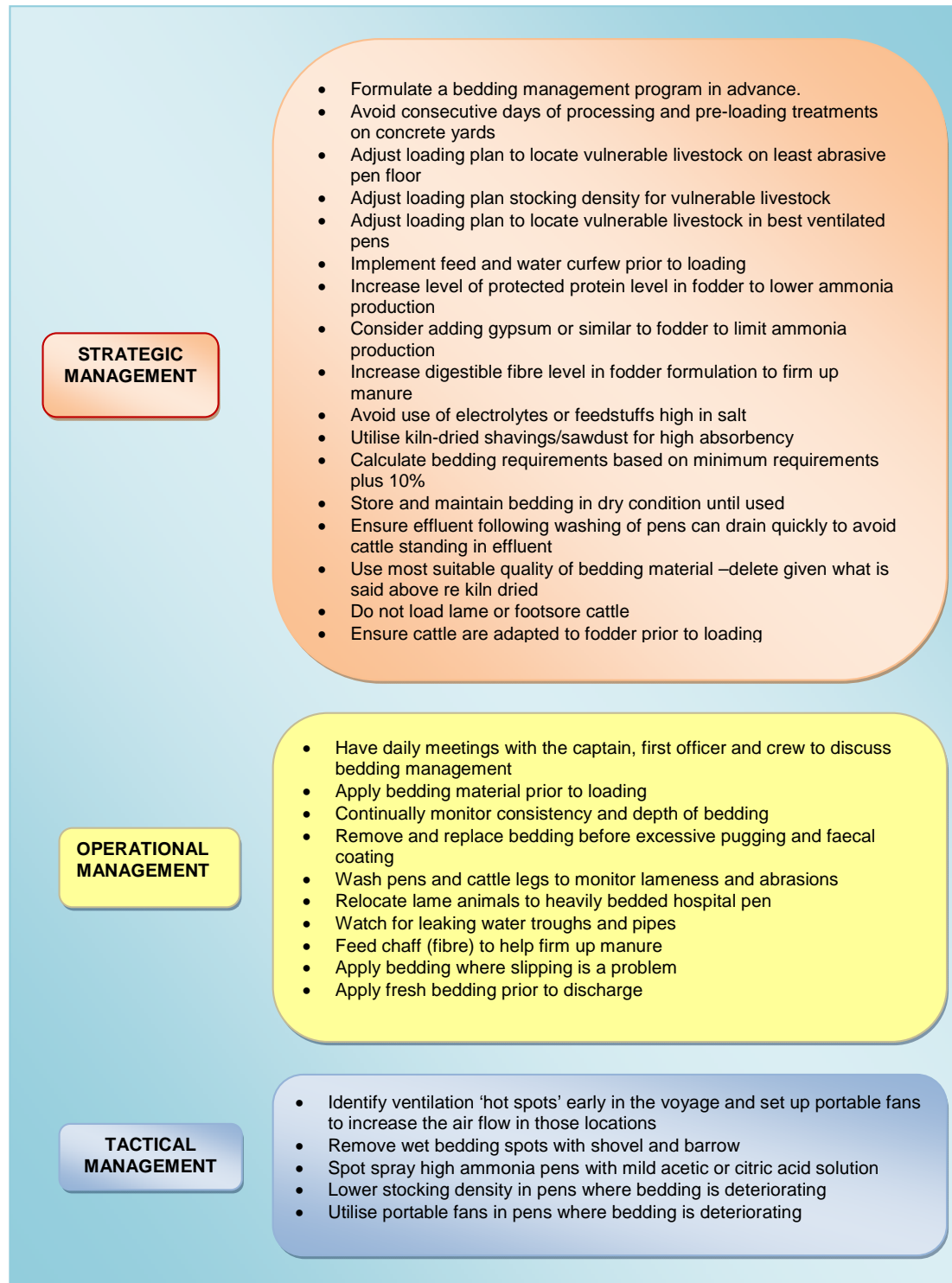
Whilst the most important factor for consideration in selecting a bedding material is its level of absorbency, other factors for consideration include availability, storage space on ship, cost and labour requirements. Based on an assessment of these factors, kiln-dried softwood sawdust and shavings are the recommended choice of bedding material from the main ports of Australia.

Experienced veterinarians and stockpersons assert the real and principal benefit of using bedding is not to provide a comfortable resting place (as might be envisaged by the general public) but to minimise leg and feet injuries. If comfort alone was the criterion, the amount of bedding would need to be of such quantities that it would increase to unworkable lengths the time needed for washdowns and disposal. This could prejudice the welfare of stock by extending the period of feed and water deprivation. It would also significantly increase the cost of bedding.

Based on current mortality rates and estimates of poor health attributable to bedding management, the cost of bedding is not likely to be recouped by a reduction in mortality rates alone. However, while the cost of bedding may not be justified purely in commercial terms through reductions in mortalities, lameness and possible live weight loss, addressing the welfare issues through bedding management will have a positive impact on the animal welfare image of the industry, assisting its long-term viability.

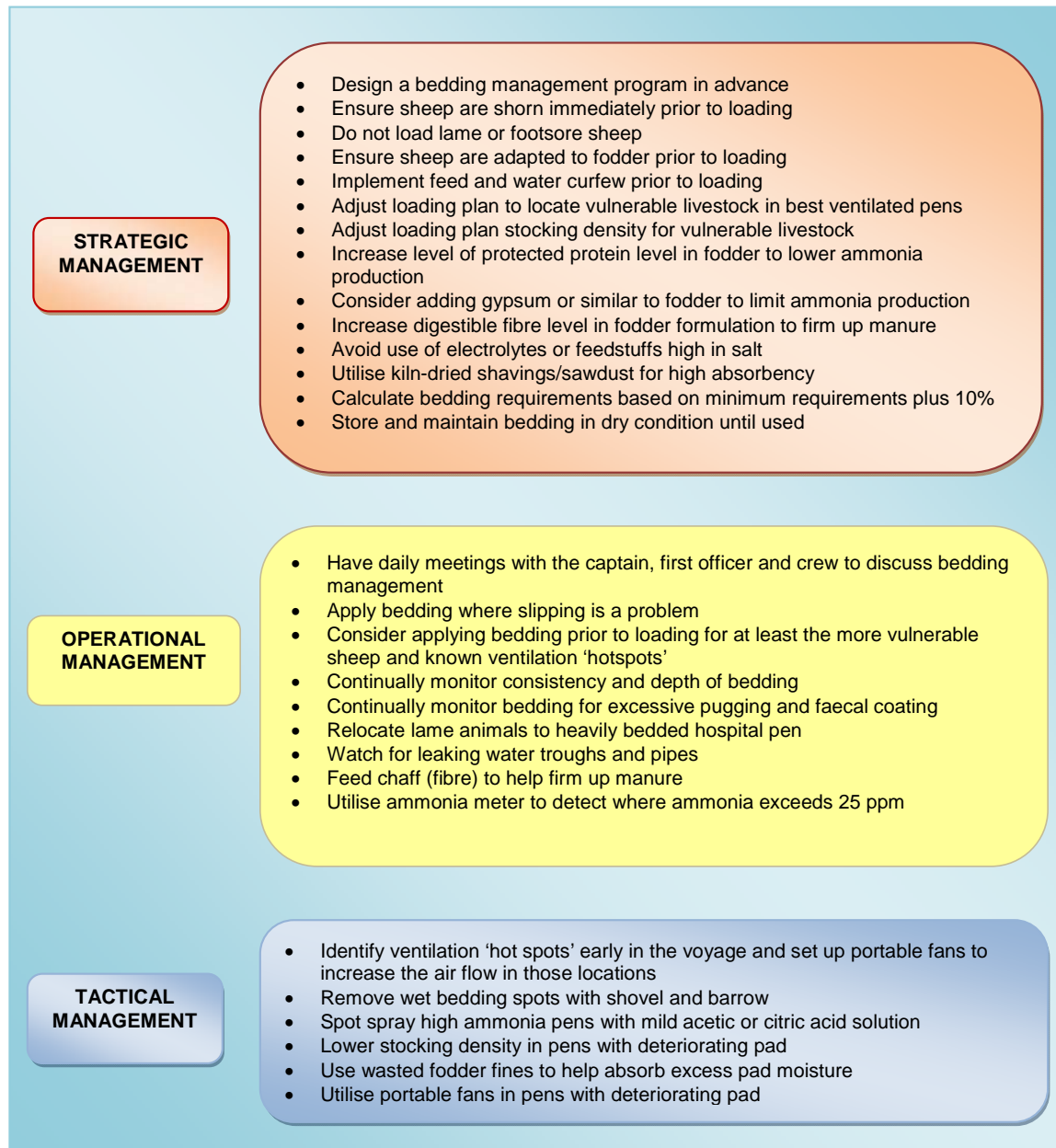
Recommendations in relation to minimising risk and managing bedding during the export process for both cattle and sheep are summarized in Figure 1 and Figure 2.

Figure 1: Cattle bedding management



Source: RMP

Figure 2: Sheep bedding management



Source: RMP

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2 Background

2.1 Project description

The use of bedding material such as straw, sawdust or other material on livestock export shipments has been practised for many decades on voyages from Australia. According to the terms of reference for this project, incidents on ships relating to the management of the bedding material have occurred in cattle pens when bedding becomes too moist and present in large quantities

Similarly insufficient bedding can reduce the proportion of time cattle spend lying down which can increase the level of lameness and abrasions during a voyage, leading to secondary problems such as leg wounds and infections. In addition, ammonia levels on decks pose specific risks to the health and welfare of animals on board, and if not well managed can lead to respiratory complaints and eye disorders (Phillips, 2007). Furthermore, extended periods of high ammonia levels may exceed limits for safe working conditions for crew.

There has been resistance by some stockpersons to wash down decks too frequently for fear of elevating deck wet bulb temperatures¹ and possibly causing heat stress in cattle, particularly on deck areas where ventilation is less than optimal. According to industry observations, problems can also arise if cattle have winter coats and manure is able to adhere to the coat, thereby affecting the animal's ability to thermo-regulate

In relation to the transport of sheep, the accumulated manure forms a pad that by its nature can present problems when high temperatures and humidity (high wet bulb temperatures) affect the consistency of the pad and the level of ammonia produced. The propensity of the pad to become very moist during such conditions, can severely affect the welfare of otherwise healthy sheep.

This project reviewed the nature and management of different types and grades of bedding material in relation to a range of identified variables such as class of stock, the qualities of the bedding material and the on-board environment. Through a process of industry consultation and a review of available literature, current bedding management practices were reviewed and assessed in terms of best practice. The essential recommendations for bedding management and pen washing were then developed in order to maximise animal health and welfare and minimise the risk of on-board incidents during transport.

2.2 Project objectives

The objectives of the project were to:

1. Review the current bedding management practices and the issues resulting from those practices; and
2. Provide recommendations to minimise the risk of bedding-related incidents and maximise the welfare of livestock during transport.

¹ Dry-bulb temperature and humidity combine to give a measure called wet-bulb temperature. Wet-bulb temperature encapsulates, in a single figure, the ability of wet skin to reject heat to the air by evaporation (Maunsell Australia, 2000)

2.3 Methodology

Following a project team meeting with MLA representatives to confirm the objectives and scope of this project, an initial list of industry contacts was prepared. These contacts formed the basis for the industry consultation. Included in the consultation process were key industry representatives in Western Australia and the Northern Territory. A list of persons contacted as part of this process is included in Appendix 12.4.

The industry consultation process sought to establish current bedding management practices for live export and the issues associated with those practices, as well as hands-on recommendations from most important participants on board the ships. Based on feedback from the short haul cattle trade, the focus of this project remained on the long haul export of cattle, sheep and goats. As a consequence, four days were spent in and around the port of Fremantle interviewing individual exporters, ship owners, ship stockpersons and shipboard veterinarians.

A review of available literature on bedding management included past research funded by the joint MLA / LiveCorp live export R&D program and research undertaken by the intensive dairy and beef industries. Some bedding management information was also found within the equine and pig industries, and also from overseas sources. Where necessary, some industry contacts were interviewed on several occasions to clarify particular issues arising from the review of current literature. Critical points resulting from the review of available literature are highlighted in Appendix 12.2.

The findings in this report are based on an analysis of industry research, a review of available literature and a selection of shipboard photographs to illustrate the problems and solutions in managing bedding on ships and costs of using bedding on livestock ships.

3 Current Practices and Issues

3.1 Existing Standards

3.1.1 Australian Standards for the Export of Livestock

Written standards for the management of bedding during live export are limited. The Australian Standards for the Export of Livestock (ASEL) (Version 2.1), last updated by the Vessel Preparation Working Group in September 2004, set the standards for the conduct of the livestock export trade, as required by the Australian, state and territory governments. The relevant extracts from the ASEL are shown in Table 1.

Management of Bedding during the Livestock Export Process

Table 1: Extracts in relation to Bedding Management from ASEL, Version 2.1

Section	Standard
S4.15	Bedding must be provided in accordance with specifications in Appendix 4.3.
S5.9	When bedding is used, it must be maintained in adequate condition to ensure the health and welfare of the livestock.
Appendix 4.3	Provision of bedding – Cattle and buffalo Cattle and buffalo exported on voyages of ten (10) days or more must be provided with sawdust, rice hulls or similar material to be used exclusively for bedding at a rate of at least seven (7) tonnes or twenty-five (25) cubic metres for every 1000 square metres of cattle pen space. This does not apply to cattle and buffalo loaded from Brisbane or a port north of latitude 26 degrees south and exported to Southeast Asia or Japan.

Source: ASEL (ver. 2.1)

The ASEL does not make any recommendations on the qualities of bedding material to be used, in particular the degree of absorbency. The bedding requirements were transferred directly from the original Australian Livestock Export Standards – March 2001 (amended August 2003), so the basis for the bedding requirements (or lack thereof) for 'Brisbane or a port north of the 26th parallel and exported to South-East Asia or Japan' is not clear. The interpretation of the Standard is that the 7 tonnes or 25 cubic metres of bedding used for every 1,000 square metres is the total bedding requirement for the duration of the voyage.

Mr Tony Brightling, one of the authors of the standards, advised that the quantity specified in the Standard was intended for voyages of 10 days or more, with one application prior to loading, one after final washdown when approaching the destination and two washdowns in between. This would represent approximately 0.6 cm of bedding for each new application of material.

Furthermore, there is no mention in the ASEL of bedding management in relation to sheep or goats.

3.1.2 Handbooks for Shipboard Stockmen

Bedding management is also addressed in the *Stockman's Handbook, Transport of Cattle by Sea – Short and Long haul voyages, April 2008*, pages 21-24 (Ainsworth, 2008) (are there authors for this). The relevant paragraphs from these pages have been reproduced in Appendix 12.1.

The main recommendations contained in the *Stockman's Handbook* are:

- The use of sawdust as the preferred bedding material;
- Without stating a frequency for washing, the limitation of the number of occurrences of washing down and deck cleanout, in order to reduce distress and possible resulting injury to cattle;

- The use of mild acids (such as acetic or citric acid), or gypsum added to the bedding to assist in the control of ammonia production in addition to washing out; and
- The timing of washing out, which should be carefully planned to ensure that the lowest possible humidity levels are achieved during passage through hot locations.

There is no mention of managing the sheep pad in the *Handbook for Shipboard Stockmen and Veterinarians (Sheep and Goats)*, (Lightfoot, 2008) (authors).

3.2 Nature and quantities of waste produced

Ruminants consume two to three per cent of body weight daily, on a dry matter basis, and water intake is 10 to 20 per cent of body weight with a resulting large output of excrement, as shown in Table 2. For cattle of typical live export body weights of 300 kilograms and 450 kilograms, the volume of manure (faeces and urine combined) is in the range of 20 to 30 litres per head (five to six per cent of body weight) per day; and for typically-sized export sheep and goats of between 30 kilograms and 45 kilograms, it is 1.2 to 1.8 litres per head (four per cent of body weight) per day.

Table 2: Daily production of manure (faeces and urine)

	Animal weight (kg)	Live weight (kg)	Total Manure (kg)	Dry Matter ^a (kg)	Organic Dry Matter ^b (kg)	Urine (L)
Cattle	300		17.4	2.6	2.2	5.4
	450		26.1	3.8	3.2	8.1
Sheep	30		1.2	0.33	0.28	0.45
	45		1.8	0.5	0.41	0.68
Goats	25		1.0	0.32	0.23	0.37
	40		1.6	0.52	0.37	0.6

a. Dry matter is everything remaining after all water is removed.

b. Organic dry matter is dry matter less the ash content (minerals).

