# final report

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Prepared by: Watts, PJ, Yan MJ, Sullivan, TJ, Luttrell, MM, Davis, RJ and Keane, OB

FSA Consulting

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Meat and Livestock Australia Limited
Locked Bag 1961
NORTH SYDNEY NSW 2059

# Feedlot bedding study

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# Abstract

In recent years, there has been increasing interest into the use of various types of pen surface amendments in Australian cattle feedlots. These amendments can include pen surface stabilisation or pen covering with bedding. The impacts that bedding materials such as wood chips and straw have on the health and welfare of lot fed cattle, as well as environmental and workplace safety outcomes, were assessed. This study collated the type and cost of regionally available bedding materials and describes the trials and the use of bedding in feedlot pens during the 2013 winter period. The study shows that bedding can play a useful role in some sections of feedlots but is not viable to cover whole production pens due to cost and handling issues.

# Executive summary

There has been increasing interest over the past several years in the use of bedding materials in Australian cattle feedlots. While the primary interest relates to the potential for improvements in production and animal health and welfare during the wet winter period, there are many other reasons these options are being examined (e.g. heat load amelioration, dag reduction, odour and greenhouse gas emissions reduction). A scoping study (B.FLT.0379 'Bedding material use in cattle feedlots') found that, although there was strong interest from lot feeders, no formal trials of bedding materials had been conducted in Australia and no information about the use of bedding had been collated. Following a presentation of the findings at a Meat and Livestock Australia (MLA)/Australian Lot Feeders Association (ALFA) Animal Welfare Committee meeting, it was agreed that a series of trials would be conducted at feedlots around Australia, with the aim of determining the most appropriate bedding type and placement for particular situations and quantifying, as best as possible, the benefits obtained from its use.

These trials were undertaken as part of this follow-on study. This report documents the type and cost of regionally available bedding materials and describes the trials using bedding in feedlot pens. These trials compared different types of bedding materials and different ways in which they are employed (e.g. full pen coverage, mounds, different depths of material, etc.). Changes in animal health, performance, animal behaviour, pen repair and maintenance costs, plus any workplace health and safety implications, associated with the use of the different bedding materials were requested to be recorded. Where possible, outcomes were compared to those achieved under normal (no bedding provided) pen conditions across a number of feedlot sites representative of the full range of regional locations and environmental conditions encountered in eastern Australia (Queensland to South Australia). Some observational data on animal use of the bedding and changes in behaviour was also collected at ten feedlots.

To improve the performance, health and welfare of confined animals and to provide a safer working environment for staff, pen surface amendment (PSA) has been used in intensive animal facilities. PSA can be grouped into two main categories:

- **Pen surface stabilisation (PSS)** - incorporating stabilising products such as cement or fly ash into the pen surface layer to provide a durable, low-permeability pen surface; and

- **Pen surface covering (PSC)** - distributing bedding materials such as wood chips or straw over the pen surface to provide improved cattle comfort and welfare outcomes.

Typical problems addressed by PSA include the following:

- *Dirty cattle:* manure and mud covering the sides and bellies of cattle (i.e. formation of 'dags').

- *Fatigue:* all livestock need to rest. However, in some circumstances, this is not possible (e.g. during transport) or when the livestock do not prefer to lie on a surface that is too hot, too cold and wet, too muddy or to sharp and uneven. Bedding can provide a comfortable surface for resting.

- *Cold stress:* reduced body temperature as a result of being wet, covered in moist manure and no provision of a clean, dry lying area.

- *Heat stress:* increased body temperature as a result of no pen shade and a dark, hot pen surface that radiates heat.
- *Excess pen surface moisture:* moisture added to the pen surface from manure, which is heavily influenced by stocking density. Rainfall also adds moisture to uncovered feedlot pens.
- *Pen surface hardness:* hard surfaces, such as compacted gravelly-clay mixes and concrete, can lead to hoof and limb injuries. It can also lead to animals and staff slipping, resulting in injury.

Bedding materials have been used in a number of areas of cattle production including:

- Saleyards
- Bedding on live export ships
- Various applications for dairy production
- Over-wintering pens in New Zealand, Ireland, Scotland and eastern USA
- Fully covered feedlots, and
- Open feedlots in Canada and northern areas of the USA.

Numerous studies in the USA and Canada have compared animal welfare, health and performance in bedding and no bedding circumstances. Although the results vary, it is clear that cattle that are provided with clean, dry bedding that they can lie down on perform better and have better welfare outcomes than cattle that are kept in deep, cold, wet manure conditions where they are reluctant to lie down. Bedding can have a positive outcome.

The following attributes can be used to assess the suitability of bedding materials for Australian covered and uncovered feedlots:

- *Absorbency* - the ability or tendency of a bedding material to absorb or soak up liquid;
- *Durability* - the ability of a bedding material to endure constant, regular loadings and resist the stress and force applied, whilst maintaining its structural form;
- *Porosity* - the measure of void spaces (air space) in material which affects drainage;
- *Softness* - the ability of the material to provide a soft standing and lying surface;
- *Recyclability* - the ability of spent bedding (mixture of manure, bedding and soil) to be treated after removal from the pen and reused as 'fresh bedding'. The term, recyclable, can be defined as 'the ability to produce a fresh supply of the same material' (i.e. spent bedding screened to separate manure and bedding, so the bedding can be reused).
- *Availability* – the ability to access the material at an economic value on an on-going basis.

Different types of bedding have been used in cattle housing systems. They include organic or inorganic materials. Organic bedding materials include wood chips, corn stalks, cereal straw; sawdust; rice and almond hulls and recycled manure (composted). Inorganic bedding materials include recycled rubber chip, manufactured rubber mats and sand, which are used in free-stall dairies in Australia, United States and Europe. In Australia, most bedding is "wood chips" but this is a poorly defined term that covers a range of products including:

- Timber harvest residues
- Timber mill processing by-products
- Sawdust
- Timber mill off-cuts
- Wood chips (“typical” wood chips are about 25 mm in length)
- Wood mulch
- Construction and demolition waste
- Recycled pallets

All but recycled pallets were trialled during this study with varying degrees of success. Except for the construction and demolition waste and recycled pallets, markets now exist for all of these timber by-products in Australia. This reduces their availability and increases their costs to the feedlot industry.

Ten feedlots participated in the bedding trials for this project. The aim was to determine the effects of introducing bedding to feedlot pens. Trial details (e.g. bedding materials, experiment layout) have been recorded. Nineteen trial applications were undertaken in total, using varying bedding materials (typical wood chips, wood mulch, corn stalks, construction and demolition waste, timber mill processing by-products and sawdust) and application of bedding materials (across the entire pen or in a central mound). Standardised questions were asked at each participating feedlot. The questions covered details on animal performance, animal welfare/behaviour, environmental issues, manure management issues, workplace health and safety, and any further comments. Due to the relatively short period of the trials and dry conditions, the results of the trials in terms of animal performance and welfare were inconclusive. However, no adverse effects were noted. No negative environmental outcomes were noted. Positive workplace health and safety effects were observed.

Feedlot pen surfaces require on-going maintenance. Pen surface material (clay or gravel) can be removed during pen cleaning and holes in the pen surface can develop due to cattle digging holes or wear adjacent to high traffic areas such as feed bunks and water troughs. Pen surface material can also be removed during pen cleaning if the interface layer is disrupted. It is speculated that the use of bedding materials will protect the pen surface and thus reduce the cost of on-going pen surface maintenance. This could off-set the cost of the bedding material. However, there is no published data available on the cost of pen surface maintenance. It was agreed that this project would include an attempt to quantify the cost of pen surface maintenance. This would be done by surveying major feedlots to obtain data on factors that contribute to pen maintenance costs and, if possible, actual costs on a per head basis. Feedlots with a combined capacity of about 25% of the Australian pen capacity were contacted.

The survey clearly demonstrated that there is little quantifiable or reliable data for pen surface repair and maintenance costs at the surveyed feedlots. This is because these costs were generally absorbed into pen cleaning and manure handling costs. The lack of rigour around cost accounting for pen surface repair works was considered to reflect the ad-hoc basis on which they were conducted and their low priority compared to other routine feedlot maintenance activities. However, annual costs are highly variable and can be significant. Pen surface repair and maintenance costs were crudely estimated to range from $16 to $60/head of pen capacity/year.

The survey results suggested that the use of pen surface covering does reduce pen surface wear and limit the formation of potholes. However, there were insufficient data to determine the cost benefit of reduced pen surface repairs and maintenance due to the use of bedding. A notable comment received from one respondent suggested that bedding actually resulted in a six-fold increase to the time, and presumably the costs, of routine pen cleaning.

The cost - benefits of bedding with regards to pen surface repairs and maintenance could not be determined from this survey. The true value of using bedding in pens would require strict cost accounting for pen cleaning and surface maintenance works (labour, plant and materials), the cost of the bedding material, an evaluation of the cost impacts of bedding on routine pen cleaning, operations and determination of the cattle productivity benefits of bedding.

Wood chip bedding will almost certainly need to be recycled and reused to make this practice economically and environmentally sustainable for extensive use in feedlots. Recycling involves separating the wood chips from the cleaned pen manure so it can be reused on the pens. A trial was undertaken to determine if wood chips could be removed from pen manure using equipment normally available at a feedlot such as vibrating screens or trommels used for manure processing. The objective was to remove wood chips that could be reused in a pen a second time, thus reducing the annual cost of wood chip bedding.

The trial was undertaken at a commercial composting facility that had both a trommel and a dual-screen vibrating shaker. Pen manure from wood chip trials set up at two feedlots was harvested after about six months in pens occupied by cattle. The harvested manure was weighed at the feedlot and transported to the composting facility where it was screened in separate trials using both types of machinery. Samples of the different screened materials were then wet-sieved and dried to manually separate the remaining wood chip from the pen manure to determine the recovery rate of wood chips.

In this trial, both rotating and vibrating screens were tested to determine their effectiveness at recovering wood chips from pen manure. An additional scenario combining the trommel and screens was run to determine if combining the different screening motions (rotational and lateral) could increase wood chip recovery rates. For the combined screening trial, the harvested manure was initially fed through the trommel and the reject material was then fed into the shaker to determine if the combined separation was greater than the individual screening processes.

After sampling, washing, weighing and drying the manure and wood chips from different screening options, it was determined that 48-55% of the wood chips that were placed in the pens were recovered. The missing wood chips were either decomposed or broken down into particles too small to be separated from the manure. Of the recovered wood chips, about 50% was of a size that could be recycled. Hence, 22-24% of wood chips could be recycled back into the pens. However, the recovery was only possible by intensive washing, not by mechanical screening. The conclusion is that typical wood chips (~25 mm size) cannot be recovered and recycled. Using both machines did not improve wood chip removal.