Source: Landline Consulting (2003)

Sheep and goats produce a dry faecal pellet compared to relatively moist cattle faeces, eliminating the need for washing down of sheep and goat pens. Generally, sheep and goat pellets have a moisture content of 50 to 60 per cent compared with 75 to 80 per cent for cattle faeces (Landline Consulting, 2003).

Some observations by ship stockpersons and shipboard veterinarians on the nature of waste produced include:

- As livestock recover from loading, adjust to the shipboard fodder and their new environment, the faeces of cattle, sheep and goats will generally firm up;
- All livestock drink and urinate more during the journey on and near the equator;
- All livestock drink and urinate more during high temperature events be that during the southern or northern hemisphere summer;

- Dairy cows will often drink, urinate and spill onto decks considerably more water than other classes of cattle. Dairy breed females may drink up to 50 litres of water per day whereas *Bos indicus* cattle in the same conditions will be drinking in the order of 25 litres per day. This is a function of the differences in weight and genotype;
- All ages and weights of rams tend to drink more water and therefore urinate more than other classes of sheep;
- *Bos indicus* cattle tend to produce firmer (lower moisture content) manure than *Bos taurus* cattle; and
- Electrolytes added to drinking water will cause higher consumption of water and therefore greater volumes of urine.

3.3 Types of bedding currently used

Industry has observed that livestock prefer clean and dry bedding on the decks of ships while in transport. As cattle produce a larger amount of more liquid waste than sheep or goats, the most important quality of bedding is the level of absorbency. The bedding materials of choice for cattle in recent years have been sawdust and wood shavings, replacing straw, which while highly absorbent and comfortable is more difficult to wash away from the decks and has caused problems with blockage of drainage systems.

The natural sheep manure pad, while dry and intact, has been the preferred choice of bedding material for sheep during live export. However, problems can occur with the sheep pad if it becomes too moist or too dry.

3.4 Long haul versus short haul

Long haul voyages from Australia are generally to the Middle East and are in excess of 10 days. Short haul journeys, generally to Asia, are usually 10 days or less.

There is a difference between the contract payment terms for the Middle Eastern and Asian markets. Generally, for the short-haul Asian markets the cattle are weighed at destination and the price calculated on that weight, whereas for the Middle Eastern cattle and sheep markets, price is calculated on a per head basis, irrespective of weight at destination. This has additional implications for bedding management for each market, as will be explained later in this report.

Journeys to the Middle East, North Africa and Russia can exceed 25 days with or without multiple loading and discharge ports and these voyages require particular attention to bedding management.

Bedding management is a less critical issue for short haul voyages, except for the more vulnerable animals such as heavy bulls, pregnant cows and heavy steers.

3.5 Animal Health and Welfare Issues

3.5.1 Stocking Densities

Stocking density and ventilation pen air turnover are regarded by the majority of industry as the two most important elements on ship in determining the successful carriage of livestock by sea. Minimum stocking densities for different classes of livestock for different times of the year are set out in the ASEL. This assumes the livestock have been suitably prepared prior to loading. In terms of bedding management, adjusting pen stocking densities can be an essential tool for optimising outcomes.

Where pen air turnover is known to be relatively low on a ship deck or pen, cattle bedding and the sheep pad will normally be of softer consistency and be at risk of deteriorating if the ambient wet bulb temperature rises above a critical point. This critical point of 31.5°C is discussed under Section 2.5.2 Heat stress. A stocking density less than the minimum prescribed by the ASEL stocking density tables will improve the efficacy of existing ventilation and reduce the amount of accumulated manure and urine. A lower stocking density will also reduce the level of pugging (damage from trampling) of the bedding for cattle or the sheep manure pad and allow livestock greater opportunity to lie down on a relative clean and dry area of a pen.

Industry practice for the export of dairy cattle, in particular cows and other heavy beef cattle, requires stocking density adjustments dependent on ship and environmental factors, which can lead to improved bedding management outcomes.

3.5.2 Heat stress

Heat stress in the on-board environment is the elevation of the core body temperature due to excessive heat absorption from the ambient temperature, when combined high humidity, high body condition score and a heavy hair coat together with deficient heat loss from convection, conduction and radiation and evaporation of moisture. When heat gains exceed heat losses, core body temperature rises – this can result in increased thirst, respiration and heart rate. The risks of exceeding the critical core body temperature are depression of the nervous system, depression of the respiratory centre, circulatory failure, lowered food intake, and energy loss (Blood and Henderson, 1963). Stock can handle excessive heat stress but not prolonged stress (Schmidt-Nielsen, 1979). Cold water spraying is the preferred treatment (Blood and Henderson, 1963).

Bedding management is of relatively minor influence in the minimisation of heat stress, whereas, ventilation measured as pen air turnover and stocking density are critical factors affecting the risk of heat stress. However, when pen bedding becomes excessively soiled and soft, this soiled bedding can contribute to a slight rise in pen wet bulb temperature as observed by shipboard veterinarians and stockpersons. The removal of bedding on a regular basis will therefore reduce this risk. Any bedding material that has a starting moisture level above 5% has been observed by industry to contribute to heat generation and atmospheric humidity before it is soiled by livestock. According to industry, some bedding materials may have moisture content as high as 30% prior to being used on board ship. An example of such a bedding material is a wood chip material sold as garden mulch and used by some exporters

For a short period following washing, there is an industry observed temporary increase in the ambient wet bulb temperature when wetting ceases, however washing cattle that are heat stressed will improve their welfare and may even reduce mortalities due to heat stress (Gaughan et al,

2005.) Whilst some stockpersons commented that they would be reluctant to wet cattle to alleviate heat stress, other respondents advised that the application by hose of 3 to 4 litres of cool water per head on the backs of cattle produced immediate and beneficial relief of heat stress. Reducing high body temperature by the application of cool water is standard veterinary medical practice (McDonald, 1981).

If the wetting of cattle is to occur, the pen floor must be washed at the same time and allowed to dry before new bedding is applied. It is important to remove as much moisture from the pen floor and air as quickly as possible after wetting cattle and that the ventilation system is working effectively.

According to industry observations, when wet bulb temperatures reach approximately 31.5°C (dry bulb temperature approximately 33°C and the relative humidity approximately 90%) bedding will increase in moisture and the incidence of pugging will increase with the corresponding increased consumption of water by cattle. Wet bulb temperature of 32°C was quoted as a common rule of thumb for action as animals may become susceptible to heat stress at these temperatures.

The Heat Stress Threshold (HST), defined as '*the maximum ambient wet bulb temperature at which heat balance of the deep body temperature can be controlled using available mechanisms of heat loss*' for various livestock classes is contained in Table 3.

Table 3: Base Heat Stress Threshold Values for 'Standard' Animals

Base Parameter	<i>Bos taurus</i>		<i>Bos indicus</i>			Merino		Awassi	
	Beef	Dairy	Beef	25% indicus	50% Indicus	Adult	lamb	adult	lamb
Weight (kg)	300	300	300	300	300	40	40	40	40
Core Temperature (degrees C)	40	40	40	40	40	40	40	40	40
Condition (Fat Score)	3	3	3	3	3	3	3	3	3
Coat	mid	mid	N/A	N/A	N/A	shorn	shorn	hairy	hairy
Acclimatisation WB Temp	15	15	15	15	16	15	15	15	15
Base HST (degrees C)	30	28.2	32.5	31.2	31.8	30.6	26.7	31.9	28.6

Source: Maunsell Australia Pty Ltd., 2003

As can be seen from Table 3, a wet bulb temperature of 31.5°C is above the base HST for all classes of cattle and sheep except for 100% to 50% *Bos indicus* derived cattle and adult Awassi animals. For cattle and sheep heavier than 300 kilograms and 40 kilograms respectively, the base HST will be lower than those depicted in Table 3 (Maunsell Australia, 2003). Depending on the ship pen air turnover and the degree of acclimatisation, industry observations are that certain classes of livestock may be affected by heat stress with their welfare further compromised by pugging in a soft manure pad.

3.5.3 Water and Electrolytes

Water is provided as required to livestock on ships. Water that finds its way onto the deck floor and bedding material will alter the consistency of bedding material. A relatively firm cattle bedding or sheep pad can turn soft and begin pugging when wet and this will be further exacerbated by a relatively high pen wet bulb temperature.

Industry has observed some cattle, in particular dairy breeds, tend to drink more water than other cattle whilst some classes of dairy animals will not only drink a lot of water but also spill a lot of

water when at the water trough. Those animals that drink more water will urinate more, which increases the moisture content of the bedding or pad. Particular attention to bedding is therefore required during relatively high wet bulb temperatures such as when near the equator and entering the Middle Eastern Gulf waters. Increased water consumption prior to discharge can make management of the bedding difficult when washing opportunities may be restricted. In certain regions such as the Suez Canal, the Black Sea and in Japanese waters, regulations prevent the discharge of effluent into the shipping lanes.

The use of electrolytes in ship drinking water appears to be waning. According to industry observations, the addition of electrolytes to drinking water usually results in a much greater consumption of water, resulting in greater urination and a resulting moisture increase in the cattle bedding or sheep pad. From the perspective of bedding alone, electrolytes are not recommended, particularly when other risk factors such as deck wet bulb temperatures are high and water consumption is already elevated.

Any factors such as high salt levels in fodder that lead to higher than normal water consumption will result in increased urination, making it more difficult to manage the moisture content and therefore consistency of bedding. This is especially so if it occurs during the northern hemisphere summer when livestock naturally drink more. This was observed by a number of industry people with direct experience of this nature.

3.5.4 Loading and discharge

Bedding material is commonly used at loading and discharge to minimise slippage at known high-risk points such as on ramps or corners. This additional use should be included in the calculation of quantities of bedding required. Bedding used this way is thought to be most important during discharge when the livestock can be stiff and tired from the voyage.

3.5.5 Hygiene

Wetness and soiling of the lying area, which translates into animal wetness and dirtiness, may cause skin lesions or aggravate existing lesions of cattle due to chemical components of the excrement attacking the skin or underlying tissue (Hartmann et al., 1997; Muller, 2004 quoted in Schulze et al. (2006)). Depending on the type of cattle and in particular their coat hair length, a faecal jacket can form if the bedding becomes too moist and too deep. This coating of faecal matter has the potential to interfere with the natural thermoregulation of cattle, especially during periods of high wet bulb temperatures, and should be washed off if necessary during the course of a voyage. However, as observed by ship stockpersons and veterinarians, during relatively low wet bulb temperatures, this faecal coat is not normally a problem and will gradually detach itself from the coat given drier conditions.

Industry reports that the hygiene of bedding is important for a number of reasons including:

- Reducing the extent of dags and discolouration of sheep and cattle leading to unfavourable presentation;
- Minimising the faecal contamination of the fleece of sheep and coats of cattle so as not to decrease heat stress thresholds;
- Reducing the risk of leg infections in livestock that have injured feet or legs;

- Minimising the faecal contamination of the udder of female dairy cattle, thus reducing the incidence of subclinical mastitis (Bovine Research Australasia, 2003); and
- Reducing the growth in fly population, which can irritate animals and help to transfer infection.

The observation by stockpersons and veterinarians that cattle lie down almost immediately after fresh bedding is laid, supports the claims of improved welfare benefits provided by providing dry bedding. Cattle prefer not to lie on wet manure. Also, the physical act of lying down and standing up in a relatively clean and dry environment allows the ship stockperson and veterinarian to better detect lameness and abrasions.

Examples of faecal contamination of coats and fleece are shown in Figure 3 to Figure 5.

Figure 3: Cattle showing faecal contamination of coat



Source: Lynn Simpson

Figure 4: Cattle coat type and length will affect the level of faecal contamination of coat



Source: Lynn Simpson

Figure 5: Sheep showing faecal contamination of fleece



Source: Lynn Simpson

3.5.6 Lameness

Absmanner et al (2009) and Platz et al (2007) noted significant alterations in the lying behaviour of bulls kept on a concrete floor, such as a higher proportion of atypical lying down and standing up movements and fewer periods lying down in comparison to bulls kept in pens with a bedded lying area.

The work by Absmanner et al (2009) studied the housing systems of beef bulls weighing between 340 kg and 600 kg, which were (a) fully concrete slatted floor pens, (b) fully slatted floor pens

covered with rubber mats, (c) straw bedded pens and (d) a system combining straw bedded pens (for bulls weighing less than 450 kg) and fully slatted floor pens (for bulls weighing more than 450 kg). It was concluded that rubber mats for slatted floors have a positive effect on the bulls' behaviour but do not reach the welfare potential of straw bedding.

Platz et al (2007) studied groups of six bulls each with a total average age of 9.8 months over a period of one year on either slatted concrete or on slatted concrete covered completely or partially with perforated rubber mats. Every three months, behaviour (preference of flooring, lying, aggression, mounting) was recorded. The incidence of skin lesions was recorded every two weeks.

The bulls preferred the rubber-coated area throughout the experiment. Animals in the rubber-coated pens showed more lying periods and had a lower incidence of skin lesions compared to bulls in the concrete only pens. Bulls in the rubber-coated pens needed less time for rising than bulls in the concrete pen. Net claw growth was comparatively greater in the rubber-coated pens. In conclusion, the results of these studies indicate that rubber coated slatted flooring has a positive influence on the housing conditions of beef cattle.

Consequently, these authors regard a hard lying surface as unsuitable for the lying behaviour of finishing bulls under intensive management.

These findings support the observations by ship stockpersons and veterinarians that certain classes of livestock require preferential treatment if normal lying and standing behaviour is to occur and the incidence of lameness is to be minimised. It was commonly reported to the authors that heavy cattle (over 380 kg) will, depending on the surface of the pen floor and the stability of the ship, incur more leg injuries than other cattle. Similarly dairy breeds (males and females) with relatively soft feet, angular conformation and inferior agility, and non-pastoral cattle with soft feet are more vulnerable to lameness as their feet can be relatively easily worn and damaged by ship pen floors. Cattle originating from southern parts of Australia during the normally wet winter will have relatively soft feet that are prone to abrasion and lameness.

Craft et al (2006) reported that the welfare of cattle is improved when using wood shavings over concrete floors in saleyards. In this study foot soreness was reduced in comparison to bare concrete if the wood shavings were at least 75 mm thick with a preference for between 100 and 150 mm in depth and the length of the wood shavings less than 100 mm. Care needs to be exercised in extrapolating the results of using soft bedding in saleyards as the average depth of bedding material used per application on ships is as reported by industry, generally less than 25 mm. However this research supports the comments from several ship stockpersons and veterinarians that more bedding than is currently used would improve the comfort and welfare of cattle. The available storage space on ships and the time required for wash downs whilst minimising time off feed and water constrains the amount of bedding that can be carried and used.

By decreasing the incidence of abrasions and lameness through the use of bedding, stockpersons and veterinarians point out that the time saved with reduced injury treatments allows the crew to spend more time monitoring and treating other livestock, which may otherwise be detected too late for effective treatment. It is not uncommon for the relocation of one lame animal to a hospital pen and its initial treatment to occupy a stockperson and member of the crew for up to three hours.

In reducing the number of leg and feet injuries, the cost of anti-inflammatory and antibiotic drugs will decrease. In extreme cases, it was reported that the drug cost for a single animal with a leg injuries can be as high as \$80.00 over the duration of the voyage.

It was difficult to ascertain an industry average incidence of lameness, abrasions, infection or diseases associated with bedding management. This information may be available in veterinary voyage reports, which are sent to the Australian Quarantine and Inspection Service (AQIS), however present administrative arrangements do not allow these reports to be released by AQIS. Benchmarking the incidence of these incidents and welfare outcomes such as the time spent lying/standing and level of faecal contamination would be a good start to better measure and control the issues surrounding bedding management. This issue has been identified as a potential future research issue and outlined in more detail in section 0.

Respondents observed that as some injuries occur prior to loading and some during the voyage, it is difficult to allocate these injuries to a specific category during the voyage. One factor observed was that pre-loading processing and treatments can be responsible for toe wear and trauma if carried out on concrete yards. In one example, 55 head (6%) were rejected out of 950 head selected for export.

Foot problems unrecognised prior to loading are exacerbated during the voyage if floor design is unsatisfactory and wash down and bedding changes are not done well. In another example, it was reported that feet lesions and lameness accounted for one-third of treatments required post-discharge.

Examples of leg abrasions are shown in Figure 6 and Figure 7.

Figure 6: Example of lower leg abrasion on heavy cattle



Source: Lynn Simpson

Figure 7: Example of upper leg abrasion on heavy cattle



Source: Lynn Simpson

3.5.7 Flooring considerations

Pen floors are generally three layers with a steel base, which is concrete-coated with a non-slip surface on the top. Some pen floors are more abrasive than others and cause significant wear and tear on cattle resulting in lameness and infection. Whilst this level of abrasion can be related to the age of the floor surface, there appears to be some variation in pen floor hardness and abrasiveness between ships irrespective of floor age. This is more than likely related to the size and shape of the grit or particles embedded in the epoxy or bitumen flooring.

Most floors consist of a steel base covered with double coating of epoxy, which sandwiches an aggregate material to reduce slippage. There are primarily two type of aggregates used on ship decks. The first is river stone, a rounded quartz particle and the second is an aluminium oxide particle. The quartz particle is smoother than the aluminium oxide, however it does not last as long. According to companies that provide ship floor coatings, the nature and most importantly the size of the particle and the thickness of the top layer of the epoxy coating determines the traction and abrasiveness of the finished surface. The overall thickness of this type of surface is in the order of 5 mm. Flooring providers report that it is usual for the deck floor to be become less abrasive with age as it wears down.

Another flooring system is the use of a bitumen product, which is laid over a primer and the aggregate is then poured onto the wet bitumen where it is partially absorbed into the bitumen. This type of surface can be up to 10 mm thick. Again the size and shape of the aggregate is the most important factor determining traction and abrasiveness.

On some ships, a type of steel mesh is laid on top of the floor to further reduce slippage. This material is effective; however according to industry observations, it can be uncomfortable for livestock when they lie down. Some older vessels that have undergone a low cost conversion to livestock carriers have sloping decks which result in slipping injuries and general discomfort.

There are various recycled rubber products available, which are used for a range of purposes including in playgrounds and on horse racing tracks, which may have some application on ships if the level of abrasions and therefore lameness is to be minimised. Such products may be significantly more expensive to lay than the epoxy flooring. Depending on the longevity of such recycled products, the benefits may make using such a product in selected areas of value. It will also be critical that rubber products can be effectively cleaned for quarantine reasons whilst protecting the ship floor from corrosion.

Industry has observed that the heavier the animal, the greater the impact on the pressure points of its limbs during lying and standing, and the less agile it will be, resulting in greater difficulty for the animal in adjusting to the relatively hard and abrasive pen flooring. Non-pastoral cattle sourced during wet winters are also reported by industry to often have problems adjusting to the floor surface due to the relative softness of their feet.

Industry has observed the following benefits associated with appropriate flooring and bedding material:

- Improved steadiness and less slippage particularly during loading and rough seas;
- The noise of cattle hooves on flooring is subdued resulting in quieter and less stressful loadings; and
- Cattle tend to settle more quickly if fresh bedding material is provided on appropriate flooring.

Given the critical importance of deck flooring, there is scope to investigate other floor surfaces, which will reduce the incidence of leg and feet abrasions, is durable and cost effective and meets quarantine standards.

3.5.8 Vessel considerations

Some vessels are designed to more efficiently wash, drain and remove livestock effluent than others. Ideally, deck design and bilge pumps should allow for effluent to be washed and drained quickly, where the effluent can be stored or dispersed overboard. Efficient and regular disposal of effluent is vitally important since prolonged wash downs will realistically impose deprivation of feed and water for long periods. Washdowns that take under around 6 hours, achieved by washing decks or holds in stages, allow cattle to get back onto feed and water without compromising good animal welfare.

Some ships need to list (tilt by the transfer of ballast water) during washing so that the water and effluent drains quickly from decks. Industry has commented that having cattle standing in slowly draining water and effluent for extended periods of time can cause the softening of feet as well as poor hygiene surrounding existing feet and leg injuries. A shipboard veterinarian has observed, in extreme cases, the slow passage of water resulting in some cattle standing in water over 30 cm deep in excess of 24 hours. This will have negative effects on the feeding and watering routine for

the crew and obviously the welfare of the cattle. Straw, hay bedding and even large quantities of sawdust or shavings can block bilge filters and pumps on some ships, thereby slowing the drainage of water from the surface of pen floors. An example of the effects of slow-draining waste water is shown in Figure 8.

Figure 8: Cattle in slow-draining effluent following deck washing



Source: Lynn Simpson

In addition, an exporter and a shipboard veterinarian remarked that the listing of the ship may damage the ships' engines as engine lubricants can be displaced while the ship is listing. This can complicate decision making around the washing of pens. Some ships are not designed for the washing of cattle pens and bedding material is removed by wheelbarrow and shovel. Whilst very primitive, this method has one good aspect in that it reduces demands on the ventilation system to remove excess water from the pen floor and moisture from the hold of the deck.

On some ships, the crew will remove pen kick boards temporarily or permanently while at sea so that bedding slurry can move from livestock pens out into alleyways where it can be more easily collected and removed. Kickboards are found on all ships as part of work-safe practices. As this slurry is removed from the alleyways and the pen edges, the depth of the pad inside the pen will not increase as quickly if slurry is retained by kick boards. The provision of pen kick boards is for the safety of crew and livestock, so their removal should be firstly considered in this context. According to ship stockpersons and shipboard veterinarians the provision of kick boards are a regulation from the Australian Maritime and Safety Authority (AMSA). As these kick boards can be up to 15cm high, they can have an important effect on drainage after washing. Also, in some instances, kick boards can block pen air movement, decreasing the drying affect on bedding material and decreasing pen ventilation.

3.5.9 Ammonia and other atmospheric gases

The incidence and control of atmospheric gases (in particular ammonia) during the intensive management of livestock has been extensively researched and managed in a wide range of livestock industries. Recent research (Phillips, 2007; Costa et al, 2003) showed that high

atmospheric ammonia levels irritate the eyes and respiratory passages, but that this effect is temporary. Very high levels of ammonia exacerbate heat stress and in cattle where the organisms of the Bovine Respiratory Disease complex are present, these levels of ammonia create conditions which are conducive to pneumonia. Costa et al (2003) states the critical value of atmospheric ammonia for cattle, sheep and goats undergoing sea transport and in feedlots in Australia should be set at 25 ppm, in line with the Australian Time Weighted Average for humans.

It is important to recognise the observations of experienced stockpersons and veterinarians trained to assess animal health that whilst ammonia is not a major issue in the welfare of cattle, it is according to shipboard veterinarians and stockpersons experienced with sheep exports, an issue of concern for sheep on ships. A common remark by industry is that where crews are well trained and experienced, ship stockpersons and veterinarians have regular meetings with the captain, first officer and bosun/crew about current bedding management practices so as to minimise any ammonia problems.

The strategic use of portable fans in identified pens where pen air turnover is low will help to cool livestock, reduce the moisture content of bedding and disperse ammonia.

Odour and ammonia emission from a livestock vessel pen are affected by the following factors:

- The moisture content of the pad or bedding;
- Stocking density;
- Ventilation (pen air turnover);
- The pH of the pad;
- Diet; and
- Pad temperature.

In summary, a number of ammonia reduction measures are available, including:

- Dietary manipulation;
- Bedding additives;
- Feed additives; and
- Other management procedures such as the removal or replacement of bedding or the washing of cattle pens.

4 Review of available literature

This study incorporated a review of available literature in relation to the management of bedding for cattle and sheep in a variety of situations. A summary of the current literature relating to livestock bedding is given in Appendix 12.2. In reviewing the available literature from the intensive raising of dairy and beef cattle and also from the horse industry, care needs to be exercised in extrapolating the results of bedding studies which are carried out under different environmental conditions to those experienced on livestock ships. The principal differences being the relatively high wet bulb temperatures experienced on ships, the comparatively small amount of bedding available for livestock on ships, and the ships' physical limitations to storing and disposing of livestock effluent.

Having pointed out these differences, there are common issues which makes the reference to other bedding studies valid and useful. These commonalities included a hard, unyielding pen floor, high stocking densities and relative little movement by livestock for an extended period of time.

Choice of bedding material depends on a number of factors, including animal health and welfare, hygiene, and manure management considerations. There have been numerous studies undertaken in Australia and overseas addressing bedding management for livestock.

In summary, the review of available literature indicates that livestock generally prefer not to lie on hard or wet surfaces. Hard and sometimes abrasive floors, particularly if they are slippery, covered in faecal matter and wet from urine present a risk of injury and this risk is more pronounced for certain classes of livestock. Straw is probably the oldest form of bedding used in the intensive animal industries and is highly respected for its overall absorbency, comfort and capacity to reduce leg injuries. The intensive livestock industries still use straw where it is cost effective and it can be efficiently disposed of, however the trend has been towards using sawdust, wood shavings, chopped paper, sand, shredded paper and artificial mats made of polypropylene derivatives.

5 Evaluation of bedding materials

5.1 Factors affecting selection of bedding material

The most important factor for consideration in selecting a bedding material is its level of absorbency.

Other factors to be considered include:

- Availability;
- Density and comfort structure (compressibility);
- Cost;
- Labour requirements;
- Flammability;

- Dust and other contaminants;
- Disposal and biodegradability; and
- Consistency of quality.

Each of these factors is considered separately in the following sections:

5.1.1 Absorbency

The amount of water that a material can retain at the point of saturation is defined as the absorbency of bedding material.

The absorbency of bedding material can be estimated using a method developed by Kains et al (1998) which is included in Appendix 12.3.

The absorbencies of 14 materials from several literature sources are shown in Table 4. These figures are a rough guide only, as absorbency of any material varies due to differences in initial moisture content and the degree of grinding, which alters the particle surface area.

Management of Bedding during the Livestock Export Process

Table 4: Absorbency of different bedding materials

Material	Form	Absorbency Factor ^a		
		Kains et al (1998) ^b	Voyles et al (year) ^b	S.D.S.U. (year) ^{bc *1}
Wheat straw	Baled	2.1		
	Chopped	2.1		2.1
Barley straw	Baled	2.0		
	Chopped	2.0		
Oat straw	Baled	2.5	2.86 (not specified if baled or chopped)	
	Chopped	2.4		2.4
Hay (unspecified type)	Baled	3.0		
	Chopped	3.0		3.0
Sawdust	Hardwood	1.5		1.5
	Softwood ²	2.5		2.5
Shavings	Hardwood ³	1.5		
	Softwood	2.0		2.0
Corn stover		2.5	2.7	2.5
Sand		0.3		
Peat moss		10.0		
Shredded paper			2.08	
Triticale straw			1.97	
Shredded lumber			1.15	
Peanut shells				2.5
Cottonseed hulls				2.5

a: Absorbency Factor = (weight after soaking – original weight) ÷ original weight

b: Weight of water held per unit weight of dry material; assumes initial moisture content of bedding is less than 10%

c: College of Agriculture & Biological Sciences / South Dakota State University / USDA – Extension Extra 1007, Updated April 2002

² Softwood is wood coming from coniferous trees.

³ Hardwood is wood coming from broad-leaved dicotyledonous trees.

The important points shown in Table 4 are:

- Peat moss and hay have a relatively high absorbency, however these materials are not readily available in Australia at a cost suitable for use as bedding material;
- Softwood sawdust and shavings have a greater absorbency than hardwood sawdust and shavings; and
- The absorbency of peanut shells and cottonseed hulls is comparable to that of softwood sawdust and shavings.

Some ships are capable of carrying an amount of straw for bedding, which due to its particle size, most often has to be removed from the pens by shovel and wheelbarrow. Depending on the nature and quality of the straw, its absorbency is thought to be comparable to kiln dried softwood shavings, however straw is recognised as offering a more comfortable bedding material for cattle.

In general terms, the more absorbent a bedding material is, the less bedding required, which means less handling time and less waste to be disposed of after it becomes saturated.

5.1.2 Availability

The year round availability of suitable bedding material is an important consideration when selecting an appropriate bedding material. This is determined to a significant extent by the port of loading. For example, sawdust is not readily available in Darwin or Townsville, whereas it is readily available in Fremantle and Portland due to the proximity of timber mills to those ports.

Availability may be affected by other economic factors. In recent times during high fuel prices, timber mills have burnt sawdust and shavings to save on their fuel costs associated with transportation, which has reduced the availability of sawdust and shavings at port.

At present, when the preferred bedding is not available in the quantity required, the exporter is forced to load a less preferred product.

5.1.3 Density and comfort structure (compressibility)

There are several considerations in relation to the density of a bedding material:

- The cost of delivery along side ship, the cost of loading onto ship and the space required for storage on board. Straw, at one extreme, while relatively absorbent is bulky making it expensive to handle and difficult to store on some ships. Materials with low starting moisture content will generally be easier to handle as they are more easily compressed and have a low volume to weight ratio.
- The structure of the bedding material after it is wet. For example, shredded paper although very absorbent tends to become a solid mat when wet and can be difficult to remove (Lammer et al, 2007). Alternatively, wood shavings retain their structure after wet, but are less absorbent. Mixing of materials of different absorbency and density may provide a practical solution.

- The level of comfort for the animals. Industry has commented that the surface area of the bedding particles appears to be an integral factor in determining the comfort of the bedding. The larger the surface area of the material, seemingly the greater the level of traction for livestock and the greater the preference for lying down.

5.1.4 Cost

Apart from the direct cost of the bedding material, the cost of delivery to the loading port and its physical loading onto the ship can be significant. Typical long haul shipment bedding costs estimated from industry consultation are in the order of \$0.02 to \$0.03 per kilogram live weight of cattle. It is difficult to estimate this cost as most shipments vary in their cargo and often carry sheep, beef cattle and dairy cattle and use different amounts of bedding depending on the class of livestock, the ship environment, voyage duration and time of year. Allowing for this lack of accuracy, the combined cost of bedding is not insignificant when the cost of cattle is in the order of \$1.70 FAS (free along side). One exporter budgets on \$6-8 per head for high value dairy cattle exported to the Middle East and China. This exporter uses green waste direct from the milling process at a cost of \$570 per tonne FAS Portland and uses regular deck washings to maintain a high level of hygiene throughout the voyage.

There appears to be two types of bedding readily available that have low starting moisture content. One Victorian product is a blend of kiln-dried pine sawdust and shavings. The supplier says the shavings are included to improve the materials absorbency. This product is supplied in biodegradable bags with an average weight of 15 kilograms and stacked at 48 bags to the pallet. The current price is around \$350 to \$420 per tonne at Portland. The supplier was not able to be precise about starting moisture content but estimates the moisture level to be around 5%.

The second readily available bedding material is kiln-dried pine shavings with a reputed starting moisture content of around 5%. It is supplied in compressed, transparent plastic bags weighing on average 20 kilograms. According to the supplier, this material will expand from around 120 litres to a volume near 240 litres after the bag is split. The current price of this product is around \$680 per tonne at Fremantle. A photograph of this product as supplied on pallets is shown in Figure 9.

Figure 9: Kiln-dried pine shavings as supplied on pallet



Other bedding material available includes a sawdust material, based on hardwood or pine with a moisture content estimated to be around 30%. This product is supplied in 20-kilogram plastic bags and some is marketed as garden mulch. This product is priced at around \$230 per tonne alongside the ship in Fremantle. Though less expensive to purchase, it has relatively poor absorbency and is reported by industry to be only useful to reduce slippage and abrasions.

There also appears to be exporter resistance to buying a product with a higher cost per tonne even though the product may offer superior absorbency and handling qualities. In some cases, exporters are purchasing and handling a lot of moisture in the product before it is applied to livestock pens.

5.1.5 Labour requirements

Handling chopped or baled straw is relatively labour intensive. Both sawdust and shavings are packed in easy-to-handle plastic bags once on the ship. Therefore, straw has not generally been used for bedding in recent times and has been replaced in the main by sawdust and shavings. One exporter contacted uses straw bedding for particular lines of heavy and pregnant cattle. Some shavings are compressed in plastic bags and are stacked on pallets. Exporters say that the pallets and bags of shavings are much easier to handle. As the shavings are supplied on pallets and most sawdust is supplied in loose bags, keeping an inventory of available bedding during the voyage is reported to be easier when using shavings.