Due to the high cost and poor availability of wood chips and the inability to economically recycle wood chips from pen manure, wide spread use of bedding materials across all pens in feedlots is not viable. However, there are some areas where bedding materials clearly are viable. These include:

- Hospital and sick pens
- Induction pens
- Laneways and high traffic processing areas
- Post-washing pens
- Mounds in production pens in cold, wet winter conditions
- Covered feedlots

The following recommendations are made.

1. The information on the types of bedding materials that are available and their viable roles within a feedlot operation should be extended to industry.
2. Given positive animal performance responses from research in the United States, and the pilot nature of demonstrations in this experiment, further research is recommended to characterise bedding responses and return on investment in Australian feedlots'
3. The practical and economic issues around the use of pen surface stabilisation should be investigated in a commercial feedlot context.

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# 1 Introduction

## 1.1 Background

There has been increasing interest over the past several years in the use of bedding materials in Australian cattle feedlots. While the primary interest relates to the potential for improvements in production, animal health and welfare during the wet winter period, there are many other reasons these options are being examined (e.g. heat load amelioration, dag reduction, odour and greenhouse gas emissions reduction). A scoping study (B.FLT.0379 'Bedding material use in cattle feedlots') completed in 2013 found that, although there was strong interest from lot feeders, no formal trials of bedding materials had been conducted in Australia and no information about the use of bedding had been collated. Following a presentation of the findings at a Meat and Livestock Australia (MLA)/Australian Lot Feeders Association (ALFA) Animal Welfare Committee meeting, it was agreed that a series of trials would be conducted at feedlots around Australia, with the aim of determining the most appropriate bedding type and placement for particular situations and quantifying, as best as possible, the benefits obtained from its use.

These trials were undertaken as part of this follow-on study. This report documents the type and cost of regionally available bedding materials and describes the trials and the use of bedding in feedlot pens. These trials compared different types of bedding materials and different ways in which they are employed (e.g. full pen coverage, windrows, different depths of material, etc.). Changes in animal health, performance, animal behaviour, pen repair and maintenance costs, plus any workplace health and safety implications, associated with the use of the different bedding materials were also recorded.

Where possible, outcomes were compared to those achieved under normal (no bedding provided) pen conditions across a number of feedlot sites representative of the full range of regional locations and environmental conditions encountered in eastern Australia (Queensland to South Australia). The trials involved control and treatment regimes and provided some quantitative assessments of changes in the study parameters. Some observational data on animal use of the bedding and changes in behaviour was also collected.

This report constitutes the Final Report for this follow-on project.

## 1.2 Project objectives

As per the contract, the project objectives are to:

1. Complete an evaluation of the use of bedding materials in Australian cattle feedlots and provide a report that incorporates:

   b. The various bedding options available including material type, size grading, availability, cost and handling aspects;
   c. Case studies on each feedlot at which bedding material has been trialled including the changes in animal health and performance, dag loading, cattle and pen rider safety, condition of the bedding over time, and pen repair and maintenance costs;
   d. An assessment of the economic viability of bedding use, including the practicalities of recycling the bedding materials; and
   e. A "best-bet" recommendation for the use of bedding materials in different circumstances to solve different problems encountered at feedlots.

2. Conduct a workshop with the ALFA Animal Health & Welfare and R&D Committees, together with industry veterinarians and nutritionists, to discuss the findings and agree on any future R&D requirements.

## 1.3 Acknowledgements

This project would not have been possible without the co-operation of several commercial feedlots. Their assistance and feedback in this project is greatly appreciated.

# 2 Methodology

In accordance with the project contract, the methodology used in the study is summarised as follows:

a. Review the various bedding options available including material type, size grading, availability, cost and handling aspects;
b. Review existing bedding use for cattle in different industries in Australia and overseas, and the outcomes on animal production and health, and environmental performances;
c. Conduct bedding trials on a number of feedlots (10 to 12) and obtain results from feedlot staff regarding the effect of the trials;
d. Conduct a survey of a number of feedlots to obtain practical and quantitative data on pen repair, maintenance processes and comparative costs between pens with and without beddings;
e. Conduct trials to separate spent beddings from two feedlots;
f. Provide "best-bet" recommendations for the use of bedding materials in different circumstances to solve different problems encountered at feedlots; and
g. Assess the economic viability of bedding use, including the practicalities of recycling the bedding materials.

# 3 Literature Review

To improve the health and welfare of confined animals and to provide a safer working environment for staff, pen surface amendment (PSA) has been used in intensive animal facilities. PSA can be grouped into two main categories:

- **Pen surface stabilisation (PSS)** - incorporating stabilising products such as cement or fly ash into the pen surface layer to provide a durable, low-permeability pen surface; and

- **Pen surface covering (PSC)** - distributing bedding materials such as wood chips or straw over the pen surface to provide improved cattle comfort and welfare outcomes.

The review is mainly focused on the types and applications of PSC (bedding).

Currently, there are no Australian published data for the effectiveness of different PSA types; how PSC should be distributed or applied within the pen; and whether or not PSA treatments provide better welfare and performance outcomes for lot fed cattle.

Due to the lack of Australian data, this review has considered research outcomes from overseas animal production systems that use bedding materials. More specifically, it provides details of:

- PSA used in intensive animal facilities
- Examples of the use of bedding materials for cattle
- Outcomes following the use of bedding materials in feedlots
- Required attributes of bedding materials
- Types of bedding material available in Australia.

## 3.1 Overview of Pen Surface Amendment used in intensive animal facilities

PSA has been used in intensive animal facilities to improve the health and welfare of confined animals and it can also provide a safer working environment for staff. Animal health and welfare is a broad term that considers the physical and psychological well-being of animals. Poor animal welfare outcomes typically lead to reduced animal performance.

Comfort is a key issue that can compromise the health and welfare of animals as well as animal productivity (i.e. weight gain). Comfort is compromised when animals are exposed to wet manure and mud and their willingness to lie down is reduced and / or as a result of lying down, they become covered in manure and mud. Conversely, comfort can be compromised when a pen surface is clean, hard and dry. For example, during extended periods of high temperatures and no shade, the pen surface can heat up and thus reduce animal's willingness to lie down and / or cause discomfort to animals that lie down. Comfort can also be comprised with hard or sharp surface conditions. Prolonged standing on concrete surfaces can cause foot soreness. Sharp items, such as rough gravel, can damage hooves causing injuries. A lack of comfort leads to fatigue. Fatigue leads to reduced animal performance.

Data from overseas feedlot research and anecdotal evidence from Australian lot feeders suggests that the issues affecting cattle comfort can be eliminated, or at least improved, through the use of PSA. This section investigates the effectiveness of using PSS additives and PSC materials to address the key issues that affect comfort of animals and safety of staff.

### 3.1.1 Typical problems addressed by PSA

The following problems affect animal health and welfare, animal performance and the safety of staff working in feedlot pens:

- *Dirty cattle:* manure and mud covering the sides and bellies of cattle (i.e. formation of 'dags').
- *Fatigue:* all livestock need to rest. However, in some circumstances, this is not possible (e.g. during transport) or when the livestock do not prefer to lie on a surface that is too hot, too cold and wet, too muddy or to sharp and uneven. Bedding can provide a comfortable surface for resting.

- *Cold stress:* reduced body temperature as a result of being wet, covered in moist manure and no provision of a clean, dry lying area.
- *Heat stress:* increased body temperature as a result of no pen shade and a dark, hot pen surface that radiates heat.
- *Excess pen surface moisture:* moisture added to the pen surface from manure, which is heavily influenced by stocking density. Rainfall also adds moisture to uncovered feedlot pens.
- *Pen surface hardness:* hard surfaces, such as compacted gravelly-clay mixes and concrete, can lead to hoof and limb injuries. It can also lead to animals and staff slipping, resulting in injury.

### 3.1.2 Possible solutions

PSS and PSC can be used to solve a range of problems. However, the use of either solution may solve one problem but, in turn, create a new problem that requires a separate solution. For example, resurfacing a feedlot pen by incorporating a PSS such as cement with the existing soil should provide a durable, hard surface that allows efficient drainage of runoff. However, the newly constructed hard surface may affect cattle comfort and lead to foot soreness and leg abrasions during the normal cattle behaviours of standing up / lying down. In this situation, the use of PSS may also require the use of PSC such as wood chips or straw to manage the cattle comfort issue that arose from resurfacing the pen.

The use of both PSS and PSC may produce a synergistic effect, whereby the combined benefits to overall cattle health and welfare; and the safety of staff is greater than the individual benefits of each treatment.

#### 3.1.2.1 Pen surface stabilisation (PSS)

Feedlots can use PSS to construct a solid pen surface, either during the initial construction phase or as a remedial action after the pen surface has broken down. Good planning and design of a new feedlot pen can negate the need to use a PSS. For example, provision of sufficient pen slope and selecting non-expansive, non-dispersive clay with sufficient strength for the construction of the sub-grade and surface should achieve a solid pen surface. However, in lieu of access to suitable soil or not being able to provide sufficient slope, a PSS could be incorporated with the in-situ soil to achieve a solid pen surface (both options require compaction).

PSS, such as fly ash, has been trialled successfully in the United States. At a beef cattle feedlot in Iowa, ash was incorporated into the soil at the pen surface. This resulted in increasing the soil strength, which resulted in keeping the cattle out of the mud, as their weight was better supported (VanDevender & Pennington 2004). Sweeten (1996) compared two ash treatments (crushed bottom ash and fly ash incorporated into the pen surface) in feedlot pens in the US and found bottom ash to be the better choice for stabilising pen surfaces. Other stabilisers such as cement or chemical stabilisation can also achieve the same outcome (i.e. a solid pen surface) but there is little information available on their use in feedlots.

In Australia, PSS has been successfully used to prepare flooring in poultry sheds. A soil stabilised base for the poultry shed floor is used. This enhances dust control and allows for efficient litter / manure removal with machinery. Clearly, poultry sheds and cattle feedlots are two very different systems. However the basic principles and drivers of floor stabilisation are the same for the two industries.

Materials, such as fly ash, have been used in the northern United States as ‘soil stabilisers’ to create a low permeability pen surface that optimises pen drainage, especially to address the ‘spring thaw’ of accumulated ice and manure laying on pen surfaces. Soil stabilisers could be used to provide pen surface conditions conducive to good animal welfare, health and performance, and manure management.

**Fly ash**

Fly ash is a by-product of coal combustion. It consists of the fine particles that rise with the flue gases. These particles are filtered from the flue gases before they reach the chimneys of coal-fired power plants. Ash which does not rise during combustion is termed bottom ash. When fly ash and bottom ash are mixed together, they are known as coal ash.

The composition of fly ash depends on the source and makeup of the coal being burned. However, all fly ash includes substantial amounts of silicon dioxide ($SiO_2$) (both amorphous and crystalline) and calcium oxide (CaO), both being endemic in many coal-bearing rock strata. Fly ash may also include arsenic, beryllium, boron, cadmium, chromium, hexavalent chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with dioxins and PAH compounds. In some cases, the combusted coal will produce fly ash with high levels of toxic constituents that qualify it as a hazardous waste that is unsuitable for sale and presents limited reuse opportunities. For this reason, some bottom ash is usually mixed to ensure levels of toxic constituents within the product qualify as non-hazardous waste.

Two classes of fly ash are defined by the American Society for Testing Materials (ASTM) C618 – Class F and Class C. These contain differing amounts of calcium, silica, alumina, and iron. Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water, to react and produce cement compounds. Class C fly ash generally contains more than 20% lime and is ‘self-cementing’.

**Fly ash use in US feedlots**

Anderson et al. (2004) undertook research into the use of fly ash for stabilising the pad of a North Dakota feedlot (Photograph 1). They found that a feedlot pad constructed from a mixture of soil and 15–25% fly ash provided a very stable surface with a relatively low material and construction cost. The price of fly ash was well below that of traditional construction materials such as asphalt, cement or lime. They suggested that the keys to successful use of fly ash are:

- mixing with an optimal soil type such as clay or clay-loam, minimal sand or gravel
- uniform distribution (blending) of soil and fly ash through sufficient tillage
- effective compaction

- adequate moisture content
- final compaction completed within two hours of placement.

Other examples of the use of fly ash in feedlots are Amosson (1997), Chirase et al. (1999) and Greenlees et al. (1998).

The potential risks associated with using fly ash are:

- health impacts from dust: Fly ash is a very dry material with a powder-like consistency. It creates dust when handled. Staff working with the material should wear appropriate personal protective equipment.
- health and environmental impacts from heavy metals: Fly ash may contain high levels of heavy metals which pose a risk to human and animal health and the surrounding environment if fly ash contaminates uncontrolled stormwater runoff.

**PHOTOGRAPH 1 – PEN WITH FLY ASH (ON RIGHT) AND PEN WITHOUT FLY ASH**

Pond ash is fly ash that has been flushed to evaporative ponds for storage. The evaporative pond is subsequently dewatered and the pond ash is excavated for disposal. Pond ash is valuable as a structural material, but it is different from fly ash because much of its cementing properties have been lost in storage. Therefore, pond ash may be an adequate compromise between hard-surface materials, such as cement and fly ash, and a highly erodible, ductile material like soil (Woodbury et al. 2013).

**Cement and chemical soil stabilisers**

Cement stabilisation is a mixture of soil and measured amounts of Portland cement and water compacted to a high density (Adaska 1990). Granular soils are preferred because they pulverise and mix more easily and require less cement than fine-grained soils. Cement concentrations range from <4% to 16% by dry weight of soil (Adaska 1990).

Chemical stabilisers, including lime, are mixed with soils (e.g. expansive clays and granular materials) that are used for road surface and sub-grade construction and other areas that are exposed to frequent machinery and animal traffic. Soil stabilisation is the permanent physical and chemical alteration of soils to enhance their physical properties. Approximately 1-2% of stabiliser is required in the mix depending on the physical characteristics of the soil (Vorobieff 2004). The chemical stabiliser is integrated into the soil material as either a powder or liquid. A large number of chemical and organic commercial stabilising products are available in Australia. There are a variety of chemical stabilisers that are classified as polymer (hydrophobic), organic (requires soil plasticity), ionic (electrically charged), salts (hydroscopic) and biological (consumes clay) (Vorobieff 2004).

Stabilisation can increase the shear strength of a soil, control the shrink-swell properties, lower soil permeability and plasticity, increase the load-bearing capacity (as measured by the California bearing ratio (CBR)), prevent water infiltration, minimise pot-holing and dust generation. Other potential benefits may include a reduced pavement thickness, elimination of excavation and material handling / transport; and eliminate the need for a sub-grade.

Proper design and testing is an important component of any stabilisation project. This allows for the establishment of design criteria as well as the determination of the proper chemical additive and admixture rate to be used to achieve the desired engineering properties. Ambient environmental and soil conditions may cause stabilising agents to perform poorly. For this reason, the Australian Stabilisation Industry Association has recommended a set of testing protocols to determine the type and rate of chemical stabilisers to be used (Vorobieff 2004).

There is little information available on the use of cement or chemical stabilisation of soil in feedlots. Parker et al. (2004) investigated the engineering properties of cement stabilised feedyard surfacing in Texas. They recommended the incorporation of 15% of cement into the fine sandy loam soil available at the site. In Australia, 2-3% cement is usually recommended. The higher level recommended by Parker et al. (2003) is partly due to the soil type but more due to the need to resist freezing – thawing cycles experienced annually. Winter snow conditions are not a design criteria for the vast majority of Australian feedlots. In terms of economics, Parker et al. (2003) calculated that the total cost of installing a 150 mm thick cement-stabilised surface was US$5.82/$m^2$, which compared favourably to costs of fly ash surfacing (US$8.28/$m^2$) and concrete (US$29.90/$m^2$).

Cement or chemical stabilisation has not been used in Australia feedlots. However, its use is common in the broiler industry where soil stabilisers such as ‘Weslig 120’ have been used successfully with a 2-3% cement incorporation to form a durable base in Australian broiler sheds. While these surfaces are not exposed to rainfall, they are exposed to moist poultry manure and bedding, and heavy machinery during the removal of spent bedding. Anecdotal evidence suggests that they are very stable, last for many years and cost about one third of the cost of an equivalent concrete floor. Photograph 2 shows equipment working on the floor surface. Photograph 3 shows very little surface erosion after many years of cleaning compared to a concrete apron at the end of the broiler shed.

**PHOTOGRAPH 2 – MACHINERY WORKING ON CEMENT-STABILISED BROILER SHED FLOOR**

**PHOTOGRAPH 3 – CEMENT-STABILISED FLOOR SURFACE ADJACENT TO CONCRETE APRON**

#### 3.1.2.2 Pen surface covering (PSC)

PSC is used in both covered and uncovered feedlots to provide improved health and welfare outcomes for cattle. The common problem that impacts both covered and uncovered feedlots is excessive moisture on the pen surface from manure deposited by the cattle and / or rainfall that has not dried by evaporation or drained out of the pen (specific only to uncovered pens). Bedding materials, such as wood chips, straw, sawdust, rice husks, almond hulls, composted manure, sand and rubber chip have been used to cover the whole pen or specific parts of the pen to provide a clean, dry resting place for cattle to lie on. Each bedding material has different physical attributes that determine its suitability and effectiveness. The physical attributes considered in this review are absorbency, durability, porosity, softness and recyclability.

Guo et al. (2011) compared different PSC types (sawdust, wheat straw, hay, rubber mulch, water) at a US feedlot to assess their dust-control effectiveness. The study found that water and hay reduced dust emissions by the greatest amount. In extreme wet and cold conditions, as experienced by some US feedlots, PSC is important in order to maintain cattle performance. Research carried out by the Carrington Research Extension Centre in North Dakota, looked at different PSC materials – cereal grain straw, corn stover, and soybean residue. The study determined that straw and soybean residue delivered better performance than corn stover, as cattle tended to eat the corn, which reduced the energy intensity of their diet and hence liveweight gains (Anderson et al. 2011).

## 3.2 Pen Surface Covering material characterisation

### 3.2.1 PSC attributes

The following attributes can be used to assess the suitability of bedding materials for Australian covered and uncovered feedlots:

- *Absorbency* - the ability or tendency of a bedding material to absorb or soak up liquid;
- *Durability* - the ability of a bedding material to endure constant, regular loadings and resist the stress and force applied, whilst maintaining its structural form;
- *Porosity* - the measure of void spaces (air space) in material which affects drainage;
- *Softness* - the ability of the material to provide a soft standing and lying surface;
- *Recyclability* - the ability of spent bedding (mixture of manure, bedding and soil) to be treated after removal from the pen and reused as ‘fresh bedding’. The term, recyclable, can be defined as ‘the ability to produce a fresh supply of the same material’ (i.e. spent bedding screened to separate manure and bedding, so the bedding can be reused).
- *Availability* – the ability to access the material at an economic value on an on-going basis.

### 3.2.2 PSC physical characteristics

In addition to the attributes listed above, there are some physical characteristics of PSC materials that should also be considered.

**Bulk Density**

The bulk density of PSC materials, measured as kg/m$^3$, is highly variable and dependent on the type of material, moisture content, particle size and degree of compaction. Bulk density can affect transport costs and material handling costs.

**Particle size distribution (PSD)**

Particle size distribution is a measure of the percentage of a material sample that is within a certain size range. Particle sizes can range from small (<1 mm) to large (>100 mm). A material is described as poorly graded if there is a small range of particle sizes. For example, sawdust, which is mainly composed of small particles of the same size, is a poorly graded material. A well-graded material has particles with a wide range of particle sizes. Later sections of this report show PSD graphs for certain PSC materials (see Section 6.4.3).

### 3.2.3 PSC cost and availability

Clearly, cost and availability are important parameters when considering suitability for use in feedlots. Materials that are expensive to purchase or transport to site may make them an unviable alternative.

In the past, by-products from the timber industry were a waste product that was difficult to dispose of. Nowadays, the timber industry has created markets for most by-products. Sawdust and wood shavings are used as animal bedding materials, particle board construction or combustion. Wood chips are used for landscaping, paper production and for combustion (bioenergy). At present, the demand for these by-products usually exceeds the supply.

## 3.3 Examples of bedding use for cattle

The following sections describe experiences of pen surface amendment in various sectors of the cattle industry.

### 3.3.1 Australian saleyards

Crafter et al. (2006) were commissioned by MLA to qualitatively evaluate the benefits to health and welfare of cattle kept in bedded pens at saleyards in Australia's southern beef zone. Saleyard stakeholders were surveyed to identify the strengths and weaknesses of several soft flooring materials including wood chips, wood chips / sawdust mix, sawdust, rubber matting, sand and natural earth / gravel. The survey also collected information on set-up and maintenance costs, ease of cleaning, material life expectancy, impact on the environment and OH&S issues.

The researchers reported that 75% of cattle buyers would prefer to buy stock from a saleyard that provides soft-flooring rather than unbedded, concreted pens. Saleyard buyers indicated a preference for wood chips and sawdust bedding materials. There were concerns about dust, mud and slush with some materials, and the longevity of rubber matting and gravel.