5.1.6 Flammability

No data was available to compare the flammability of different bedding types, however industry sources say that kiln dried wood shavings are more flammable than sawdust which is, in turn, more flammable than straw. The risk of bedding igniting on ships is highest while stored awaiting use (ref). From industry comment, it seems it is difficult to keep bedding dry while stored on most ships, so the risk of fire from stored bedding would seem to be minimal. Bedding is normally stored on open decks protected by tarpaulins or only in the plastic bags in which it is sold. Moisture from rain and sea spray is likely to enter any broken bags. Given some materials have high starting moisture content, the risk of spontaneous combustion would be greatest if such material were stored for a prolonged period in a warm, dry environment.

5.1.7 Dust and other contaminants

The high concentration of airborne particles in bedding and the negative properties of these pollutants on animal health, welfare and productivity can be a concern for livestock. Materials should be dust and mould free to minimise the risk of lung and breathing problems for crew and livestock. The material must be free of chemical contaminants.

According to Kains et al (1998), chemical contaminants are difficult to identify and their presence depends upon the original material and processing received. Lead, asbestos, volatile organic chemicals and wood preservatives are a few of the possible contaminants. Historically newspaper ink contained lead and other compounds, posing a threat to animal health when it was used as bedding. Many newspapers have changed to a soybean or other edible oil-based ink that does not pose a threat to livestock.

No major problems with dust or contaminants in bedding material were revealed, except by one exporter who buys only dust-extracted sawdust as a precautionary measure. Excessive dust in the

bedding material is thought to increase the incidence of eye problems during the voyage. Eye problems from the pad only occurred where crew were careless in handling hoses and splashed slurry into the faces of cattle. This is easily rectified. There was some concern that very dry and highly absorbent bedding can float into the exhaust vents if placed in pens with high pen air turnover. How much bedding was wasted this way was not apparent but is thought to be a relatively minor issue.

The natural sheep pad can cause dust problems if it is very dry and can cause eye irritation possibly leading to eye infections. Deck ventilation (natural and mechanical) is a major determinant of how much dust is a problem from the sheep pad.

5.1.8 Disposal and biodegradability

Whatever bedding material is used, it must be able to be effectively removed from ship's pens. Some ships are better able than others to wash, drain and pump bedding from decks to effluent storage tanks or directly into the sea. Some ships have poor deck drainage, low volume scuppers (drain holes) and low capacity bilge filters and pumps. In general terms, the longer the fibre of the bedding, the more difficult it is for ships to wash and dispose of used bedding material. Straw is problematical, while sawdust and shavings are less arduous.

Where the washing of pens is not possible, bedding material must be removed by shovel and barrow.

It is important that bedding material is biodegradable and will not cause harm to the ocean environment when properly dispersed at sea. The relative biodegradability is highest with straw, followed by sawdust, with wood shavings having the lowest biodegradability. Any non-organic contaminants in the bedding may compromise the biodegradability of bedding material.

5.1.9 Consistency of quality

In consulting with the suppliers of different bedding materials, there was no evidence that these materials are sold under a system of quality assurance. Assuming there is no distortion in the supply and demand for bedding material, which appears not to be the case, the industry would ideally insist that the suppliers of bedding provide a physical and chemical analysis of the material to provide proof of quality so that its suitability for use as bedding can be determined. Information provided would include physical composition, processing methods, moisture content/absorbency, level of dust/mould and physical and chemical contaminants. This would allow the industry to purchase bedding not only on weight or volume but also on these other qualities with the level of absorbency being the most important.

5.1.10 Other materials

A Welsh study, The Woodchip for Livestock Bedding Project (2008) evaluated the potential of woodchip as an alternative bedding material to straw for use indoors with sheep and beef cattle. Their demonstrations found a starting moisture content of less than 30% is critical to maximise the absorbency of woodchip and that woodchip was a good alternative to straw.

5.1.11 Moisture content

Bedding material that is supplied damp is only useful for anti-slip purposes and to assist in reducing feet and leg cuts and abrasions as cattle lie down and stand. Bedding material that is supplied damp will release heat and moisture into the air of the deck hold after it is laid on deck. Using bedding with initial moisture content above around 5% has limited benefits if absorbency is to be maximized. Bedding material supplied to exporters can have moisture levels of around 30% (often sold as garden mulch). According to a number of ship stockpersons and veterinarians this material is often thrown overboard without being used as it has limited value.

A considerable proportion of the sawdust and wood shavings used by the Australian live export industry have a starting moisture content estimated to be around 30%. An example is shown in Figure 10. Using bedding with such high starting moisture content negates much of the absorbency benefits.

Figure 10: Relatively moist, freshly laid hardwood sawdust



There are kiln-dried bedding materials available in Australia.

Figure 11 shows softwood shavings that have been recently laid on clean pen floor.

Figure 11: Relatively dry, freshly laid shavings



5.1.12 Chemical and physical characteristics

Misselbrook and Powell (2005) conducted a study which assessed at a laboratory scale, the relative importance of the chemical characteristics and physical characteristics of five different bedding materials – chopped wheat straw, sand, pine shavings, chopped newspaper, chopped corn stalks, and recycled manure solids on ammonia emissions from dairy cattle urine.

When beddings were soaked in urine to their absorbance capacities, ammonia emissions over 48 hours were analysed against the varying chemical and physical characteristics. Differences in the chemical characteristics of the beddings did not explain differences in emission. The physical characteristics of bedding materials were of more significance, as ammonia emissions increased linearly with absorbance capacity and decreased as the bulk density of the packed beddings increased.

This study supports shipboard observations where the higher the moisture level of the used bedding, the greater the smell of ammonia, and that where the manure pad is relative dry and firm, the release of ammonia is minimised. The dryness and physical consistency of the pad are affected by the shipboard wet bulb temperature, volume of urine, water spillage and the nature of the bedding material being used.

5.2 Quantity of bedding required

Several stockpersons and veterinarians who are engaged on long haul voyages believe there is never enough bedding carried on ships. It would seem that the cost of the bedding material and available dry storage space on ships are the main reasons for this opinion. In addition, the capacity of the vessel's drainage and pumping system to cope with large volumes of effluent limits the quantity of bedding used so that lengthy washdowns and /or breakdowns are avoided, minimising the risk to the welfare of cattle due to deprivation of feed and water. Often on the fully enclosed ships, bedding material is stored in livestock pens, thereby taking up valuable pen area.

According to Crafter et al. (2006), who examined soft flooring options for saleyards, there are no Australian data on the likely volumetric requirements for the bedding material needed to absorb moisture from the urine and faeces voided by cattle housed within buildings. However in North America, the Mid West Planning Service does provide such recommendations (Livestock Waste Facilities Handbook, 1993 as cited by Crafter et al, 2006). These are shown in Table 5, along with the water absorption capacity and the typical bulk density of these materials (Potts and Casey, 1999 as cited by Crafter et al, 2006). Requirements are expressed as kilograms of bedding material per day per tonne of live weight.

Table 5: Bulk density, absorption and requirements for various types of bedding material

Bedding material	Bulk density	Water absorption	Requirements
Sawdust (pine)	225 kg/m ³	2.5 kg/kg	4.1 kg/d/t LWT
Shavings (pine)	150 kg/m ³	2.0 kg/kg	3.1 kg/d/t LWT
Straw (barley)	40 kg/m ³	2.2 kg/kg	11 kg/d/t LWT

Source: Crafter, I., White, F., Carey, B. and Shephard, R. (2006) Review of soft flooring options for saleyards – southern beef zone. *Project Report AHW.158*, Meat and Livestock Australia, Sydney.

The relatively low requirement for sawdust and shavings compared to straw illustrates the benefits of using these materials as livestock bedding. This indicates that given an identical starting moisture level, less shavings are required than sawdust on the basis of absorbency alone.

5.3 Estimating bedding cost

According to the majority of stockpersons and shipboard veterinarians, the minimum amount of bedding to be used prior to loading and on each change is around 60 kilograms (approximately 0.36 m³ based on kiln-dried wood shavings) per 15 m² of pen area. This is equivalent to around 4 tonnes or 24 m³ per 1,000 m² of pen area. This is based on using kiln-dried (less than 5% moisture) softwood sawdust, shavings or a blend of sawdust and shavings. In practice, this minimum amount of bedding material is not always applied and this appears to be chiefly for economic reasons.

Assuming the application rate of 4 tonnes or 24 m³ per 1000m² of pen area of kiln dried pine shavings or sawdust is used at each bedding change, the cost can be typically calculated as shown in Table 6.

Table 6: Bedding cost calculation – long haul voyage

Assumed deck area	5,000 m ²
Stock numbers	3,225 head
Average weight per head	400kg
Stocking density (minimum as per ASEL)	1.55 m ² per head
Total Live Weight	1,290 tonne
Voyage duration	16 days
Timing of fresh bedding applications	Days 0, 7, 11 and 15
Bedding material	Kiln-dried pine shavings or sawdust
Quantity of bedding material required*	80 tonne
Depth of bedding material after each application	2.4 cm
Loaded cost of bedding material	\$700 per tonne
Cost of bedding – Total	\$56,000
Cost of bedding – per m ²	\$11.20
Cost of bedding – per kg	\$0.04
Cost of bedding – per head	\$17.40

* Based on 4 tonnes of bedding material per 1,000m² over four applications

Using the data shown in Table 2 and based on the typical scenario as outlined above, the daily production of manure (faeces and urine) is in the order of 64.5 tonne (64,500 L) to 96.8 tonne (96,750 L) for 3,225 head of cattle. This is equivalent to 1,032 tonne (1,032,000 L) to 1,548 tonne (1,548,000 L) over the entire voyage. This amount of manure would, if left untouched, rise off the pen floor to a height of 20 to 30 cm.

Interestingly, the amount of bedding required as calculated in Table 2, is equivalent to 3.9 kilograms of bedding material per day per tonne live weight, which is comparable to the requirements quoted by Crafter et al (2006) for sawdust as shown in Table 5.

In simple terms, this cost of bedding material equates to an equivalent loss of value of around 66 head through death or rejection at discharge (or a 2.0% voyage mortality) assuming an onboard value of \$850.00 per head. Based on current mortality rates, this cost of bedding is not likely to be recouped by a reduction in mortality alone. In contrast to the Australian domestic live cattle market, where lame cattle are rejected from sale, for most long haul overseas markets, if the cattle can walk off the ship even if severely lame, there is no price penalty imposed by the buyer on the exporter. The subsequent losses after discharge appear to be worn by the overseas buyer alone.

Whilst cost is a factor in the quantity of bedding loaded, it is of lesser importance than on-board bedding management. The belief that more bedding would provide better welfare can only hold true if the time taken for washdowns and drainage is brief. Efficient drainage and effluent pumping systems are absolutely critical components of the management of the welfare of on-board stock.

When pumps become blocked or fail, time is wasted in repairing or replacing them. Effluent washes around the decks for long periods and stock go without feed and water until the effluent is removed.

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On a 10,000 head ship, the washdown of all pens can take up to 10 to 12 hours to complete and as a result, stock can be without feed and water for a long period.

Table 7 illustrates the increasing or decreasing cost as a higher or a lower application rate of bedding material is used.

Table 7: Estimated costs varying amount of bedding material

Rate of Application (t/1,000m ²)	Rate of Application (m ³ /1,000m ²)	Quantity loaded per voyage (t)	Quantity loaded per voyage (m ³)	Bedding material cost per voyage*	Bedding material cost per head	Bedding material cost per kg LW	Equivalent saving in mortality (head per voyage)
2.7	16	54	320	\$37,800	\$11.70	\$0.029	45
4.0	24	80	480	\$56,000	\$17.40	\$0.044	66
5.3	32	106	640	\$74,200	\$23.00	\$0.058	88

* Assumes bedding material applied on four occasions at the same rate.

If the cost of kiln-dried and suitable bedding material was to increase or decrease, the effect on costs is shown in Table 8. Obviously, the lower the price per tonne of material, the lower the cost per head and kilogram live weight.

Table 8: Estimated costs varying price of bedding material

Cost of loaded bedding material (\$/tonne)	Bedding material cost per voyage*	Bedding material cost per head	Bedding material cost per kg LW	Equivalent saving in mortality (head per voyage)
\$300	\$24,000	\$7.50	\$0.019	29
\$400	\$32,000	\$9.90	\$0.026	38
\$500	\$40,000	\$12.40	\$0.031	47
\$600	\$48,000	\$14.90	\$0.037	57
\$700	\$56,000	\$17.40	\$0.044	66
\$800	\$64,000	\$19.80	\$0.050	76
\$900	\$72,000	\$22.30	\$0.056	85

* Assumes a constant rate of application of 4.0 tonne/1,000 m².

Assuming the average live weight of the cattle loaded is 450 kg (rather than 400kg) at a lower stocking density of 1.74 m² per head, then the total loaded number is 2,873 head, which is a total loaded live weight of 1,293,000 kg. The bedding cost remains at \$11.20 per m² and \$0.04 per kg, while the cost per head increases to \$19.50 per head.

6 Minimising Risks and Improving Welfare

6.1 Cattle bedding management

The advantages and disadvantages of using appropriate bedding material for cattle on ships based on industry consultation are shown in Table 9.

Table 9: Advantages and disadvantages of using bedding material in cattle pens

Advantages	Disadvantages
<ul style="list-style-type: none"> • Reduces slippage • Minimises abrasions • Increases comfort during standing and lying • Improves hygiene • Reduces ammonia levels • Minimises feet and leg injuries • Minimises lameness • Decreases air humidity and wet bulb temperature • Improves presentation at discharge • Reduces time spent lying in wet faeces • Reduces amount of faecal matter adhering to coat • Improves public perceptions of industry 	<ul style="list-style-type: none"> • Cost not directly recoverable in terms of decreased mortality • Takes up valuable space on ship • Increases demands on drainage and pumps • Increases labour time to handle and apply • Increases labour required to handle and remove

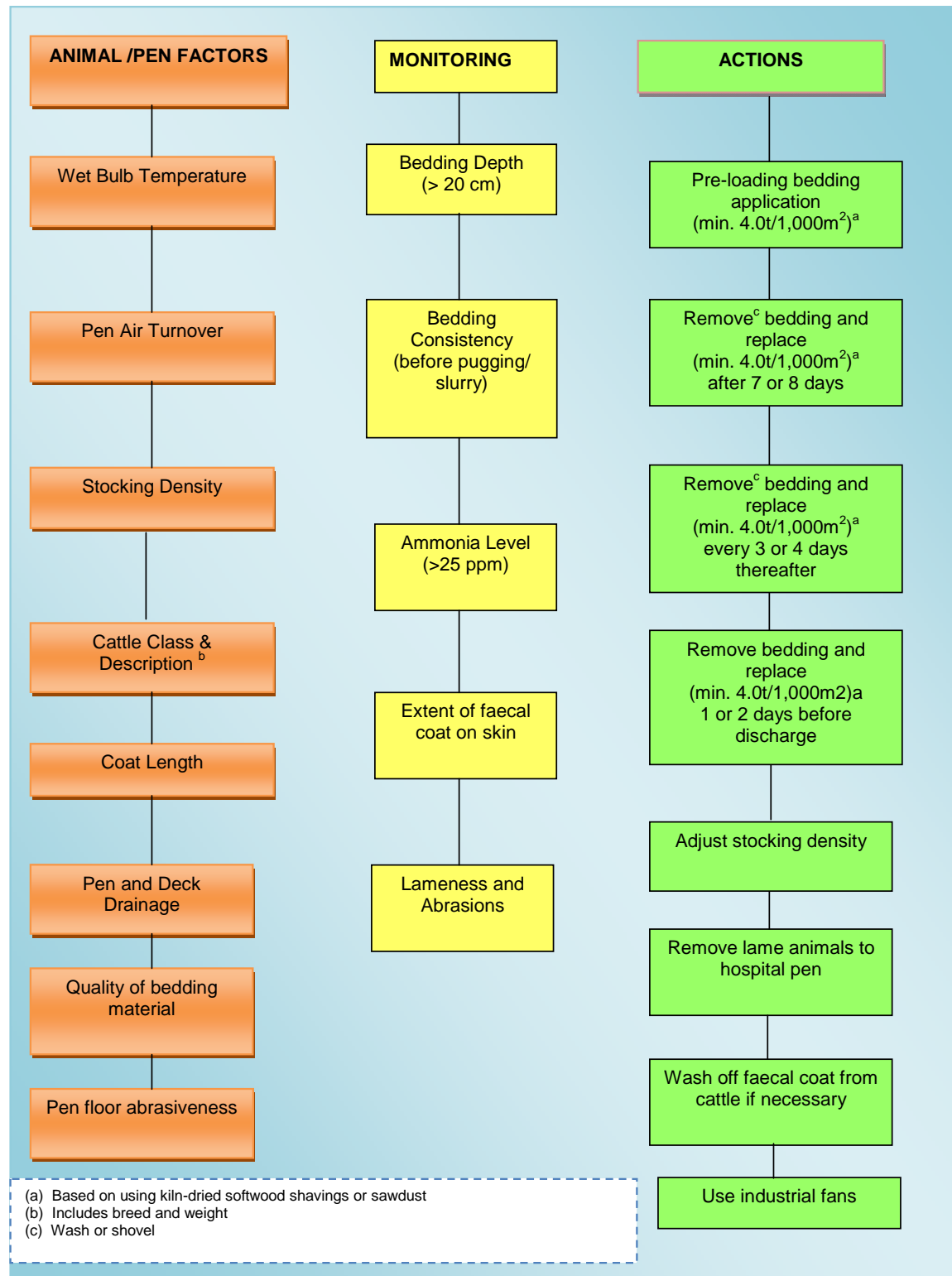
The preference of cattle for clean dry bedding on the decks of ships is a common observation by ship stockpersons and shipboard veterinarians. Cattle of most classes will immediately lie down on fresh bedding following pen washing. The fresh bedding material will generally only stay dry for around two hours; however according to industry comment, this additional lying time can markedly improve the stamina of cattle during a voyage. It was further observed that dairy breeds showed the highest preference for clean, dry bedding, followed by *Bos taurus* breeds and then *Bos indicus* breeds. The heavier the animal, the greater is the apparent preference for bedding. Heavy cattle are often less agile than lighter cattle and because of their relatively high mass can have an increased incidence of leg and feet abrasions.