In their literature review, Crafter et al. (2006) found that providing soft flooring at saleyards posed little risk of increased spread of contagious disease between cattle, and from cattle to man. The risk is manageable if soft floor pens are well-designed and maintained, and if pen use is appropriate (i.e. segregating age groups and cattle to designated pens or areas at the saleyards). A well-designed pen with soft flooring can significantly improve the welfare of cattle sold through saleyards and these benefits outweigh the increased biosecurity risk that the small likelihood of disease spread poses.

Flooring quality and management have a direct effect on foot and leg health, and saleyard hygiene. Foot soreness, lameness and claw lesions can result from excessive exposure to hard and abrasive flooring, particularly if the cattle's feet are not accustomed to the flooring. Rushen (2004) found that Canadian dairy cows walk faster on softer surfaces and their gait also improves, compared with walking on concrete. Crafter et al. (2006) believe that soft flooring in Australian saleyards achieves the same outcomes for beef cattle. They found that soft flooring improved general welfare and reduced the incidence of foot soreness of cattle in saleyards with concrete floors using the following treatments:

- 100-150 mm depth of wood chips (at least 75 mm as the minimum) with a maximum chip length of 100 mm
- >75 mm depth of wood chips and sawdust mix.

Rubber matting, sand and screened earth and gravel also provided better welfare compared to cattle standing directly on concrete. Gravel should be screened to produce a uniform particle size and also remove elongated or jagged particles that cause foot soreness.

Animal welfare and OH&S are two very big challenges facing all operators in the meat and livestock industry. Crafter et al. (2006) identified that saleyard floors must aim to provide:

- a safe environment for man and beast
- adequate thermal insulation
- an appropriate degree of softness and friction
- low risk of abrasion
- efficient access for maintenance and cleaning
- a low biosecurity risk
- efficient manure management.

### 3.3.2 Live export

Australian cattle are routinely transported short and long distances by sea to markets such as Indonesia and the Middle East. These journeys can last up to 25 days so the welfare of livestock must be monitored and protected to prevent injuries and mortalities. The housing conditions and listing (swaying) of the ships carrying the livestock can create an unsafe and unsanitary environment for animals. The supply of bedding and adherence to suitable stocking densities in each pen allow cattle to rest more comfortably than cattle kept on a bare steel floor (Banney et al. 2009). Bedding also absorbs moisture from the manure produced by cattle in transit which helps reduce dags, and potentially cold stress, of the animals.

Cattle weighing 450 kg can produce approximately 26 kg of manure per day (≈85% moisture) (Banney et al. 2009). A build-up of this material over a long journey will create both unhealthy and unsafe conditions for cattle in transit. Ammonia volatilising from these wastes can cause respiratory problems in cattle when inhaled over long periods of time in confined spaces. Bare steel floors, covered in wet manure, reduce the traction of hooves on the surface resulting in cattle falling on their knees causing abrasions and shorn hooves; and forces cattle to lay in deep manure that cakes onto their hides (Banney et al. 2009).

The most important characteristic of transport bedding is absorbency (Banney et al. 2009). Highly absorbent bedding such as straw and sawdust provide suitable betting materials for sea transit, not only for absorbency but for management by on-board stockmen. Softwood shavings and hay are also effective absorbent materials (Banney et al. 2009). Another factor in bedding choice is storage capacity and bulk density of the bedding material. Sawdust is seen as the optimum choice for export ships when all factors are considered, but it must be kiln-dried to remove the majority of residual moisture before use.

### 3.3.3 Dairies

Bedding is used in a range of dairy systems, including freestalls, loose housing and wintering systems.

The Australian and US dairy industries provide bedding for cows that are permanently confined in freestalls and loose housing systems, and also in loafing areas where cattle can stand, lie down or rest. Another system is a dairy feedpad, which is an area in which cows are provided supplementary feed (i.e. partial mixed ration), before moving onto pasture. O'Keefe et al. (2010) explained the use of bedding within these types of dairy farming systems using following descriptions.

*Freestall dairy:* These can be open-air, partially or fully enclosed structures in which dairy cattle are housed and provided with feed and water. They can be used to house dairy cattle for extended periods and include a bedding area for cattle to lie down, and possibly a loafing area for cattle to stand. The term 'freestall' refers to the bedding area where cattle are allocated specific cubicles (stalls), which they may enter to lie down. Feed and cow alleys, and bedding areas are cleaned regularly (usually daily) to maintain cow comfort and health.

*Loafing area* is a formed surface adjacent to the feedpad complex, or alleys on the feedpad. Its primary purpose is to provide a separate section away from the feeding area for cattle to stand, lie, ruminate or idle.

*Loose housing dairy:* Alternatives, such as straw-bedded yards or compost-bedded pack, offer excellent cow comfort and fewer injuries than freestall housing although the cows can be dirtier, and there may be a higher incidence of mastitis and some forms of lameness. The key difference is that the stalls and stall alleys are replaced with a bedded pack that is aerated at least twice daily. The bedded pack consists of a mixture of solid manure and adsorbent organic bedding (i.e. straw or sawdust).

*Feedpad dairy* is a permanent feedpad with a bedded area for the cattle to lie down in an unrestricted space. The bedded area may be deep bedded straw or compost bedded pack.

Good management is the key to the success of compost dairy systems. They require excellent pack and ventilation management; appropriate stocking rates and bedding use; and excellent cow preparation procedures at milking time. The bedded pack needs to be aerated twice daily to refresh the surface and enhance microbial activity in the pack (Endres & Janni 2008).

### 3.3.4 Out-wintering systems

In the high rainfall regions of New Zealand, Ireland, and the UK, some dairy and beef farms use wintering systems to restrict grazing over the wettest months of the year. These systems fall into two categories:

- Out-wintering pads (OWPs), or 'standoff pads' are wood chip pads overlying an impermeable subsoil or lining, with drainage pipes delivering effluent to a pond or tank.
- Corrals, which are wood chip pads overlying freely draining soil and with no impermeable lining.

The generic term "wood chip pads" can be used to describe both systems. However, it is important to note that for this discussion, the majority focuses on OWPs. Photograph 4 shows a typical out-wintering pad for dairy cattle in New Zealand. These systems can provide useful design and management data for Australian lot feeders who are interested in using PSC at their feedlots.

Figure 1 shows a typical cross section of a New Zealand OWP. The OWP includes a drainage system to divert contaminated runoff from underneath the bedding into an effluent system and has a wood chip bedding thickness of 0.5 to 1.0 m. In Ireland, the minimum typical wood chip bedding depth is 2 m, while in Scotland it is 0.4 m (Smith et al. 2010).

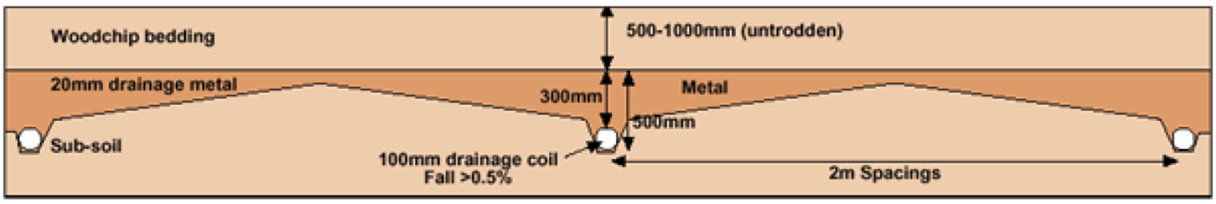



**FIGURE 1 – CROSS SECTION OF TYPICAL NEW ZEALAND OWP**

Typical wood chip bedding materials used at OWPs vary throughout the literature, with the most common types being timber by-products and wood mulch (see Sections 3.5.1 for bedding material definitions). The size of wood chip bedding material is important. Smaller size promotes animal comfort, however can result in dirty animals and drainage issues

(Longhurst et al. 2013, Smith et al. 2010). Coarse chips (5-10 cm) encourage rapid drainage and a clean pad surface. A compromise can be reached, with a base layer of coarse chip covered with a surface layer of fine chip (EBLEX 2011).

Out-wintering pads can provide animal welfare and production benefits in terms of improved daily liveweight gain and feed conversion; generate a more manageable effluent which can reduce impacts on surface water if uncontrolled discharges occur; and lower ammonia emissions (Dumont et al. 2012). In addition, wood chip pads can help reduce the incidence of lameness in animals, by reducing the wet muddy conditions experienced on concrete pads (EBLEX 2011, Menard et al. 2009). These benefits could potentially be seen for Australian feedlots using similar bedding systems and management strategies.

Dumont et al. (2012) investigated the effect of typical wood chip size on animal welfare and found daily liveweight gain was highest for cattle housed on the finest grade (sawdust) while it was lowest for the coarsest grade (5 to 10 cm wood chip). Chadwick et al. (2009) had similar results, with daily liveweight gain greatest for animals bedded on sawdust, and lowest for the coarsest wood chip (7.5 cm). EBLEX (2011) reported on liveweight gain and feed efficiency of finishing steers out-wintered on wood chip pads relative to indoor housing, and found that animal performance was improved significantly using the OWP system. This performance improvement trend was also reported by the Scottish Agricultural College (2007) and French and Hickey (2009). The Scottish Agricultural College (2007) report suggests that the reason for the increased performance efficiency is due to cattle experiencing less heat stress when housed outdoors. It did not assess changes in performance using different bedding materials.

Effluent (including drainage) produced from OWP systems had significantly less polluting potential than conventional cattle effluent (Chadwick et al. 2009, EBLEX 2011). Fenton (2012) determined that using an OWP in conjunction with best management practices for effluent control, reduced N loss in effluent runoff and drainage by 40% compared to traditional effluent management at dairy feedpads.

**PHOTOGRAPH 4 – OUT-WINTERING PAD FOR DAIRY CATTLE IN NEW ZEALAND**

Ammonia emissions from manures is largely driven by surface processes, with the rapid hydrolysis of urea from thin layers of manure on concrete surfaces. Smith et al. (2007) determined that where the exposure of manure and air is reduced, ammonia emissions decrease significantly. They suggested that the rapid drainage of effluent from the surface of the wood chip layer on the OWP would lead to reduced $NH_3$ emissions. Smith et al. (2010) conducted a technical review of the literature on wood chip pads for out-wintering cattle. They suggested that the $NH_3$-N emissions reported by Vinten et al. (2006) on wood chip pads were between the range reported for grazing cattle and cattle housed on concrete floors. Hill et al. (2006) reported 25% less $NH_3$-N emissions from OWPs than slatted cattle housing.

Therefore, OWPs can offer significant benefits in terms of animal health, welfare and production; and they potentially reduce the nutrient loading of effluent and lower ammonia emissions; when compared to conventional dairy and beef housing systems. These benefits may potentially be seen for feedlot cattle housed on wood chips in Australia, due to the similarities between the two systems.