It was stressed by a number of shipboard veterinarians and stockpersons that from solely an animal health point of view, timely deck washings are more important than the supply of fresh bedding following washes. Washing and removing soiled bedding and at the same time washing the legs of cattle improves general hygiene and makes the diagnosis of leg injuries easier. Often if minor injuries are missed because they are covered in faecal matter, the injury can become infected, more difficult and expensive to treat and possibly lead to severe lameness.

6.2 Checklist

Figure 12 illustrates what animal/pen factors, monitoring and actions are important in the management of cattle bedding. Issues under each heading serve as a bedding management checklist prior to and during a voyage. This illustration applies to long haul cattle voyages and to vulnerable cattle on short haul voyages.

Figure 12: Cattle bedding management checklist on ship



Specific recommendations for best practice in relation to cattle bedding management for both long haul and short haul trips are outlined below.

6.3 Long haul voyages – recommended best practice

6.3.1 Pre-loading

- Avoid loading cattle with relatively soft feet because of environmental reasons and cattle that are showing signs of lameness or tenderness of the feet. Sometimes, cattle can be assembled and prepared for export on hard surfaces that cause the feet to become tender.
- It is important to implement a feed and water curfew on cattle prior to loading to reduce the amount of faeces and urine produced during the loading process. A curfew will extend the life of the initial bedding material. Industry was not clear on the duration of feed and water curfews, however standard practice seems to be an overnight curfew. Curfew duration should be balanced against maintaining optimal rumen health and appetite. The manure pad and associated bedding material is normally never as dry and firm as it is before the first pen wash.
- To minimise bedding material being wasted through cattle kicking it outside the pen, the bedding material laid prior to loading should be laid in a line or a heap in the middle of each pen and not spread around the pen.
- If available, bedding material should always be laid prior to loading. Bedding material can be difficult and expensive to land at some northern and relatively isolated ports such as Port Hedland, Wyndham and Karumba.
- Depending on the nature of the ship's ventilation, it may be necessary to minimise the movement of bedding particles around the hold of the deck, by delaying the laying of bedding material as late as possible before loading. Bedding material in the line of supply vents is often displaced while still dry to other parts of the deck floor or other parts of the hold.

6.3.2 Pen washing and bedding replacement

- The regular washing of pens is more important than applying fresh bedding. Regular washing removes faecal matter and will help the crew to locate feet and leg wounds. Washing and the subsequent temporary cooling effect depending on the deck wet bulb temperature also improves cattle appetites. One exporter commented that on extended long haul voyages of up to 30 days, on a continual schedule where dairy heifers have been washed every second day with no bedding used, the result was low rates of injuries and mortalities during each voyage .
- According to industry reports, washing the decks will provide a temporary respite for around an hour or two when the wet bulb temperature may decrease by as much as 2 to 3°C. This assumes the ship's ventilation system is working normally. Gaughan et al (2005) states that at all times, ensure there is normal air movement for the pen or deck, that is, if the ventilation system fails do not wet cattle.

- The first pen wash is a relatively quick wash of the cattle, i.e. on lower legs only. For most cattle, washing is a novel experience; however stockpersons have remarked that most cattle quickly learn to enjoy the experience. As cattle become familiar with washing, gates between pens can be opened: creating more space for cattle on the lower end of the social pecking order and allowing cattle to walk some short distance during the day. This small amount of walking helps to relieve the tedium experienced by cattle on long haul voyages.
- For all voyages in excess of 10 days duration, bedding should be provided for cattle prior to loading. Before the pre-loading bedding becomes deep and moist (to the point at which cattle are pugging the manure pad), it should be washed out and replaced. Typically this is 7 to 8 days into a Middle East voyage, which coincides with proximity to the equator and an associated rise in ambient wet bulb temperature. After this initial wash and bedding replacement, subsequent washes with bedding replacement should be timed to happen every 3 to 4 days. Fresh bedding should be laid around 1 to 2 days prior to discharge after a final pen wash.
- Because of the pooling of water on the deck floor after washing and the resulting high relative humidity after washing, the bedding used at the suggested minimum application rate will not remain dry for more than two or three hours as faeces and urine accumulate in the pen.
- After 7 to 8 days, the bedding may be up to 15 to 20 cm deep depending on the curfew prior to loading and the adaptation of the cattle to the shipboard fodder. If the wet bulb temperature rises, the pad will increase its moisture content, soften and if left will become a deep slurry rather than a pad. The objective is to prevent cattle pugging the bedding by keeping the pad as dry as possible. Routine spot shovelling of moist bedding can extend the interval between wash downs.
- The number of pen washings is generally only limited by the time available to the ship's crew and the ship's level of automation of feeding and watering. Automated feeding and watering systems will lessen the risk of cattle being off feed and water due to the crew being busy with pen washing, however often cattle will need to be moved back into their pen from an adjacent pen after washing. The first wash can be extremely stressful to cattle and effort should be made to not directly wet the cattle by using low pressure and not intentionally wetting above the lower legs of cattle.
- Replacement bedding should not be thrown into washed pens until the floor surface is relatively dry. This will depend on the ventilation efficacy in the particular pen and the prevailing ambient wet bulb temperature, as well as the ability of the crew to manually scrape the pen floor free of surface water.
- Normally after the first two washes, most cattle are at ease with the washing of pens with some cattle behaving as if they enjoy the experience. Dairy cattle and some *Bos indicus* cattle apparently adjust to the washing experience more quickly than other cattle.
- Some stockpersons have a preference for using freshwater for washing or alternatively using saltwater and then following up with rinsing the deck with fresh water. The perceived benefits of using freshwater include less salt retained on cattle hair and less salt

penetration of ship steel infrastructure. Most believe that washing with salt water alone is acceptable; in fact some believe the salt water assists in the healing of cuts and abrasions.

- A number of stockpersons reported feeding a small amount of chaff to cattle following washing to reinforce to the cattle the positive experience of pen washing and to help stimulate appetite. This appears to be a particularly useful exercise if cattle are heat stressed and require frequent washing, such as daily washing. Supplementing the normal shipboard fodder (pellets) with chaff will also act to slow down the rate of passage of fodder through the digestive system and often help to firm up manure. This helps to create drier, firmer bedding and therefore assists overall bedding management.
- Regular pen washings, even daily washing, do not seem to soften cattle hooves; rather regular washing has the significant advantage of allowing the crew to see any cuts and abrasions on feet and legs more easily. The sooner cuts and abrasions are detected, the earlier an animal can be treated and recover.
- On some ships or on some decks, pen washing is not possible due to poor drainage or water draining from higher decks onto livestock on decks below. In this case, if bedding removal is required during the voyage, this can be done by temporarily relocating cattle into other pens and using a shovel and barrow. Care needs to be taken that this movement of cattle does not cause excessive stress on the cattle. Shovelling soiled bedding is slow and labour intensive compared to washing; however it has the advantage of not adding moisture to the deck floor or air of the deck hold.

6.3.3 Type of bedding material recommended

The consensus from industry is that kiln-dried shavings provide optimal absorbency, meaning less of this material is required than other less absorbent materials. This material is also effective in reducing slippage and abrasions with the pen floor. It is the most costly material on a per tonne basis; however it is supplied in compressed bales, which make handling relatively less expensive and more user friendly than other materials.

6.3.4 Quantities of bedding required

- The ASEL states that cattle and buffalo exported on voyages of ten (10) days or more must be provided with sawdust, rice hulls or similar material to be used exclusively for bedding at a rate of at least seven (7) tonnes or twenty-five (25) cubic metres for every 1000 square metres of cattle pen space. This does not apply to cattle and buffalo loaded from Brisbane or a port north of latitude 26 degrees south and exported to Southeast Asia or Japan.
- Bedding on the pen floor will help to dry out the floor surface and remove some moisture from the atmosphere immediately after it is laid. Freshly laid kiln-dried bedding at the recommended minimum quantity (see below) following washing will keep the manure and urine on the deck floor firm for two to three hours only.
- The minimum recommended amount of bedding used on each change is around 60 kilograms (approximately 0.36 m³) for every 15 m² of pen area. This is equivalent to around 4 tonne or 24 m³ per 1,000 m² of pen area. This amount of material will have an average floor depth of 2.4 cm. This is based on using kiln-dried (less than 5% moisture) pine sawdust, shavings or a blend of sawdust and shavings. Significantly higher application

rates would be required for other much less absorbent materials if the same degree of absorbency is to be achieved.

- The use of a minimum of 4 tonne of material per 1,000 m² of pen space for each bedding change is not always possible and often the required amount of bedding is not loaded on the ship. The reasons may be related to cost, availability, storage space on the ship and importantly ability to dispose of pen effluent in a timely manner.
- Some stockpersons and veterinarians would ideally like to see the quantity of bedding laid prior to loading as much higher, up to 120 kilograms (0.72 m³) for every 15 m² of pen area or double the minimum amount described above. These quantities are based on using a kiln-dried product. Cost, time and availability are likely to constrain using this much bedding at loading for all classes of livestock, however industry observation is that the first bedding laid is the most important for most voyages. Some stockpersons believe the use of this additional bedding at loading would extend the time to first wash by at least two days, which may save on bedding material later in the voyage. On some ships the amount of bedding used is constrained by the efficiency of the deck drainage and bilge pumps to remove the washed material. The more bedding used, the longer the washing and drainage will take which can impact on the feeding and watering times for cattle.
- Consideration should be given to increasing the amount of bedding (kiln-dried) provided to dairy cattle and other high value animals, i.e. in the order of 5 to 6 tonnes per 1,000 m². However as with other classes of cattle, the appropriate stocking density and regular washing is generally more critical than the provision of bedding.
- Sufficient bedding should be loaded to allow for a bedding change at around 1-2 days prior to discharge. The provision of new bedding prior to discharge is largely for cosmetic reasons for the buyer and inspectors at the country of destination. In some countries this improved presentation is an essential aspect of the entire export process.

6.3.5 Timing of washing

- The most appropriate time to wash pens is before rather than when it is due. This timing is based on the visual assessment of the bedding consistency, the bedding depth (quantity) and sometimes the smell of ammonia. If the ammonia level is high (over 25 ppm), this means the bedding has become too moist and is overdue for removal and changing.
- Bedding consistency and depth are the most important assessments with cattle; bedding should be washed out and replaced before it becomes sloppy and deep and adheres to the legs and lower parts of the body of cattle. In practice, this is not always possible, so the aim is to minimise the amount of pugging, fluid manure and the resulting adhesion of manure to the coat of cattle. A deeper pad will retain heat and moisture and can turn to slurry very quickly as the deck wet bulb temperature increases. Figure 13 shows a cattle manure pad that has become too sloppy and too deep and is at risk of deteriorating further if deck wet bulb temperature was to increase.

Figure 13: Excessively sloppy and deep cattle manure pad



Source: Grahame Best

- If the time is available, most ships can wash and dispose of any quantity of soiled bedding; however it is more important to limit the depth of bedding in the event of a rise in its moisture level. With softening, cattle will start pugging the bedding, finding it difficult and uncomfortable to stand up, walk and lie down. As cattle lie down on such bedding, they gradually become more covered in wet manure.
- If cattle are under stress from heat, they should be washed as often as needed to relieve the obvious signs of stress. Replacing the bedding is less important and less practical if cattle are for example being washed on a daily basis. Washing cattle on a regular basis occupies a lot of time and priority consideration should be assigned to the ship's schedule of feeding, watering and hospital pen duties. The larger ships can take up to three days to wash all cattle decks under a normal schedule.

6.3.6 Other uses for bedding material

- In addition to providing bedding material to pens, bedding should be carried to specifically reduce the slippage of cattle during loading and discharge on both on the ship and on the loading/unloading ramps.
- An allowance should be made for bedding material to be provided in ship hospital pens. Bedding is applied in hospital pens at much higher rates than the suggested minimum rate as many of the animals in these pens are severely lame and require a softer surface. The softer flooring will allow lame animals to lie down and stand up with more comfort.

6.3.7 Pad management

- The cattle manure pad may increase to a depth of up to 15 to 20 cm, which is not an obstacle on most ships unless the manure consistency changes and cattle begin to pug the manure pad. Bedding should not be allowed to exceed 20 to 30 cm in depth even if it has a

firm, dry consistency. If the manure pad did increase in moisture, the welfare problems with cattle pugging in such a deep pad would be significant, particularly in both smaller and heavier classes of cattle. The consistency of the bedding can change in a matter of hours if the environmental conditions alter. On some ships it can take three days to wash all pens and the welfare risks increase with the depth of the pad. These risks include severe pugging which can interfere with the ability of cattle to stand up, lie down and generally move about the pen; the development of a coating of the animal's body with manure which can impede core temperature regulation; increased ammonia levels which can lead to respiratory complaints impeding heat regulation; and feet and leg infections from rising effluent levels.

- Increasing the percentage of digestible roughage or fibre and lowering the percentage of protein in shipboard rations may help to firm up manure, however this should not be done at the expense of ration palatability. Feeding diets that contain good quality cereal hay, lower protein (12% or less) or a greater proportion of rumen by-pass (RBP) or un-degraded intake protein (UIP) (25% of the ration protein) will decrease the urea-N substrate for ammonia production (Costa et al, 2003). Supplementing the shipboard ration with chaff also helps to firm up the faeces.
- The key to bedding management is to keep the manure pad as dry as possible for as long as possible. Frequent removal by washing or shovelling will help to control the moisture content of the pad, as will the repeated application of absorbent bedding material. Many of the stockpersons and veterinarians interviewed for this project commented that the more bedding material available on ship the better the health and welfare outcomes. Several interviewees indicated that from their own experience, there is generally never enough bedding loaded onto ships.

6.3.8 Prioritisation of bedding use

- The priority use for bedding material is on slippery ramps and corners and in hospital pens, based on industry consultation is listed in Table 10. Non-pastoral *Bos taurus* breeds as a group have a higher priority than *Bos indicus* cattle. Lighter *Bos indicus* cattle from a pastoral background have the lowest priority for bedding.

Table 10: Prioritisation of the use of bedding material for cattle

Priority	Class
1	Ramps and corners
2	Hospital pen
3	Stud stock
4	Pregnant cattle
5	Dairy cows
6	Dairy bulls
7	Dairy heifers
8	Non-pastoral heavy ¹ beef bulls
9	Non-pastoral heavy ¹ beef cows
10	Non-pastoral beef heifers and steers
11	Pastoral heavy ¹ cows
12	Pastoral bulls
13	Pastoral heifers and steers
14	Buffalo

¹ Heavy denotes an animal with a live weight over 380 kg

6.4 Short haul voyages – recommended best practice

6.4.1 Pre-loading

- For cattle that are transported to any destination where the voyage duration exceeds 10 days, the provision of bedding at loading should be considered depending on the vulnerability of the loaded livestock to abrasions and lameness. Voyages to destinations, which are classified as short haul voyages and involve multiple loading and discharge ports can necessitate the use of bedding material if vulnerable livestock spend more than 10 days on ship.