### 3.3.5 Northern US uncovered feedlots

Bedding materials are widely used in beef feedlots in Canada and northern US states because the colder climatic conditions are uncomfortable for the cattle (Miller et al. 2006). Bedding materials are typically either cereal straw or wood chips (Photograph 5). They are added to pens in winter to provide bedded and un-bedded areas. The bedded areas are referred to as ‘packs’ or ‘mounds’. They promote animal comfort and cleanliness by keeping cattle drier and warmer, as the bedding pack partially composts releasing heat (Miller et al. 2006, Olson et al. 2006). For a typical Canadian beef feedlot, the bedding pack mound occupies the greatest surface area of the pen (Miller et al. 2006). Bedding may be continually added to the pen during winter depending on the amount of dags on animals and the conditions of the bedding pack (Olson et al. 2006). Fresh bedding material is usually added at least weekly, and gradually dispersed and compacted by the confined animals (Miller et al. 2006).

**PHOTOGRAPH 5 – STRAW BEDDING IN A NORTH DAKOTA FEEDLOT**

### 3.3.6 Fully covered feedlots

In some circumstances, feedlots can be fully covered (i.e. with a roof that excludes rainfall). Such feedlots are typical in areas of heavy rainfall (e.g. Indonesia) or areas with severe, cold winters (northern USA and Canada). For covered feedlots, bedding is essential to both absorb manure moisture and to provide a soft flooring surface. Sawdust, straw and corn stalks have been used successfully in covered feedlots (see Photograph 6 and Photograph 7).

**PHOTOGRAPH 6 – SAWDUST BEDDING IN COVERED FEEDLOT IN INDONESIA**

**PHOTOGRAPH 7 – CORN STALK BEDDING IN COVERED FEEDLOT IN NEBRASKA**

## 3.4 Outcomes from the use of bedding in cattle feedlots

When bedding materials are used in feedlots, it would be expected that there would be a positive animal welfare / health / performance outcome. However, there may also be changes in the environmental performance of the feedlot and manure characteristics. The following sections provide data on these outcomes.

### 3.4.1 Impact of bedding on the moisture content of the feedlot pad

Pad moisture content has important implications for the environmental performance of cattle feedlots. Stocking density has a significant influence on pad moisture content. Every day, cattle add moisture to the pen surface by manure (faeces and urine) deposition. Figure 2 shows the estimated moisture added to the pen surface each year for cattle of various weights kept at different stocking densities. This simple calculation assumes that cattle excrete 5% of their liveweight each day and manure is 90% moisture. Heavy cattle (750 kg) stocked at 10 $m^2$/head can add over 1200 mm of moisture per year (3.3 mm/day). During winter, this can exceed the evaporation rate (depending on location) and the pad remains moist. Under these conditions, odour problems are likely to develop. On the other hand, light cattle kept at 20 $m^2$/head contribute less than 1 mm of moisture/day. In summer, evaporation readily removes this moisture and dust can become a problem. Therefore, the choice of stocking density should achieve a balance between a pen surface that is too dry and one that is too wet. This is dependent on local climate, cattle size and other factors.

Following the USA example, the first feedlots in Australia stocked pens at about 10 $m^2$/head. Experience has now shown that this stocking density is only appropriate in drier zones (annual rainfall <500 mm/yr). A stocking density of about 15 $m^2$/head is now considered more appropriate for feedlots in the main grain growing regions of Australia.

The effect of added moisture is a particular issue for covered feedlots where, for economic reasons, stocking densities are high (around 4-6 $m^2$/head). Even though rainfall is excluded, the added moisture can exceed 2000 mm/yr and pen surfaces quickly become wet. Under these circumstances, the use of a bedding material to absorb the moisture is essential. This bedding should be removed and replaced every few weeks.

Hence, due to the excess application of moisture to the pen surface, the most likely application of bedding for manure moisture control is in open pens in winter-dominant rainfall zones and in covered feedlots. The function of the bedding is to:

1. absorb as much moisture as possible to provide a drier pen surface
2. minimise the formation of dags on the animal hide
3. provide a dry and/or warm resting area within a pen that is mainly wet.

### 3.4.2 Animal production, health and welfare outcomes

A range of animal productivity measures have been used to assess the benefits of using bedding in animal systems. This section outlines how bedding can be used to improve cattle performance and provide better welfare outcomes.

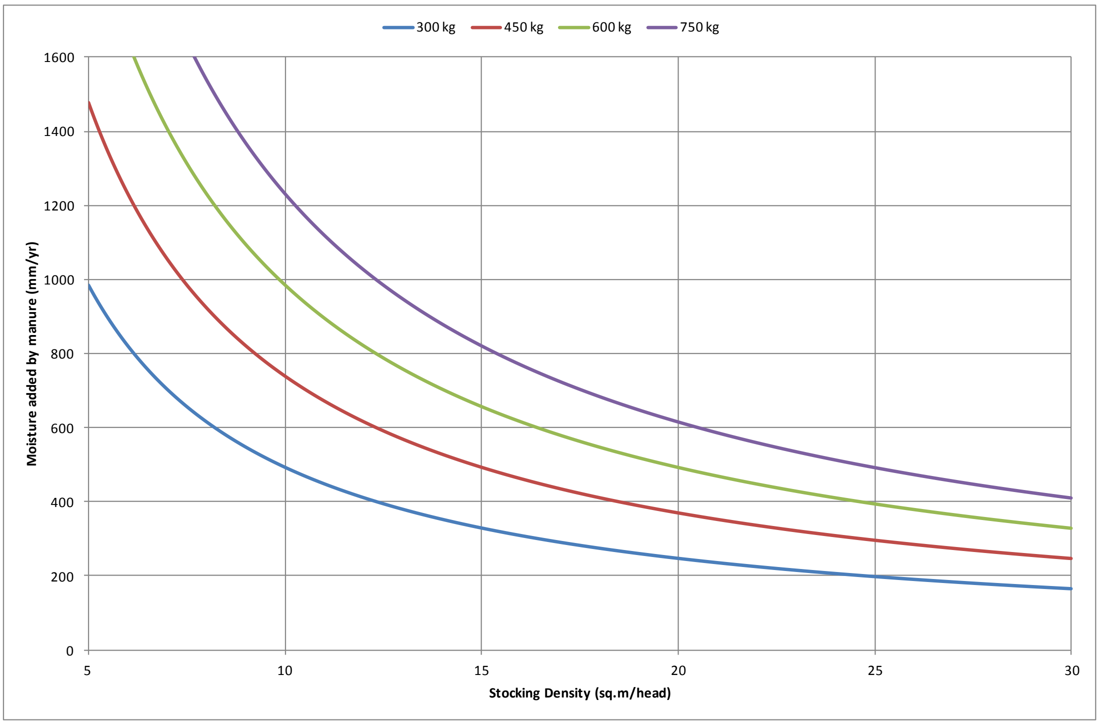



**FIGURE 2 – EFFECT OF STOCKING DENSITY AND CATTLE LIVEWEIGHT ON MOISTURE ADDED TO PEN SURFACE**

### 3.4.2.1 Animal performance

Cattle performance and carcass quality can be measured using various indicators including average daily gain (ADG), feed conversion ratio (FCR), marbling score, dressing percentage, meat quality rating and ultimately sale price (Mader & Colgan 2007). Optimum ADG is achieved when cattle convert their feed ration to muscle and fat efficiently, progressively over their period of time on feed (National Research Council 2001). Efficient feed conversion is compromised when cattle expend energy battling against cold temperatures, injury, disease and muddy conditions under foot (NFACC 2012).

Cattle confined to muddy pens and paddocks have a tendency to eat less frequently. In cold climates, cattle may accumulate mud on their hide (matted within the hair), which reduces their ability insulate themselves (Mader & Colgan 2007). A study of 414 cross-bred steers, exposed to different pen densities and bedding volumes, found that cattle achieved higher ADG when afforded bedding and higher gain when pen densities decreased (Mader & Colgan 2007). Pastoor et al. (2012) found that higher ADG was achieved in housed cattle kept on bedding than in cattle kept in open lots. Pastoor et al. (2012) suggests that cattle fed in bedded confinement buildings may have reduced metabolic requirements and show improved cattle comfort. The results of two trials conducted in South Dakota found that providing straw bedding at approximately 1 kg /head/day during the feeding period improved ADG by approximately 7% and FCR by approximately 6% (Birkelo & Lounsbery 1992, Stanton & Schultz 1996). The benefits of bedding were not observed in the early part of these studies, but rather in the last 90 to 100 days of each study (Mader 2003).

In feeding trials at the Carrington Research Centre in North Dakota, Anderson et al. (2011) found that FCR, ADG, marbling score and dressing percentage were all improved by providing bedding in pens. In their research, the cattle in the bedded pen were provided with 1.5 kg of fresh straw head/day over the four-month winter period. After the trial, the researchers suggested that, for every 25 mm of mud depth in the pen, 0.5 kg/head/day of bedding should be added. The bedded pen yielded better cattle performance than the unbedded pen, including increased ADG (+0.39 kg/day), marbling score (+13%) and dressing percentage (+1.5%) (Anderson et al. 2011). Mader & Colgan (2007) also found that FCR, marbling scores and dressing percentage improved when straw bedding was supplied.

A further consideration in selecting a suitable bedding material is that cattle may choose to eat straw or corn stubble bedding (NFACC 2012), but it is unlikely that they will eat wood chips. Incomplete consumption of their full ration may impact cattle performance.

#### 3.4.2.2 Animal welfare

Welfare is determined by the health and behaviour of the cattle, both of which are affected by housing systems. Once cattle are confined to any degree, comfort becomes critically important in ensuring good welfare. Management is the key to success in any system. If poorly managed, any system can result in significant health and welfare issues, such as lesions on legs and joints, inappropriate behaviour and dirty cattle, leading to lameness and poorer performance (O'Keefe et al. 2010).

Bedding can prevent muddy conditions developing on pen surfaces and can offer animals a comfortable resting place in wet conditions. The welfare of cattle must be closely managed in feedlot pens as any injury, discomfort or ruminal acidosis can impact on feed intake, feed conversion and weight gain. The causes of discomfort to cattle in feedlot pens are lameness, pen floor mud, disease, temperature stress, painful procedures and unsuitable nutrition. A number of these welfare issues can be attributed directly or indirectly to pen surface conditions. Lameness has a significant effect on the welfare of cattle because it results in pain and reduces the ability of cattle to move and therefore to access feed and water (NFACC 2012).