6.4.2 Increased fodder and water consumption

- It is common for cattle on short haul voyages to be sold on the basis of their discharge weight. For this reason, fodder and water consumption can be comparatively higher than that on long haul voyages, which generally feed a maintenance ration. This can create more faeces and urine in pens causing pen floors to quickly accumulate a moist faecal pad.
- Brahman-cross cows sourced from north Australia that are in forward condition will often never settle and eat properly on short haul voyages, and will often urinate excessively. The weight of these cows is generally over 380 kg and this, combined with their age (often culled for age cows), and associated lack of agility increases their risk of lameness. Their excessive urination can complicate bedding management.

6.4.3 Use of bedding

- Although not required by the ASEL, bedding is reported to be used by some exporters on the short haul (less than 10 days) trade carrying heavy classes of steers, cows, bulls and dairy breeds.

- Short-haul trips where some cattle can be on board for over 10 days pose additional logistics for bedding management. On some multiple port voyages due to the frequency of loading and discharging, the crew may not have sufficient time to wash or use bedding material. As feeding and watering and the discharge weight is more important on short haul voyages, the crew can be too busy to wash and change bedding on some short haul voyages. The majority of stockpersons who have travelled on both short haul and long haul voyages believe that as a minimum, bedding material should be applied in pens where cattle are likely to be on board greater than 10 days and particularly for cattle more vulnerable to feet and leg injuries, being dairy cattle, cattle over 380 kg and non-pastoral cattle.
- Non-pastoral cattle originating from southern Australia during the Australian winter with a live weight over 380 kilograms and on a short haul voyage will benefit from receiving suitable bedding material. Similarly pastoral cattle such as heavy cows and heavy bulls may require bedding to help reduce lameness and manage the pugging of bedding. Bedding should be provided on all voyages as a minimum to reduce slippage during loading/unloading and to improve hygiene and the quality of rest in hospital pens.

6.4.4 Pen washing

- On longer, short haul trips it is possible to have a considerable build up of manure if washing is not conducted. This can lead to increased risks of bedding deterioration if high wet bulb temperatures are experienced and cattle have a relatively low heat stress threshold. *Bos taurus* cattle carrying a lot of hair may be at a higher risk of heat stress if washing does not periodically remove faecal contamination from their coat.
- On short haul voyages (less than 10 days) the inclusion of at least one pen wash will reduce the workload for the crew on the return trip to Australia and will improve the pen environment for cattle.

6.5 Sheep bedding management

The advantages and disadvantages of using appropriate bedding material for sheep on ships based on industry consultation are shown in Table 11.

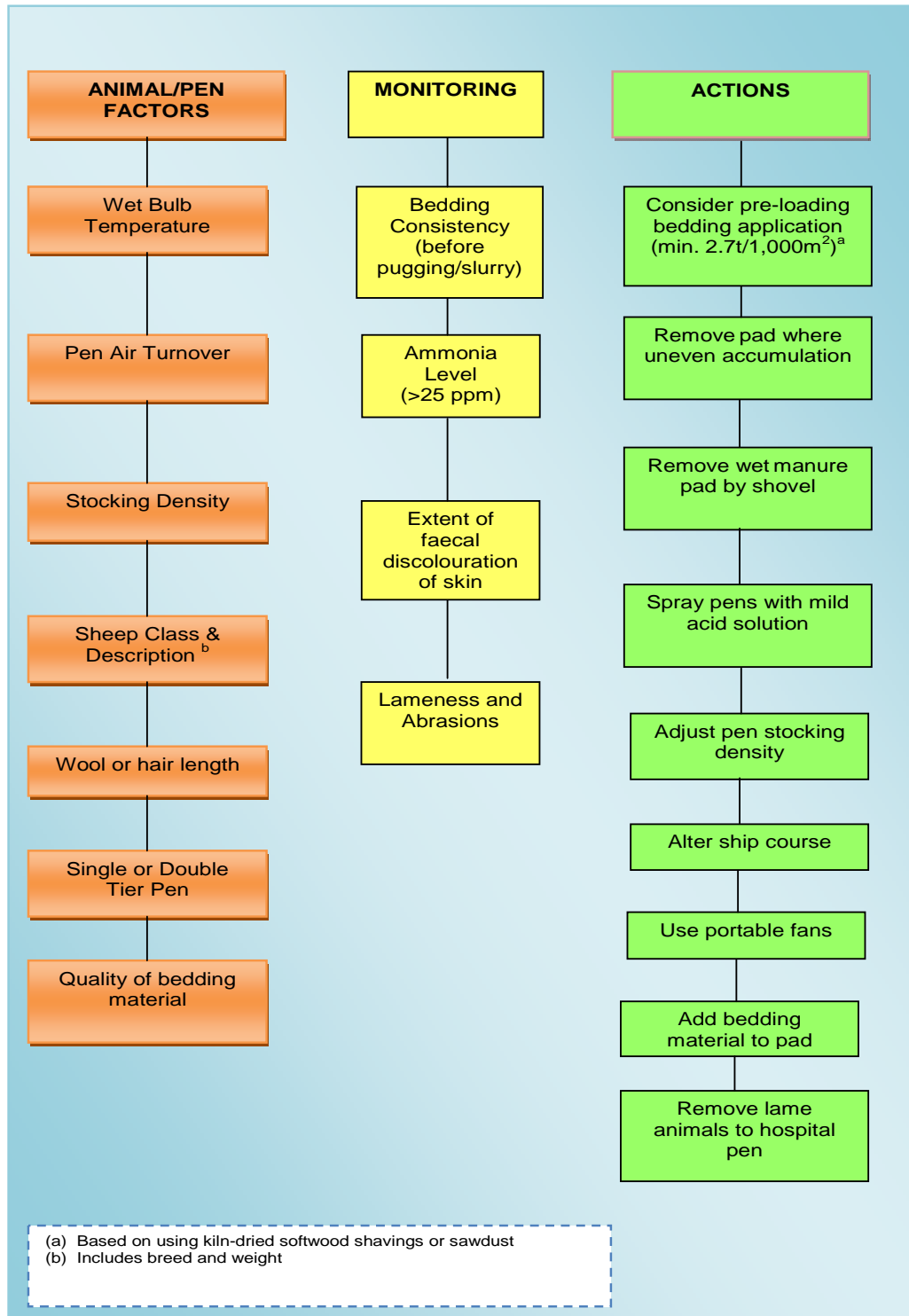
Table 11: Advantages and disadvantages of using bedding material in sheep pens

Advantages	Disadvantages
<ul style="list-style-type: none">• Assists in maintaining firmness of natural manure pad• Reduces ammonia level• Decreases air humidity and wet bulb temperature• Reduces slippage during loading and unloading• Improves presentation at discharge• Reduces time spent lying in wet faeces• Reduces amount of faeces adhering to fleece• Improves industry perceptions	<ul style="list-style-type: none">• Cost not directly recoverable in terms of decreased mortality• Takes up valuable space on ship• Increases labour required to handle and apply• Increases labour required to handle and remove

6.6 Checklist

Figure 14Error! Reference source not found. illustrates what animal / pen factors, monitoring and actions are important in the management of the sheep pad. Issues under each heading serve as a pad management checklist prior to and during a voyage.

Figure 14: Sheep pad management checklist on ship



6.7 The sheep pad

Bedding material is not normally used in the management of the sheep pad except as a short-term remedy to help mop up moist areas of the manure pad. For most voyages, the natural pad provides a firm, trouble-free surface, which is not touched until during the return voyage. Problems with the sheep pad can occur when high deck wet bulb temperatures cause the pad to increase in moisture and soften. When the pad is soft, sheep will begin to pug the pad and become contaminated with wet faeces. At the same time, the softening pad will lead to a spike in the release of ammonia and other gases. These problems are normally sporadic in nature and largely dependent on the prevailing wet bulb temperature.

The sheep pad will normally build up to a depth of 10 cm and remain sufficiently dry so that sheep will not pug the surface. Constant surveillance by the crew is required for burst water pipes, which can flood sheep pens and destroy firm sheep pads. Using the data supplied by Landline Consulting (2003) and assuming a cargo of 50,000 sheep with an average weight of 45 kg, up to 90 tonne (90,000 L) per day of total manure (faeces and urine) is produced. This is equivalent to 1,440 tonne (1,440,000 L) of manure over a voyage of 16 days. This amount of manure will rise off the pen floor to a height 9.2 cm of at a stocking density of 0.31 m² per head

Specific recommendations for best practice in relation to sheep pad management are outlined below.

6.7.1 Pre-loading – recommended best practice

- So as to reduce the incidence of contamination of sheep with a faecal 'jacket' and the related discolouration of the sheep fleece, it is important that sheep be shorn as close as possible to the loading date providing the weather and other animal welfare considerations allow. Gross contamination of the fleece (commonly referred to as very discoloured sheep by industry) can interfere with the sheep's thermoregulatory mechanisms and can also cause buyer resistance on arrival at the country of destination.
- Some hair breeds of sheep, such as the Awassi, will often not be shorn prior to loading, meaning this class of animal should be loaded in well ventilated pens close to supply vents and at an appropriate stocking density. This will help to reduce the risk of Awassi sheep being contaminated by a deteriorating pad.
- The use of bedding material before and during the laying of the sheep pad may provide a moisture 'buffer' to reduce the risk of sheep pad deterioration. The application of bedding material prior to sheep loading is not currently widespread and as a consequence, the benefits of using bedding in this way are not conclusive. Figure 15 shows sheep with fresh bedding immediately after loading.

Figure 15: Sheep with freshly laid pine shavings on pen floor



6.7.2 Management of ammonia levels

- Episodes of high wet bulb temperature leading to a softening of the sheep pad are most common during the northern hemisphere summer months of July and August and can occur on open decks while in port for discharge when there is little natural air movement.
- There is normally a spike in ammonia levels after 1 to 2 days into the voyage and this is a common problem during the voyage with levels suspected to exceed 20 to 25 ppm. Much higher levels of ammonia can be recorded during a period of exceedingly high ambient wet bulb temperatures and where pen air turnover is not satisfactory.
- Shovelling the pad from pens is seen as a last resort after managing the stocking density, the positioning of more vulnerable sheep relative to ventilation points and the strategic use of bedding material. The ideal situation is to maintain the sheep pad as dry as possible at all times. The best indication of this state is when the feet of sheep are not sinking into the pad. When this sinking occurs, there is a small and continuous release of ammonia throughout the voyage. The worst case scenario is having a dry pad for most of the journey and a high wet bulb temperature softening a relatively deep pad in a matter of hours, thereby releasing a large amount of 'stored' ammonia within a short space of time. Ammonia episodes like this can lead to poor welfare outcomes for crew and livestock.
- Ammonia levels can be objectively measured on ships using hand held ammonia meters provided a strict protocol for calibration and recharging is followed. Where there is a local build up of ammonia in excess of 25 ppm, management practices as described above can be used to provide at least temporary relief. Ammonia levels on open decks can be reduced by a change to the ship's course or zigzagging to pick up crosswinds, which help to disperse the ammonia.
- As with cattle pens, portable industrial fans can be used in local areas where the pad is deteriorating and livestock are being affected by high wet bulb temperature or high ammonia levels.

6.7.3 Pad maintenance

- Effective ventilation and appropriate stocking densities are important determinants of how the sheep pad is managed on ships. Areas which have an inherent higher risk of the pad softening are often located near exhaust vents where the deck air can be relatively warm and moist.
- Where the softening of pads is localised, removing the deteriorating pad with shovel and barrow can relieve the situation. This usually requires the temporary transfer of the affected sheep into other pens or alleyways. Reducing stocking densities in the affected pens can also assist. Another option when the sheep pad is softening is to add bedding material or waste fines from fodder to the moist areas to help absorb the moisture and firm up the pad.
- Wetting the surface of the sheep pad slightly can minimise dust in the deck hold atmosphere and the potential spread of pinkeye and other eye infections. On some ships, sheep are located in pens immediately adjacent to the outside of ship (i.e. no alleyway) and can receive a lot of wind, which blows dust off the pad onto other sheep and promoting the spread of pink eye. Eye irritation is seen more with sheep than cattle as a consequence of high ammonia levels. Treating sheep for eye problems means an additional stress on the problem sheep and his pen mates through the catching and treating process.
- Depending on the design of open decks and the pens, bad weather and large waves can wet some sheep pens. Normally the associated deterioration of the pad is short-lived if followed by dry weather, calmer seas and drying crosswinds.
- If sheep begin to pug their pad, the crew can add bedding material mainly near water and feed troughs or throw in chaff or fodder fines. Generally the lack of working space means shovelling out pens is difficult and often not efficient. The management of the bedding where sheep travel on decks with double tiered pens is more difficult than where sheep travel in single tier decks. Using a shovel in pens on double tiers presents more complications than sheep on single tiers. Pens on the bottom of double tiers will often have less ventilation (lower pen air turnover) and it is difficult to see and get access to any sheep requiring treatment.
- Young sheep appear to drink and urinate more than older sheep thereby increasing the moisture level of their pad. Young sheep are also closer to the deck floor and manure pad than older sheep and can therefore be more prone to respiratory damage resulting from high ammonia emissions.
- Stockpersons and veterinarians believe heavy rams should be treated like heavy cattle in that they should receive bedding material, which is removed and changed regularly by shovel and barrow. Heavy sheep like heavy cattle will more easily pug a softening pad. Generally lighter sheep travel better than heavier sheep.
- Industry observations are that all rams of any age and weight, consume more water and urinate more than other classes of sheep, therefore increasing the risk of the pad softening during high wet bulb temperatures. The worst scenario is when there are 2 to 3 days of high wet bulb temperatures on all decks since management options at this scale are limited. Generally this situation is exacerbated at pens located closest to exhaust vents and distant from supply vents.

- If the deck wet bulb temperature is increasing and the pad is deteriorating, the crew will sometimes remove feed troughs. This reduces feed consumption and the energy generated with digestion and helps to reduce sheep core body temperature. On some ships, the removal of the feed troughs will also allow better air circulation.
- Often the sheep pad will, over time, be raised in height in the middle of the pen compared to the pen perimeter, which increases the risk of sheep smothering. Again the only options are to shovel out the pens and add bedding material to help firm up the pad to minimise the formation of the high spot in the middle of the pen.

A dry, firm sheep pad is illustrated in Figure 16, while Figure 17 shows an excessively moist pad that is being pugged.

Figure 16: Sheep pad – surface consistency is dry and firm with minimal pugging



Source: Lynn Simpson

Figure 17: Sheep pad – surface is excessively moist and soft with pugging



Source: Lynn Simpson

6.7.4 Water spillage

- Stockpersons stress the importance of minimising the spillage of water from water troughs and the leaking of water pipes (see Figure 18). Both factors will increase the risk of pugging the sheep pad. The bottom tier of double tier sheep pens is often where water and moisture will collect, thereby affecting the welfare of the sheep on the bottom tier.

Figure 18: The effects of a broken water pipe on a sheep pad



Source: Lynn Simpson

6.7.5 Prioritisation of bedding use

As for cattle, the priority use for bedding material with sheep is on slippery ramps and corners and in hospital pens. The prioritization of use of bedding material based on industry consultation is

shown in Table 12. Rams and heavy classes of sheep are more problematical for pen management than lighter classes of sheep.

Table 12: Prioritisation of the use of bedding material for sheep and goats

Priority	Class
1	Ramps and corners
2	Hospital pen
3	Stud stock
4	Pregnant sheep
5	Heavy ¹ rams
6	Young rams
7	Heavy ¹ ewes
8	Heavy ¹ wethers
9	Light wethers

¹ Heavy denotes an animal with a live weight over 40 kg.

7 Possible changes to the Australian Standard for the Export of Livestock and Stockpersons' Handbooks

The report (see Figure 1 and Figure 2) contains a number of recommendations and guidelines, which may be incorporated into the existing Australian Standard for the Export of Livestock and stockpersons handbooks.

It is recommended this be done through close consultation between industry, the Vessel Preparation Working Group and the authors of the handbooks for cattle and sheep.

8 Knowledge gaps and research priorities

A number of possible research concepts were raised during the course of this project, as a result of the detailed literary review and industry consultation. These topics are shown in Table 13.