Confined cattle need adequate space to walk, lie, feed and water to minimise the effects of bullying of younger and less dominant stock. Bullied cattle will often drink and eat insufficient quantities. Overcrowding will also increase bullying and reduce lying time. Cattle that rest for insufficient periods often show higher levels of lameness (Krawczel et al. 2008). Provision of bedding for confined cattle can eliminate or mitigate stress, injury, dirtiness and the need to isolate and treat sick animals.

Cattle that are unable or unwilling to rest on the pen floor can cause muddy conditions under hoof through persistent movements / pacing on the surface. Firstly, this causes energy loss as animals try to pull their hoofs from the mud. Dijkman & Lawrence (1997) found that cattle used about 20% more energy in muddy conditions compared with walking on smooth ground. Slippery, muddy concrete aprons around feed bunks and water troughs may deter cattle from consuming feed and water (Stokka et al. 2001). Pens that incorporate earthen or bedded mounds create a comfortable area out of the mud for cattle to sit or lie (Mader 2003). In studies with dairy cows, Fisher et al. (2003) found that cows preferred to lie on wood chips and concrete surfaces rather than muddy areas. They also found that cows exposed to bare concrete flooring had a lower bodyweight and gait length at the end of the four day trial, compared to those on wood chips.

#### 3.4.2.3 Hoof and upper limb injury

Most lameness arises from conditions affecting the hoof. An important aspect of lameness management is the type of surface the cattle walk on and the moisture content of that surface. Surfaces should not be excessively abrasive, slippery or continuously heavily contaminated with mud or manure (Cook et al. 2004).

Cattle that are continuously walking or standing in slurry manure (urine and faeces) and mud can be predisposed to excessive hoof hydration, heel horn erosion, wear, infection and lameness. It is preferable for hooves to be able to dry out on a daily basis (Borderas et al. 2004).

Lameness accounted for 16% of all feedlot health problems in past surveys of Kansas and Oklahoma feedlots (Griffin et al. 1993), while a US beef quality audit in 1999 reported that lameness was observed in slaughterhouse holding pens in about 31% of cattle (Roeber et al. 2001). NFACC (2012) reported that the most common causes of lameness were foot rot, necrosis, injury and infection. Increased incidence of infectious lameness is associated with pen conditions that affect skin integrity, in particular wet or muddy conditions and chronic exposure to moisture (NFACC 2012, Stokka et al. 2001). In addition, steers diagnosed with foot rot gained weight more slowly and needed more days on feed to reach processing weight (Tibbetts et al. 2006). Hoof health was said to be better for beef cattle provided with straw or other bedding under foot rather than a bare slatted floor (Tessitore et al. 2011). Somers et al. (2003) found a higher incidence of hoof disorders in dairy cattle housed on bare concrete or slatted sheds compared with those using straw bedding. The use of out-wintering pads for beef and dairy cattle can reduce the incidence of lameness of cattle compared to cattle housed on concrete floors (EBLEX 2011). Prevention of lameness in cattle not only helps to optimise daily gain and overall performance, it also reduces the need for medications to treat the problem.

Conditions of the upper limb, such as hock lesions, knee lesions and adventitious bursa may also occur. These are often due to inappropriate bedding type or thickness.

#### 3.4.2.4 Dags and animal cleanliness

The presence of manure and mud on the hides of feedlot cattle changes from a cold stress or heat loss issue in the feedlot to a hide cleanliness issue when cattle are ready for processing. In Australia, these accumulations of pen surface material, manure and / or mud, are known as ‘dags’ while in North America they are called ‘tag’ (Jordan et al. 1999, Pointon et al. 2012). A major concern from an abattoir’s perspective is the potential for bacterial contamination of the live animal to be transferred to the carcase (Reid et al. 2002). A Canadian beef quality audit found that 43% of beef cattle had mud or manure on the hide at time of slaughter (Van Donkersgoed et al. 2001). In Australia, cattle must be presented clean for slaughter. Abattoirs are often reluctant to permit cattle into their facilities if there is significant mud or manure on them (MLA 2010). Hence, dag removal from cattle hides generally occurs before the animals leave the feedlot.

Dags can lead to bacterial contamination of the carcase during processing. Reid et al (2002) found traces of *E coli 0157* and *Salmonella spp.* on 22% and 10% respectively, of 90 carcasses tested. The highest instance of these bacteria occurred on the brisket area which is where dags are most abundant (Van Donkersgoed et al. 2001) and where the hide is cut during processing. Elder et al. (2000) found a non-motile variant of *E coli 0157* was prevalent on cattle pre and post processing, and also on carcases after treatment with an anti-microbial agent. Carcases can be robustly cleaned with chemicals, post stunning, in an attempt to reduce the contamination risk (MLA 2010). Nou et al. (2003) demonstrated that chemical de-hairing as part of a commercial operation did reduce the incidence of hide-to-carcase contamination with pathogens such as *E. coli O157*. However, this procedure requires significant investment, can slow down line speed, may expose staff to noxious chemicals and is difficult with larger cattle compared to sheep or lambs (MLA 2010). It is better to simply prevent dag formation.

At Australian feedlots, dag removal (cattle washing) can entail a combination of soaking with cold water to soften up the material, followed by cleaning of the hides with toothed metal scrapers and or high-pressure hosing. When washing is undertaken in winter, a long time gap between soaking and scraping can result in cattle losing significant heat to compensate for the chilling effect. Busby & Strohbehn (2008) calculated that up to 14 kg of manure, mud and other material could be attached to a hide and this would have to be scraped off to meet Australian standards. Removal of dags can put cattle under stress just prior to slaughter and could result in poorer meat quality or 'dark cutting' (MLA 2010). Hence, resting of cattle after washing can be desirable but not if further dag formation occurs in the post-washing holding pen.

#### 3.4.2.5 Dag prevention options

There are a number of options to prevent the build-up of dags or manage muddy, under-hoof conditions in outdoor feedlot pens. Pen surface stabilisation is one method. Conditions that promote runoff reduce the likelihood of excessive muddy conditions forming after rainfall events (Anderson et al. 2004). A reduction in mud volume should correlate to less dags and generally improve hide cleanliness. Hence, more frequent pen cleaning and pen cleaning immediately before the winter rainfall period are options for dag reduction.

Excess moisture on feedlot pen surfaces, existing as mud or pools of water, can be soaked up by bedding materials such as straw and sawdust which can be applied before or after rainfall events. Straw can be continually added to the pen over time, as required, using standard machinery or a straw cannon that fires shredded material from outside the pen (Anderson et al. 2011). Cattle can aid the dispersal and soaking action of straw as they drag the material around the pen with their hooves (Mader & Colgan 2007).

Sawdust has been used in feedlot pens but its effectiveness in reducing dags is limited as it can quickly become part of the mud and manure layer through its high surface area and absorbency (Iowa Beef Centre 2010). The combined manure, mud and sawdust can then attach to the hair of cattle. A similar experience is reported in Australia for rice hulls.

Wood chip is another bedding material that can be used to eliminate or mitigate the formation of dags. Like straw, wood chips can provide a bedded area on which cattle can walk and lie, allowing minimal contact with mud and manure on the exposed pen surface

(NFACC 2012). This has the benefit of not allowing the cattle to walk upon and churn up the pen floor. Anecdotal evidence also points to the ability of wood chips to clean manure and mud from cattle without penetrating the hide. Wood chips shape, size and sharpness effect how they contact with the body of cattle. Manure and mud can be scraped from the cattle through their regular motions of sitting, lying and standing on wood chips.

#### 3.4.2.6 Dag assessment methods

Two methods can be used to assess the amount of mud and manure attached to the hide of cattle. The first is to measure the weight or volume of material after it is removed. The other is to visually assess, and rank or score the dag or mud coverage (see Table 1). Weighing or determining volume of scraped-off material may not be feasible in a feedlot situation as it would require capital and time investment, and probably slow down throughput of cattle in the wash station. Jordan et al. (1999) quantitatively assessed a mud score system that can be applied to individual cattle or an entire pen.

#### 3.4.2.7 Cold and heat stress

Heat loss in winter affects the performance of cattle in unbedded pens since wet mud and manure cakes to the hide of cattle requiring them to burn energy to counteract the chilling effect (NFACC 2012). Degen and Young (1993) found that cold-adapted steers aged five years produced about 16% more heat energy standing in 0.5 m of water, compared to those not standing in any water. The animals were also sprayed with water to mimic rainfall and their rate of heat production further increased by 39-56%. While temperatures in the lot feeding areas of Australia do not reach the lows seen in parts of the northern United States, heat loss can still be an issue for cattle introduced quickly to a much colder environment than they are used to (NFACC 2012). Tolerance to cold is age dependent and very young calves are much more susceptible to cold stress than older weaned animals (Carstens 1994). Gonyou et al. (1979) concluded that shivering in cattle was more associated with acclimatisation than actual temperatures. Supplying bedding in a feedlot pen provides animals with a place to lie down that is partially raised above the mud and wet pen surface.

Bedding also provides a comfortable place for cattle to rest upon during warm conditions. Tuomisto et al. (2009) found that dairy bulls spent about 75% of their time resting on straw bedding in an uninsulated barn in summer and the rest of their time lying on the concrete floor. Heat stress can cause cattle to crowd together, possibly through fly annoyance or for seeking mutual shade. This may reduce airflow and evaporative heat loss (Nienaber & Hahn 2007). Distributing bedding over a greater area or the entire pen surface could encourage cattle to rest further apart and counteract this problem.

While Australian feedlots do not experience the extremely cold temperatures and snow fall of some of their northern United States counterparts, seasonal rainfall in a number of regions of the country is sufficient to create persistent muddy pen conditions. Temperatures have reached lows of between -5 and -10°C in lot feeding regions of Victoria, New South Wales and Queensland. Coupled with persistent or one-off rainfall events, these temperatures could create cold stress environments that impinge on cattle welfare and performance.

Confined cattle in muddy pens will generally develop ‘dags’. The presence of wet dags on cattle, coupled with exposure to persistent cold conditions, can lower their core body temperature, which may lead to cold stress and reduced performance.

**TABLE 1 – EXAMPLE OF MUD SCORE (DAG) RATINGS**

| Mud Score | Description | Image |
|---|---|---|
| 1 | no dag, clean hide |  |
| 2 | small lumps of manure attached to the hide in limited areas of the legs and underbelly |  |
| 3 | small and large lumps of manure attached to the hide covering larger areas of the legs, side and underbelly |  |
| 4 | small and large lumps of manure attached to the hide in even larger areas along the hind quarter, stomach and front shoulder |  |
| 5 | lumps of manure attached to the hide continuously on the underbelly and side of the animal from brisket to rear quarter |  |

### 3.4.3 Environmental and manure management outcomes

The use of bedding in feedlots can have an impact on important environmental and amenity issues such as odour, dust, and runoff quality and quantity. It can also impact on the quality of manure harvested from pens and the ability to successfully reuse manure / spent bedding. This section outlines how bedding can be used to manage or eliminate the aforementioned environmental and amenity issues; and how it impacts manure and spent bedding management. If the use of bedding is to be routinely adopted in Australia, evidence of successful environmental outcomes will need to be provided to regulatory agencies to gain licensing acceptance.