The five highest priority ideas from this list are:

1. Investigate and trial alternative, less abrasive, deck flooring with the aim of reducing lameness, abrasions and improving animal comfort while maintaining traction, cleaning and longevity characteristics;
2. Evaluate the application of bedding material before and during the laying of the sheep pad;
3. Develop a scoring system for bedding condition, abrasions, lameness, body faecal contamination and time spent lying/standing to assist industry to benchmark and improve health and welfare outcomes associated with bedding.

4. Conduct shipboard trials using fodder containing lower levels of unprotected protein and higher levels of more digestible fibre to examine reductions in faecal production and ammonia emissions, while maintaining palatability and least cost ration principles.
5. Demonstrate the gains from modifying load plans to stow sheep based on their vulnerability to pad problems in areas with lower moisture content in fully enclosed vessels.

Table 13: Possible Research, Development and Extension concepts

Domain	Concept	Sheep or Cattle	Estimated Priority
Planning	Demonstrate the gains from modifying load plans to stow sheep based on their vulnerability to pad problems in areas with lower moisture content in fully enclosed vessels.	Sheep	High
	Convene regular workshops for stockpersons and veterinarians to continually review and improve shipboard management.	Both	Medium
Monitoring/Objective measurement	Develop a scoring system for bedding condition, abrasions, lameness, body faecal contamination and time spent lying/standing to assist industry to benchmark and improve health and welfare outcomes associated with bedding.	Both	High
	Demonstrate any additional benefits of using moisture meters in sheep pads over and above visual appraisal by experienced stockpersons and veterinarians.	Sheep	Low
Bedding material	Investigate with suppliers the introduction of bedding material quality assurance.	Both	Low
	Evaluate the application of bedding material before and during the laying of the sheep pad.	Sheep	High
	Investigate the use of alternative bedding materials.	Both	Medium
	Investigate benefits of impregnating bedding material during its manufacture with Gypsum, Zeolite, citric acid or similar to reduce ammonia emissions.	Both	Medium
	Investigate the use of live bacteria in bedding to help digest the manure pad.	Both	Low
	Investigate and compare the cost/benefit of a range of bedding application rates prior to loading and during the voyage.	Cattle	Low

Table 13: Possible Research, Development and Extension concepts (continued)

Domain	Concept	Sheep or Cattle	Estimated Priority
Pen flooring	Investigate and quantify the net benefits of using rubber matting or a recycled rubber product on the floor of hospital pens.	Both	Low
	Investigate and trial alternative, less abrasive deck flooring with the aim of reducing lameness, abrasions and improving animal comfort while maintaining traction, cleaning and longevity characteristics.	Both	High
Ammonia control	Conduct shipboard trials using fodder containing gypsum and other feed additives such as Zeolite and Yucca and lower levels of unprotected protein and higher levels of more digestible fibre to examine reductions in ammonia emissions.	Both	Sheep – High Cattle – Medium
	Investigate feasibility of producing a pellet product containing an agent to lower the pH of bedding e.g. a mild acid in a pellet form like the urea prill.	Both	Low
	Investigate the mode of action and possible application of the active ingredient(s) used in human waterless urinal systems.	Both	Low

9 Success in achieving objectives

The agreed objectives of this project were to:

1. Review the current bedding management practices and issues; and
2. Provide recommendations to minimise the risk of bedding related incidents and maximise the welfare of livestock during transport.

These objectives have been met through successful industry consultation and review of available literature, and the resulting conclusions and recommendations are included in this report.

10 Impact on meat and livestock industry

Improvements to bedding management during the export of livestock by sea will reduce the risks of mortalities and poor health and welfare outcomes. By adopting recommendations included in this report in the use of bedding, animal health and welfare will be enhanced. While the commercial benefits of improved bedding management do not always outweigh the costs, improvements in bedding management will help to ensure the continual improvement of health and welfare results on live export ships. Addressing animal welfare issues through bedding management will also assist in improving the public perception of the trade. Therefore, the adoption of this report's recommendations will see both immediate and ongoing benefits.

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12 Appendices

12.1 Extract from Stockman's handbook on transport of cattle by sea

Decks and Bedding

The management of bedding and cleaning is a constant compromise between allowing a build up of soft, relatively dry faeces to provide a comfortable pad for the cattle to lay down on and a need to remove loose, wet faeces and urine which discourage animals from lying down, produce ammonia and contribute to increased humidity. The most appropriate management of the deck may vary from day to day and needs the careful consideration of all concerned in order to design a regime, which provides maximum comfort for the animals onboard. Research initiatives are currently under way to learn more about the management of ammonia on livestock vessels.

The issues relating to the decks and bedding are clearly much less critical on short haul voyages.

As the majority of stock transported in the short haul trade are tropically adapted animals, bedding is usually only used for special categories of stock which require additional care such as pregnant dairy cows. The majority of short haul voyages do not use bedding of any sort. Policy regarding deck washing on short haul voyages varies considerably depending on the exporter, stockman and shipping company's individual experiences. No single management method is considered to be the most appropriate on short voyages. Good results are obtained from a range of approaches which include some voyages where no deck cleaning is done to those where decks are thoroughly washed every day. The decision on deck management for short haul voyages should be a matter for all of the parties involved to decide based on the individual circumstances faced during each voyage. The same general principals as described below are true for both short haul and long haul. The information in this section should all be considered before deciding on a specific course of action.

The AQIS regulation requiring all long haul voyages to load sawdust or other bedding material has proved to be a major advantage to bedding management and overall animal comfort.

A number of bedding materials has been trialled including hay, straw, wood shaving, rice hulls and sawdust. Sawdust seems to be the most favoured of the alternatives. Wood shavings and straw that generally have longer fibres, have caused some bilge pumping systems to block up.

Sawdust provides the animal with a comfortable, non-slip pad immediately. When faeces and urine drop onto it, their moisture is partly absorbed into the sawdust and the bedding / deck stays drier for longer. Cleaning is only indicated if the bedding conditions become wet or the ammonia levels high enough to warrant a full clean out.

The general aim of the bedding exercise is to clean the deck the least number of times during the voyage while maintaining animal comfort and preventing the build up of ammonia gas.

Washing down distresses cattle and causes them to move around the pen in such a way as to increase the possibility of death or injuries either to themselves or the animals they crash into or step on. Obviously reducing the level of this type of activity to a minimum will also reduce the opportunities for deaths and injuries. This becomes even more important in rough weather and when the cargo includes particularly fragile animals such as pregnant females.

As an additional aid to the control of ammonia gas it may be possible to keep the levels of this gas production under control to some extent by the application of mild acids such as Acetic or Citric acid. These can be mist sprayed on the bedding pad to neutralise the ammonia (2% acid misted twice per day can significantly lengthen the periods between washing out).

Recent research has shown that dietary additives have the capacity to acidify the urine which has a similar result as spraying the bedding with weak acid – ammonia release is reduced. More research needs to be done to clarify the best options for this approach. Another approach to reducing ammonia is to add gypsum to the sawdust bedding at an inclusion rate of 50%. While this has proved effective in reducing ammonia release, the effectiveness is reduced at high temperatures so dietary additives are likely to provide the most practical solution.

As mentioned in the previous section on temperature and humidity, the cleaning of wet decks contributes in the short term to an increase in humidity in the cattle space but subsequently results in a net reduction. The magnitude of this reduction in humidity is dependent on the effectiveness of the deck drainage. If the decks remain wet or have significant puddles of water lying in low areas after the wash then any favourable affect on humidity will be reduced. Placing sawdust or other bedding materials in the wet patches will result in a significant reduction in the humidity in the immediate area. If this is practised over the whole deck the net reduction in humidity can be dramatic.

Cleaning events should be planned to take the passage through hot locations into account, i.e. when approaching the equator or the Gulf of Aden, cleaning should be programmed to allow for the lowest humidity following the cleaning process to coincide with the passage through the hottest locations.

If the vessel's ventilation is adequate, the decks are well drained and sawdust is available to treat any wet spots then washing out during passage through hot locations may be appropriate. This is something, which should be considered very carefully by all parties before being undertaken.

One option for cleaning the deck without hosing is to simply shovel the accessible faeces from the floor of the pen or alleyway into wheelbarrows and remove it to the bilges or throw it overboard. While this will be less effective than hosing the pen and represent more work for the crew, it will reduce the fouling of the floor with much less stress to the stock and will immediately reduce humidity especially if accompanied by the application of sawdust. This option may be most appropriate for pens containing sick or particularly stressed animals.

The use of sawdust has been suspected of increasing the number of eye infections on some vessels. There is a possibility that hosing down the decks causes sawdust particles to lodge in animal's eyes thus initiating these infections. This should be considered when cleaning out sawdust bedding with a view to minimising the splashing of the deck wash into the faces of the stock.

On some vessels where stocking densities are quite low, e.g. pregnant dairy cows on long haul voyages, the stockmen and crew have been able to redistribute animals prior to cleaning in order to produce an empty pen. After the empty pen has been cleaned out by hosing or shovelling, the animals in the next pen are moved in and the process repeated for the entire deck. This allows cleaning to take place in only empty pens. Once the cleaning event has been completed then the animals are redistributed again to utilise all of the space on the deck.

Hosing the decks down with very cold seawater can be a dangerous and stressful event for warm cattle. Regardless of how careful the crew is, the cattle will still be sprayed to some

extent with the cold water. Cold shock has the same capacity as heat stress to result in the development of an outbreak of pneumonia or other stress induced illness. Any attempt to clean the decks by hosing with very cold seawater should be delayed until the vessel reaches warmer waters.

12.2 Critical points from available literature on livestock bedding

A summary of the current literature relating to livestock bedding is listed below:

Bedding materials

- Research by Fregonesi, Veira, von Keyserlingk and Weary (2007) addressed the effect of wet bedding on stall preference and use. The authors concluded that dairy cows show a clear preference for a dry lying surface, and they spend more time standing outside the stall when only wet bedding is available.
- According to De Palo, Tateo, Zezza, Corrente and Centoducati (2006), the comfort of dairy cows was predominantly influenced by environmental temperature and humidity, with the preferred floor materials being polyethylene vinyl acetate mats, polypropylene vinyl acetate mats, wood shavings and solid manure in that order. However under conditions of heat stress (temperature humidity index of 80 or wet bulb temperature of approximately 29 degrees centigrade), the cattle preferred wood shavings and solid manure as bedding.
- Manninen, de Passille, Rushen, Norring and Saloniemi (2002) studied the preferences of 44 Friesian dairy cows for different kinds of stall bedding materials in unheated cubicle housing in winter and in summer. Three types of materials were examined: concrete with large amount of straw, soft rubber mat with a thin layer of straw (2 to 3 mm), and sand without straw. The results showed that the total time lying down in cubicles was significantly shorter on sand than on straw or rubber mats, in both winter and summer.
- Manninen et al. (2002) reported that cows avoided sand bedding, preferring straw or rubber mats, and suggested the poor thermal properties and instability of sand as reasons for avoidance. However, Tucker et al. (2003) showed the importance of preconditioning in such preference studies, reporting that cows previously bedded on straw would prefer straw when given a choice of straw or sand, and those previously on sand would prefer sand.
- O'Connell and Meaney (1997) reported that cows showed a preference for sawdust over newspaper and that the newspaper bedding required replacing more often, resulting in cost implications. In terms of hygiene, no significant effects on cleanliness or health of stock were noted among sawdust, newspaper, straw, or shavings (O'Connell and Meaney, 1997; Livesey et al., 2003), but Hogan et al. (1989) reported that organic beddings gave increased bacterial counts when compared with inorganic bedding materials (sand or crushed limestone).
- In a study by Weary and Taszkun (2000), producers using sand bedding reported good stall acceptance by cows, but more work is required to determine cow preferences for different bedding materials and differences in cow comfort relating to bedding type. One study found that cows were more likely to use, and spent more time lying in stalls with sand bedding, than those with a wooden floor. In one laboratory experiment, cows given the choice between three stalls identical in all respects except the type of bedding

(sawdust, sand, and geotextile mattress) showed a strong preference for using the sawdust-bedded stall. More work is required to determine how sawdust and mattress bedded stalls can be designed or managed in ways that reduce the prevalence of lesions to more acceptable levels.

- It is important that the soft floor material is kept below a certain moisture level to allow oxygen to be present in the floor and remain an aerobic environment (Crafter et al, 2006). If cattle saleyards are open to the weather, the benefits are likely to be minor if wet weather persists and the saturated bedding remains wet for extended periods, particularly in winter due to mud, odour and slippage of cattle and handlers. Mud reduces cow mobility and increases the labour required to move cows, and saturation reduces hoof hardness and increases susceptibility to wear and damage (Rushen et al, 2004). Cattle must have dry flooring for standing in order to control the incidence of lameness.

Flooring

- Using intensively housed, beef cattle, Lowe, Steen and Beattie (2001) conducted a study to determine the preference for floor types. The four floors tested were a fully slatted floor, a fully slatted floor covered with rubber mats, a solid floor with sawdust bedding, and a solid floor with straw bedding. In this study, straw was the most preferred floor type, followed by sawdust, then mats, and finally slats.
- Gardner (2001) in a paper titled *The Welfare of Pigs: Review of Recent Literature* cites literature stating that pigs kept on solid floors and provided with bedding such as straw, have been found to eat more and gain more weight and they tend to have fewer leg injuries, such as adventitious bursitis (Lyons et al., 1995; Mouttotou et al., 1998). Slatted floors and a lack of bedding, on the other hand, have been found to contribute the most to leg injuries (Lyons et al., 1995).
- Crafter, White, Carey and Shephard (2006) in their report in their review of soft flooring options for saleyards in southern Australia found that soft floors in saleyards may encourage lying activity and can help to minimise lameness in yarded cattle. However, surfaces must not become waterlogged as this will also prevent normal lying activity. Cattle that are yarded for prolonged periods (24 hours or longer) therefore require access to surfaces suitable for lying, access to shade in hot weather and dry comfortable surfaces in cold weather. Soft flooring in this review included wood shavings, wood shavings/sawdust mix, sawdust, rubber matting, sand and natural earth/gravel.
- The results of a survey by Crafter, White, Carey and Shephard (2006) of cattle buyers, cattle road transporters and vendors on soft flooring options for saleyards showed:
 - 62.5% of those surveyed had purchased cattle showing signs of lameness;
 - Of these, 75% had negative consequences (i.e. death or severe setback); and
 - Weaner and heavy cattle (e.g. old cows) and particularly European breeds were the worst affected.

Although there are differences in the hardness and surface characteristics between the concrete floors of saleyards and ship deck flooring, it is reasonable to make some comparisons between saleyard concrete floors and ship flooring. There are of course, differences in deck flooring from ship to ship and in concrete flooring from saleyard to saleyard.

- Christer Bergsten (2004) as cited by Crafter et al (2006) argues that although concrete is a “cheap, strong material for constructions and easy to clean”, lameness and claw horn lesions (sole ulcers, double soles, white line lesions, dermatitis and heel horn erosion) were significantly associated with concrete floors; especially when combined with loose housing systems and poor hygiene.
- Canadian researchers Jeffrey Rushen and Anne Marie de Passillé as cited by Crafter et al (2006) take a more strident anti-concrete stance when they write, “Under no circumstances should dairy cattle be expected to lie on bare concrete. A large survey of several hundred dairy herds in Norway found that simply providing a rubber mat or some litter bedding reduced the incidence of mastitis by 14% compared to cattle kept on concrete floors (Rushen and de Passille).”
- According to Craft et al (2006), it is clear that soft flooring decreases the incidence of foot soreness in southern beef saleyards. Cattle should have the ability to lie down when required. Lying reduces wear on feet, assists with thermoregulation and relieves fatigue.
- Soft flooring improves comfort by making it easier for cattle to stand up and lie down thereby reducing the likelihood of knee injuries (Rushen et al, 2001). The same authors have shown that dairy cattle kept on softer flooring during long-term housing stood up and lay down almost twice as often as cattle on concrete. When they stood up they also stayed standing for longer before lying down again. This suggests that the main advantages of the softer flooring are apparent when the animals are changing position. This conclusion is sourced from a Canadian study that compared lactating dairy cows kept on concrete floors with a small quantity of straw, or dairy cows kept either on geotextile "mattresses" or soft rubber mats. Cattle housed on the mats lay down on average 1.5 hours longer each day. The use of soft mats also halved the incidence of swellings, especially of the front knees, and thus seems likely to reduce the incidence of leg problems. The Canadian study showed that the degree of softness of the floor is particularly important for dairy cows.
- Phillips and Morris (2002) conducted experiments to determine the preference of eight Friesian cows for floors with different levels of friction, produced by surface-dressing an epoxy resin coating (smooth) with various sizes of bauxite aggregates (0.5, 1.2 and 2.5 mm). The cows were trained for 10 days prior to the preference testing. The results showed that the cows could distinguish between floors with different levels of friction. Preference tests indicated that there were no consistent preferences for floor type. This lack of preference, together with the fact that the cows did not change their walking speed (although adjusting their stride), suggests that the cows felt no immediate discomfort. Floors coated with large aggregates may thus be used in livestock buildings where there is a danger of the animals slipping. However, the longer-term implications on hoof abrasion have yet to be investigated.
- Færevik et al (2004) working with indoor sheep in Norway found shorn but not unshorn ewes, preferred softer floors with low thermal conductivity (straw and wood).

Animal Health and Welfare

- Fregonesi (2003) in looking at the behaviour, performance and health indicators of welfare for dairy cows housed in straw yard or cubicle systems concluded that total lying time, lying synchrony and locomotion score are potential indicators for the assessment of dairy cow welfare in different housing environments.

- Cook (2004) in his paper titled *The Influence of Barn Design on Dairy Cow Hygiene, Lameness and Udder Health* indicated a lying time of around 11 hours per day would be an appropriate target for intensively raised dairy cows. There is a growing body of evidence that increased lying times have a beneficial effect on lameness prevalence and claw health in the dairy environment.
- Schulze Westerath et al (2006) in a study of leg lesions in finishing bulls concluded that both rubber coated slats and cubicles provided with soft lying mats were favourable with regard to the levels of lesions and swellings of the leg joints of finishing bulls compared to concrete slats. However, these levels were even lower in pens with a straw bedded lying area.
- McCarthy (2002) in a MLA / LiveCorp funded project report, titled *The Best Practice Management of Pregnant Dairy Cattle on Long Haul Voyages* made the following recommendations under bedding management:
 - Dairy cattle would seem to drink more during periods of heat stress, which results in excessive urination. This leads to rapid deterioration of state of the bedding.
 - Additional sawdust should be provided for pregnant dairy cattle.
 - Desirably there should be enough sawdust for every wash during the voyage, however, if washing frequency is increased this may become impractical.
 - Good quality (pine) sawdust should be used, with low moisture content.
 - Their higher feed intake may lead to greater manure production and this may dictate more frequent washing. Washing every 2 to 3 days (or even every day) may be required due to the rapid deterioration of the bedding.
 - If sufficient sawdust for every wash is unavailable (or becomes unpractical), sawdust should be conserved for sick pens, hot spots and more vulnerable groups and/or areas on the vessel.
 - Save some sawdust for unloading to ensure alleyways and/or discharge ramps are not slippery.
 - Be careful when washing to avoid distress among the cattle, especially on the first one or two washes.
 - Avoid the direct jetting of water onto cattle and where possible, avoid manure splashing onto the udder of lactating cows.

The summary best practice recommendation from this report was to carry additional bedding material where possible and be prepared to wash on a more frequent basis.

- In transporting dairy cows in particular, McCarthy (2002) adds that:
 - Slippery floors are a big hazard to this class of cattle due to their instability. Abrasive surfaces are also a hazard. Leg injuries in the form of grazes or abrasions are common and need to be treated promptly.
 - The use of portable rubber mats to assist in raising downer cows was reported to be a useful aid.
 - Areas that become slippery should receive additional sawdust.
- Weary and Taszkun (2000) found a lower prevalence and severity of lesions in dairy cows on farms using sawdust-bedded stalls, and still lower levels on farms using sand bedding. However, some care is required in interpreting these results because farms differed in many other ways such as herd size. The authors also found no evidence that lesions correlate with the frequency at which new bedding is added to stalls. This

surprised the authors as contact with wet bedding may make the skin less effective as a barrier, and wet, soiled bedding provides a medium for infection following some trauma to the skin.

Ammonia

- Costa, Accioly and Cake (2003) in the MLA/LiveCorp funded live export project *Determining critical atmospheric ammonia levels for cattle, sheep and goats - a literature review* made the following findings:
 - Ammonia gas is volatilised into the atmosphere by the action of bacterial urease enzymes in the bedding or manure pads, breaking down urea into urine and also undigested protein in faeces.
 - Volatilisation of ammonia from the bedding or pad increases when pH rises above 7.0 and with increasing ambient temperature.
 - Atmospheric ammonia concentration is typically 15 ppm (with a range of 10 to 50 ppm) onboard vessels during transport of cattle and sheep. Common readings below decks reach 20 to 30 ppm.
 - The Australian National Occupational Health and Safety Commission has three standards for exposure to atmospheric contaminants such as ammonia gas in the occupational environment: the time-weight average (TWA) exposure limit for humans working for up to eight-hour shifts on a 40-hour week; the short-term exposure limit (STEL) which is a time-weight average measured over 15 minutes and should not be exceeded in any working day; and the permissible exposure limit which is the maximum concentration that humans are permitted to enter. The time-weighted average (TWA) exposure limit for atmospheric ammonia for humans is 25 ppm. The short-term exposure limit (STEL) is 35 ppm. The permissible exposure limit (PEL) for ammonia is 50 ppm.
 - Under Australian legislation and workplace conditions, atmospheric ammonia concentrations should be below the TWA, STEL and PEL concentrations. However, each of these concentration limits could be exceeded under usual conditions recorded on vessels used for live export.
 - Atmospheric ammonia can be reduced by a number of atmospheric and nutritional means:
 - Establishing adequate ventilation rates onboard vessels.
 - Feeding diets that contain good quality cereal hay, lower protein (12% or less) or a greater proportion of rumen by-pass (RBP) or un-degraded intake protein (UIP) (25% of the ration protein) will decrease the urea-N substrate for ammonia production.
 - Using salts such as calcium chloride or ammonium chloride at 1% in rations to acidify urine and decrease the pH of bedding. The lower pH reduces volatilisation of ammonia.
 - Adding bedding agents that reduce the pH (e.g. gypsum) to reduce ammonia volatilisation.
 - Production indices such as feed intake, average daily gain and feed conversion efficiency are all adversely affected in lambs, calves, and pigs by exposure to ammonia levels of 50 ppm or more. However, there was no significant production effect below this concentration of ammonia. Moreover, the length of exposure is much greater during live export. From the literature, it is not possible to clearly deduce the effects of these longer exposures to atmospheric ammonia of 25 ppm or more.
 - The respiratory system of cattle is poorly adapted anatomically and physiologically to handle respiratory challenge from ammonia, heat, or exercise.

- High ammonia concentrations can irritate the upper respiratory tract leading to coughing (particularly on hot days) and rapid breathing. The small airways of the lower respiratory tract become inflamed after exposure to ammonia.
- Pneumonia as a consequence of high ammonia concentrations is not fully understood on livestock ships, however it is thought to be a significant cause of mortalities in cattle during live export.
- The critical value of atmospheric ammonia above which cattle welfare and production could be adversely affected should be set at 25 ppm. This value is the same as the TWA for humans and 5 ppm above the European standard for pig housing systems.
- It is unlikely that sheep or goats are going to be qualitatively or quantitatively different to cattle in their respiratory responses to ammonia. Therefore the same critical value for atmospheric ammonia of 25 ppm should be applied to sheep and goats.

In summary, a number of ammonia reduction measures are available, including:

- Dietary manipulation;
 - Bedding additives;
 - Feed additives; and
 - Management procedures.
- One of the aims of a study by Misselbrook and Powell (2005) was to assess, at a laboratory scale, the relative importance of the physical (urine absorbance capacity, bulk density) characteristics of five bedding materials (chopped wheat straw, sand, pine shavings, chopped newspaper, chopped corn stalks, and recycled manure solids) on ammonia emissions from dairy cattle urine. Recycled manure solids were the most absorbent of the bedding types (4.2 g of urine/g of bedding), and sand was the least (0.3 g of urine/g of bedding). When beddings were soaked in urine to their absorbance capacities, NH_3 emissions over 48 h (expressed as a proportion of the urine N absorbed) were not significantly different among bedding types. When equal volumes of urine were applied to equal depths of dry bedding, ammonia emissions over 48 h were significantly less from sand and pine shavings (23 and 42% of applied urine N, respectively) than from chopped newspaper, chopped corn stalks, and recycled manure solids (62, 68, and 65% of applied urine N, respectively), whereas emissions from chopped wheat straw (55% applied urine N) only differed significantly from that from sand. NH_3 emissions increased linearly with absorbance capacity and decreased as the bulk density of the packed beddings increased.

The results from Misselbrook and Powell (2005) suggest practical applications for bedding used in cattle housing. In terms of urine absorbance, cattle may stay drier on a more absorbent material. If low ammonia emission is an important criterion for bedding selection, then it is important that bedding is maintained such that they do not become saturated with urine, as emissions will then be high regardless of bedding type.

- Bozkurt (2006) investigated the use of Zeolite to reduce ammonia accumulation in housed beef cattle. Using 41 animals in total and divided into two groups (with and without Zeolite), young cattle averaging 200 and 180 kilograms gained 128 kilograms and 90 kilograms respectively over a period of four months. There were significant differences ($p < 0.05$) in total weight gain and daily weight gain in favour of the Zeolite treatment. The author concluded that Zeolite can be used to reduce ammonia accumulation and improve animal performance. Curiously the levels of ammonia emissions were not measured in this work. The author suggests the effective way to reduce ammonia released from confined cattle barns is to use restricted protein levels in rations supplemented with energy from easily digestible carbohydrates.

- In the work by Costa et al (2003) several commercially available products were tested for their efficacy to reduce ammonia emission when added to the bedding of feed. Key findings were:
 - Gypsum added to sawdust bedding at an inclusion rate of 50% was effective in reducing ammonia emission. The effect is reduced at high temperatures (30°C, dry bulb). The main effect of gypsum is to reduce bedding pH.
 - De-Odorase (Alltech-Kentucky, USA) in the bedding reduced ammonia emission in a variable manner, but was ineffective when added to the diet.

Several other bedding compounds were tested for their ability to reduce ammonia volatilisation (Agrotain, Zeolite, Spongolite and Stable Plus). Most products resulted in some depression of ammonia emission but none were better than either gypsum except for Agrotain. Unfortunately Agrotain was considered to have potential toxic effects of its own.

- Further to these ammonia studies, McCarthy (2003) in the MLA / LiveCorp funded live export project titled *Investigation into reducing odour emissions from partly loaded sheep vessels whilst in port* provides an insight into ammonia emissions on ships. Dietary manipulation was considered the “best bet” odour reduction measure. Dietary manipulation aims to reduce the level of rumen degradable protein and include more digestible ingredients in the feed. However according to the author, protein levels have already been reduced in shipping pellets and there may be little scope to reduce protein any further. The use of more digestible roughage by feed millers is recommended.
- In a related project, a number of feed and bedding additives were evaluated under experimental conditions (Kitessa et al 2003). The bedding additives proved ineffective under the conditions of the trial. These products may require further development to apply them to the livestock export situation. The results of the feed additives were more encouraging. Gypsum was the most effective feed additive. This was a statistically significant result ($p < 0.05$). It can be used to partially replace lime as a binder in the manufacturing process.

The benchmarking activities undertaken in this project suggested a strong linkage between pad moisture and odour emission rates. It was recommended that exporters identify areas on the vessel that achieve lower pad moisture and stow the most vulnerable sheep in these areas. The report suggested that the identification of these areas may require the use of a hand held moisture-measuring instrument.

Both Zeolite and Yucca were found to be effective in the work by Kitessa et al (2003), however, the wide variation in response resulted in these differences being not significantly significant. Both products have the potential to demonstrate productivity gains and this would help justify the \$6-\$10 per tonne cost of inclusion.

- Vessels with high pen air turnovers and single, sheep tiers are likely to achieve much lower pad moisture than vessels with low ventilation rates and dual tiers (McCarthy, 2003).
- Phillips (2007) studied the effects of different ammonia concentrations (0, 15, 30 & 45 ppm) on the physiology and behaviour of steers and wethers held for 12 days under micro-climate and stocking density conditions which simulated a voyage from Australia to the Middle East during the Northern summer. Ammonia increased macrophage activity in bronchial alveolar lavages of sheep and cattle, and increased lacrimation, nasal secretions and coughing in cattle. This suggests that under simulated shipboard conditions, ammonia irritates the eyes and nasal passage of cattle and the respiratory surfaces of both species.

Sheep, but not cattle, exposed to 30 and 45 ppm ammonia lost 6-8 % of their live weight. Ammonia had no effect on cattle behaviour and little consistent effect on sheep behaviour, and there was no effect of ammonia on the haematological parameters of either species. 28 days after exposure the animals were removed from the ammonia and macrophage activity had decreased and sheep live weight increased; suggesting the effects of ammonia were temporary.

12.3 Measuring the absorbency of bedding material

The absorbency of bedding material can be estimated using the following method (Kains, Lovell, Payne and Tremblay, 1998):

1. Place 1 kg of the bedding material in a bag made of porous but non-absorbent material (such as an onion bag or one leg of an old pair of panty-hose) and weigh it.
2. Place the bag in a bucket of water and leave it completely immersed for 24 hours. Use sufficient water so that some free water is left in the bucket at the end of 24 hours. A 20 litre bucket should be adequate.
3. Remove the bag from the water and hang to drain but only until it has stopped dripping, not so long that the sample has started to dry out.
4. Reweigh the bag of bedding and calculate the absorbency factor using the following formula:

Absorbency Factor = (weight after soaking – original weight) ÷ original weight

If the bedding material and bag weigh 1 kg before soaking and 3.5 kg after, the absorbency factor is: $(3.5 - 1) \div 1 = 2.5$

12.4 Persons contacted for industry consultation

Surname	FirstName	Job	Company
Ainsworth	Ross	Veterinarian	Australasian Livestock Services
Back	Mike	Veterinarian	
Beatty	David	Veterinarian	
Beckett	Gary	Stockman	
Best	Grahame	Veterinarian	
Bradshaw	Ian	Veterinarian	
Browne	Darryn	Stockman	
Brightling	Tony	Exporter	Elders International
Bryant	Peter	Bedding Supplier	Portland Sawdust and Fodder
Childwell	Peter	Bedding Supplier	Salmon Industries
Daws	Graham	Exporter	Emanuel Exports Pty Ltd
Edwards	John	Exporter	Al Jabri Australia Pty Ltd
Finucan	Michael	Industry	MLA
Ghosheh	Ahmad	Exporter	Ausvision Rural Services Pty Ltd
Gordon	Mike	Exporter	Rural Export & Trading (W.A.) Pty Ltd
Grahame	Bruce	Veterinarian	AQIS
Grandison	Peter	Veterinarian	
Hanson	Kevin	Stockman	
Hendersen	Ian	Stockman	
Hill	Adam	Industry	NTLEA
Jarvie	David	Exporter	Wellard Rural Exports Pty Ltd
Kernan	Paul	Exporter	Ausvision Rural Services Pty Ltd
Lindsay	David	Stockman	
Lowe	Bob	Stockman	
Major	Graeme	Floors	Gecko Special Coatings
McCarthy	Jay	Stockman	
McCarthy	Mike	Veterinarian	
Meerwald	Steve	Exporter	Wellard Rural Exports Pty Ltd
Nickels	Bob	Veterinarian	
Niemeyer	Andrew	Exporter	Charterair
Nissen	Henrik	Ship Owner	Dens Ocean
Noble	John	Stockman	
Ong Sotto	Manny	Ship Owner	Vroon Australia
Paradice	Jim	Veterinarian	Animal Welfare Branch, PIAPH
Piggott	Ron	Stockman	
Johnson	Lloyd	Veterinarian	
Remerez	Fabio	Stockman	
Robertson	Martin	Veterinarian	
Roegar	Haydn	Veterinarian	AQIS
Sherridan	Allan	Veterinarian	Animal Welfare Branch, PIAPH
Simpson	Lynn	Veterinarian	
Stanton	Michael	Exporter	International Livestock Export Pty Ltd
Stinson	Peter	Industry	LiveCorp
Timms	Roger	Industry	LiveShip
Tulloch	John	Veterinarian	