#### 3.4.3.1 Odour

Odour and dust are persistent issues for beef cattle feedlots. Odour and dust can be carried up to 1 km from the feedlot in optimum conditions and this can create nuisance and public health issues for nearby households and townships (Sweeten & Miner 1993). Moisture on the pen surface is the most significant factor in limiting dust entering the atmosphere. It also has the effect of enhancing odours, adding to the plume that surrounds a feedlot or other intensive livestock establishment (Nicholas et al. 2004). Bedding will alter the moisture gain and loss characteristics of the feedlot surface, as well as the porosity of the manure pack. This will probably alter odour emissions. Bedding that promotes pen surface drying and encourages runoff is likely to reduce odour emissions. Bedding that absorbs and retains manure moisture on the surface may increase odour emissions if anaerobic conditions occur. Bedding will also reduce the exposure of dry, dusty surfaces to wind and the agitating effects of cattle hooves.

Feedlot odour studies usually involve sampling at the pen surface under various environmental conditions. However, no literature was found on odour measurements from bedded pens that conform to a national standard such as the AS/NZS 4323.3-2001 outlined in Hudson et al. (2009). A recent study by Spiehs et al. (2013) measured the effect of various bedding materials on the concentrations of odorous volatile organic compounds (VOCs) and *E. coli* at beef feedlots. Corn, soybean and wheat straw, switchgrass, wood chips, wood shavings, corn cobs, and shredded paper were all used as bedding for two six-week periods. Based on VOC concentrations in each of the materials at the end of both six-week periods, the wood shavings had the lowest calculated odour activity values while the corn cobs and shredded newspaper had the highest. Bedding material is mostly used during wet winter months (Mader 2003) when odour emissions are likely to be higher due to the effect of moisture on the emission rate (Nicholas et al. 2004). Watts et al. (1994) found that odour emissions from a feedlot pen surface were sixty times greater when wet. Feedlot pens without bedding can allow runoff to collect in potholes (Olson et al. 2006) and behind manure walls under fences, increasing the possibility of moisture enhanced odour. Pens bedded with straw and wood chips can absorb both moisture (McAllister et al. 1998) and VOCs such as volatile fatty acids, phenols and other known odorants and prevent them entering the atmosphere (Mackie et al. 1998). The absorption of odorants and urea to the bedding materials would result in these contaminants being transferred to the manure stockpile / composting area, rather than leaving pen in runoff and entering the holding pond.

While there is considerable speculation about the effect of bedding on odour emissions, there does not appear to be any studies completed that have used olfactometry methods accepted in Australia.

#### 3.4.3.2 Dust

Dust is a major cause of respiratory problems for feedlot cattle. Large amounts of airborne particles are emitted from feedlots in dry and windy areas. Dry, pulverised pen manure has the potential to become air-borne dust particles and can cause respiratory problems in animals, staff and the surrounding community. Yu el al. (2012) modelled the effects that dust, temperature and extreme climate variables on the performance of animals. Dust was found to significantly lower the sale weight of cattle, whilst the temperature data were inconclusive. A variety of medical complaints are reported to be more common in people who live near intensive piggeries, than in people without this exposure. Von Essen & Auvermann (2005) reported that respiratory health effects, including symptoms of pulmonary disease and lung function test result abnormalities, have been described in workers employed in intensive livestock feeding operations. Airborne substances include dust containing endotoxins and other microbial products as well as ammonia, hydrogen sulphide and a variety of volatile organic compounds.

Dust can be controlled through pen cleaning, wetting down of the pen surface, or potentially by placing bedding material such as wood chips or straw over the pen surface. Bedding materials soak up and retain moisture and help consolidate the manure on the surface of a feedlot pen (NFACC 2012). The moisture retained could help delay the drying out of manure and, in turn, prevent dust entering the atmosphere. Cattle are more likely to rest on a bedded area than on an uncovered surface, wet or dry, and this could prevent excessive movement of livestock within pens that is known to contribute to dust generation (Fisher et al. 2003, Tuomisto et al. 2009).

#### 3.4.3.3 Runoff quantity and quality

Runoff from cattle feedlot pens occurs when rainfall hits the hard compacted layer over the pen surface. This layer, combined with slope, restricts infiltration of rainfall, forcing runoff out of pens and into drains (Olson et al. 2006). MacAlpine (1996) measured higher infiltration rates in newly-constructed pen floors with no compacted layer than in a three-year-old pen floor with manure and compacted layers. Runoff rate is affected by manure build up. This creates a sponge-like layer that can delay or regulate the release of water from pens (Watts & McKay 1986). Depressions created by cattle hooves in wet manure layers can retain water during rainfall events, which is eventually released when the ridges retaining the water collapse (Lott 1995). Lott (1995) also found that rough feedlot pen surfaces stored twice the rainfall of smooth surfaces before runoff began. Large potholes or depressions also influence the release of water from pens where retaining ridges do not breakdown over time.

A comprehensive study of feedlot runoff by Olson et al. (2006) during the period 2008-2009 found that bedding material, either straw or wood chips, delayed runoff compared to exposed pen surfaces. In the first year of the study, bedding type had a significant effect on the time to collect 2, 4, 6, and 8 L of runoff, with longer times recorded to collect runoff from straw-bedded pens than from wood chip bedded pens. The time to record 2 and 12 L of runoff were roughly 22% and 10% higher for straw and wood chips, respectively. The differences between straw and wood chips were reversed during the second year but not significantly. Abstraction of water by bedded pens was 62% and 44% higher than bare pen floors. The overall results demonstrate that bedding material can help control runoff. The results also point to a higher absorption of water by straw compared to wood chips. During a 120-day trial at the same feedlot, McAllister et al. (1998), cited in Olson et al. (2006), found that cattle were bedded 1.4 times more often with straw than with wood chips. Greater wood chips density meant that three times the weight of wood chips was added compared to straw, but wood chips had a much higher water content, 45.5% compared to 12.1%. When dry weights are considered, 1.9 times more wood chips (by mass) were used compared to straw. These data show that straw has potential to be more absorbent than wood chips bedding but other issues need to be considered. These include durability, porosity, longevity, availability and transport costs (where volume, not weight, is usually the basis for transport cost).

Bedding materials act as a reservoir for major nutrients such as nitrogen and phosphorus. These nutrients can be stored long term and removed to a composting or recycling site instead of entering the effluent treatment and land irrigation systems. Trials (see Section 3.3.4) have shown that switching from a conventional housing system to an OWP can result in a significant reduction in the nutrients (N and P) contained in the effluent (Chadwick et al. 2009, EBLEX 2011, Fenton 2012). Bedding material is also useful in the attenuation of zoonotic pathogens, preventing them from entering the effluent system. Using a rainfall simulator to investigate the effect of rainfall on feedlot pen surfaces, Miller et al. (2006) found that bedding stored higher concentrations of chemical and biological material than the underlying pen surface. Bedding packs were major reservoirs of nitrogen**,** soluble salts, and total coliforms. The type of bedding material (wood chips or straw) and the pen location changed the storage capacity. Intensive rainfall events can cause a flushing of nutrients into the effluent system, where as a standard manure covered pen might produce a more gradual, uniform release over time (Olson et al. 2006).

Clearly, any PSA will alter the quantity and quality of runoff from an open feedlot pen surface. PSS is likely to increase runoff volumes by creating a hard, smooth impermeable surface. PSC are likely to retain moisture on the surface and thus reduce runoff. No data exists in Australia to quantify these changes. PSA are also likely to alter runoff quality but no data exists to predict these changes.

## 3.5 Types of bedding material for pen surface covering (PSC) in Australia

Pen surface covering, or bedding, is used in overseas animal production systems, usually to increase animal comfort and performance, reduce odour production and intensity, and minimise the deterioration of earthen pen surfaces resulting from frequent animal traffic and / or persistent wet conditions (O'Keefe et al. 2010). Different types of bedding are used. They include organic or inorganic materials. Organic bedding materials include wood chips, cereal straw; sawdust; rice and almond hulls and recycled manure (composted). Inorganic bedding materials include recycled rubber chip, manufactured rubber mats and sand, which are used in free-stall dairies in Australia, United States and Europe.

Sections 3.5.1 to 3.5.3 describe the types different categories of bedding materials and examples of their use in this trial. Section 3.5.4 report on the availability and cost of a number of proposed bedding materials that are available in Australia.

### 3.5.1 Timber by-products

Wood chip is a generic and poorly-defined term used when referring to bedding materials. There are a wide range of timber by-products that fall under this generic term, each with different properties. The following sections describe the different types of timber by-products, their origin and their attributes. The timber by-products can be categorised from their position in the life cycle of timber. They are:

1. Timber harvest residues
2. Timber mill processing by-products
3. Sawdust
4. Timber mill off-cuts
5. Wood chips
6. Wood mulch
7. Construction and demolition waste
8. Recycled pallets

During this project, virtually every type of timber by-product was trialled in a commercial feedlot.

#### 3.5.1.1 Timber harvest residues

When timber is harvested in the forest, residues are produced. These include bark, leaf, branch strippings and tree tops from trees stripped during the cutting and stacking processes and pre-commercial thinnings. Hardwood bark is usually stripped in the forest and left there. However, softwood (pine) bark is usually stripped at the timber mill.

From a PSC material viewpoint, this material has a well-graded PSD which includes many small readily degradable particles (e.g. leaves) that easily become integrated into the pen manure. This material could not be recovered from the manure but might aid subsequent composting by changing the C:N ratio of the pen manure (see Section 0). This material has a low bulk density and, while it is cheap to purchase on-site, it is expensive to transport. Hence, this material would only be suitable if the forest is close to the feedlot. Unfortunately, there are not many Australian feedlots located close to commercial plantation timber forests.

One feedlot is this study used blue-gum residue that has been tub-grinded (Photograph 8). The bedding was sourced directly from the blue-gum company at \$10 - \$15/m$^3$. The material was used once only and removed from the pen when cleaning occurred. Another feedlot was offered the material shown in Photograph 9 but did not use the material due to concerns about the sharpness of some of the splinters.

Photograph 10 shows timber harvest residue in use at one of the trial feedlots. The site has a relatively high and strongly winter-dominant rainfall which results in pens being wet for several months throughout the winter. During wet winters, the pen manure becomes a wet slurry. This not only causes a heavy dag load on the cattle but reduces animal comfort in cold windy conditions as the cattle do not like to lie in the wet, cold manure slurry. Photograph 10 shows a mound of forest harvest residue bedding is placed longitudinally in the centre of each pen with enough area for the cattle to rest on the mound. The bedding system has been used for several years now to provide a dry, comfortable area for cattle to lie in each pen during winter. Fresh bedding is added throughout the winter depending on the weather conditions. This is a similar use of bedding to that in northern US states and Canada (Photograph 5).


**PHOTOGRAPH 8 – BEDDING OPTION – BLUE-GUM HARVEST RESIDUE**


**PHOTOGRAPH 9 – BEDDING OPTION – FOREST HARVEST RESIDUE**

**PHOTOGRAPH 10 - WET CONDITIONS WITH TIMBER HARVEST RESIDUE AS A BEDDING MOUND**

### 3.5.1.2 Timber mill processing by-products

Around half of the wood arriving at Australian mills for processing becomes a finished product. The remainder is residue or waste. Residue from sawmilling includes bark, sawdust, log edges, off-cuts (shorts), wood chip, chip fines, planer shavings, and post peel. Post peel is the waste that originates during the formation of cylindrical timber posts, typically referred to as 'treated pine posts' which are used widely in the Australian viticulture, horticulture and dairy industries.

Timber shavings are produced when rough sawn timber is dressed to specific section sizes. Shavings tend to be quite dry as timber is usually seasoned before moulding. Shavings usually break down into small particles. They have been used as bedding material in poultry farms and can readily be used for bioenergy (burning).

Off-cuts are produced at timber mills when finished material is docked to a specific length. Typically, off-cuts are less than 250 mm long (Photograph 11). As there is a limited market for this waste, off-cuts are often processed by a wood chipper or tub grinder before off-site sales. In both processes, fine material (chip fines) is a by-product.

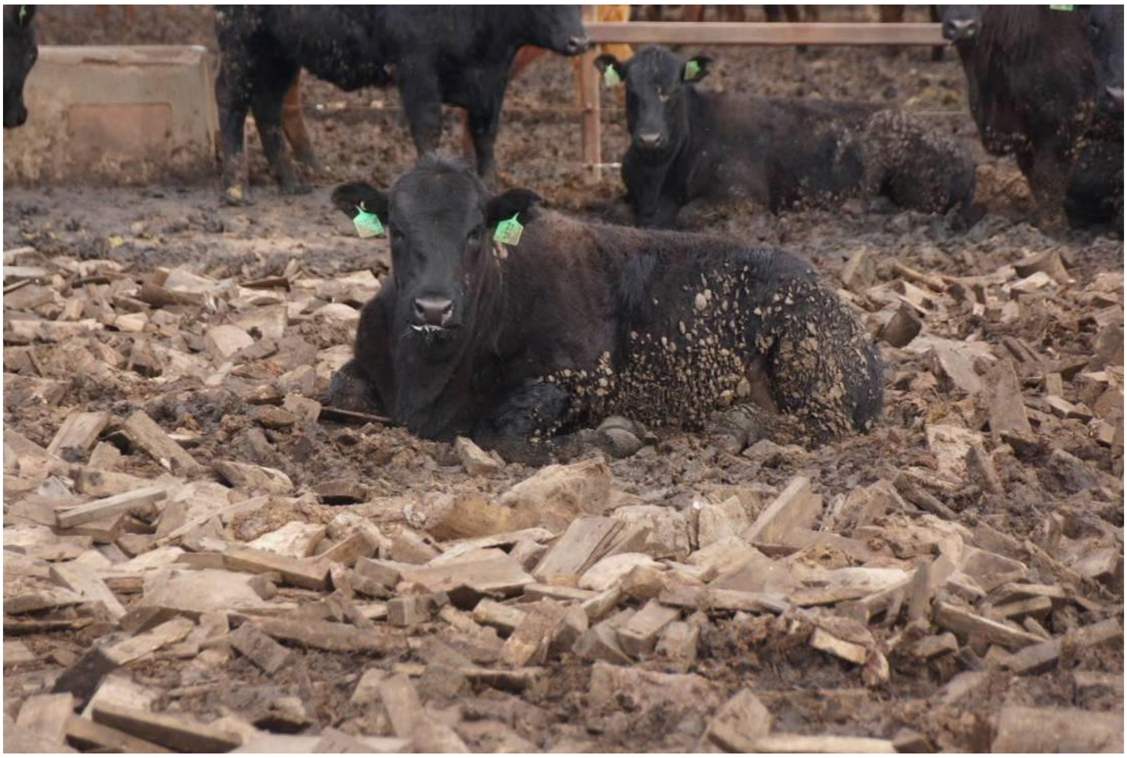
In this study, one lot feeder used large timber off-cuts in their pens as bedding material. Photograph 12 shows off-cuts in a pen. The off-cuts were up to 300 mm long and 150 mm wide. This feedlot is in a winter-dominant rainfall zone. After the effect of added moisture from cattle is taken into account, this feedlot experiences winter months where there is a net addition of moisture to the pens and they remain wet for a prolonged period, usually from May through to August. During the trial period, the weather was slightly drier than average. Initially cattle avoided the off-cuts and walked around the edges of the pen (Photograph 13).

However, they soon adapted to the material and were willing to lie on the off-cuts (Photograph 14) in preference to lying in wet manure.

**PHOTOGRAPH 11 – BEDDING OPTION – TIMBER OFF-CUTS**

**PHOTOGRAPH 12 – TIMBER OFF-CUTS BEING USED ACROSS THE ENTIRE PEN**

**PHOTOGRAPH 13 –TIMBER OFF-CUTS AND CONCRETE FEED BUNK APRON**



**PHOTOGRAPH 14 – CATTLE LYING ON TIMBER OFF-CUTS**

#### 3.5.1.3 Wood chips

Wood chips are produced both at timber mills and during the disposal of trees removed in urban and infrastructure situations (e.g. road construction). The market for wood chips is paper manufacture, landscaping or a biofuel (i.e. combustion). In these situations, it is desirable to have chips of uniform size. Wood chippers typically are designed to produce chips that are 25 mm to 30 mm in length. Chip fines and over-size chip are often screened from the final product.

Typical wet bulk densities of Australian softwoods wood chips of range from 0.27-0.35 t/m$^3$ for pine and increase to 0.50 t/m$^3$ for hard woods like Australian blue gum (Korman, 2006, Woodgas 2013). The bulk density of wood chips of the same timber can vary widely depending on moisture content and particle size. As the particle size of the wood chips decreases, the bulk density will increase, due to the minimisation of void space within the sample. Similarly, by increasing the moisture content of the timber, the bulk density increases. Bulk density will increase with smaller particle sizes and / or higher moisture content. The typical bulk density of pine and blue gum wood chips in Australia ranges between 350-500 kg/m$^3$.

Wood chips can hold as much as 200% of its weight in water, depending on the kind of timber used, its age and chip size. Wood chips from green timber can have a moisture content of about 50%. Hence, the use of green wood chips in a feedlot will have limited moisture absorbency. A batch of well-graded, smaller wood chips has a higher surface area to volume ratio and better water holding capacity (i.e. increase absorbency) than wood chips with larger pieces. McLean and Wildig (2000) noted that smaller chip size and uniform grading had a significant impact on the cost of material, as more labour and processing time was required to screen the wood residues to achieve a uniform, well graded batch. The porosity of wood chips ranges from 50-60% (Ragland et al. 1991).

In this trial, wood chip costs varied from \$15 to 42.5/m$^3$ delivered, whereas sawdust was about \$3 to 10/m$^3$. In south-east Queensland, one feedlot had wood chip available at \$20/m$^3$ delivered. This material had a bulk density, as delivered, of about 380 kg/m$^3$.

Photograph 15 is an example of a typical wood chip product, 25 mm x 25 mm. Several feedlots applied bedding materials in post-washing pens only. Photograph 16 and Photograph 17 are examples of typical wood chip use in a post-washing pen. Photograph 18 shows detail of the wood chips in a post-washing pen. This shows that the particle size of the wood chip reduces over time as the chip split laterally.

Other feedlots used wood chips in production pens, hospitals, laneways and induction pens.


**PHOTOGRAPH 15– TYPICAL WOOD CHIP**

**PHOTOGRAPH 16 - TYPICAL WOOD CHIP USED IN A POST-WASHING PEN**

**PHOTOGRAPH 17 –RECENTLY WASHED CATTLE IN POST-WASHING PEN DURING RAINFALL**


**PHOTOGRAPH 18 - TYPICAL WOOD CHIP IN POST-WASHING PEN (DETAIL)**

### 3.5.1.4 Wood mulch

Wood mulch is produced when wood by-products are processed in a tub-grinder rather than a wood chipper. This produces a product consisting of shattered and broken splinters rather than uniform short chips. Tub-grinders can process a wider range of timber shapes (e.g. fine limbs and branches) than chippers, which require a uniform feed of straighter, longer timber.

One feedlot was offered wood mulch to use as bedding (Photograph 19). This material was timber trash that had gone through a tub grinder and was available at $15/m$^3$. However, the splinters were quite sharp and the lot feeder felt that this material might lead to hoof injuries. The wood mulch was not used even though it was cheaper than wood chip from the same saw mill. However, at another feedlot, a similar product was offered and used (Photograph 20). That feedlot did not report any increase in hoof injuries as a result of using the wood mulch. The cattle soon compacted the wood mulch down into a uniform surface with few exposed sharp splinters. Photograph 21 shows the wood mulch used after six months of cattle occupancy compared to an adjacent pen where wood chips were used at a depth of 200 mm. Ultimately, there was little difference between the pens but the wood mulch was much cheaper. No re-useable product could be recovered from either pen.

**PHOTOGRAPH 19 – WOOD MULCH PRODUCED BY A TUB GRINDER**


**PHOTOGRAPH 20 –WOOD MULCH USED IN FEEDLOT TRIAL**

**PHOTOGRAPH 21 –BEDDING PENS - LEFT (200 MM WOOD CHIP), RIGHT (WOOD MULCH)**

#### 3.5.1.5 Sawdust and shavings

Sawdust from green timber typically has a moisture content of about 35% to 45%. Crafter et al. (2006) reported that sawdust had an average bulk density of 225 kg/m$^3$ and an absorption rate of 2.5 kg of water per kg of sawdust. Sawdust with smaller particle sizes retains more water than batches with larger particle sizes. Particle density influences porosity, and particle size influences the capacity of sawdust to retain moisture (Maharani et al. 2010). Over 90% of sawdust particles are <4.8 mm in size. Shavings from seasoned timber typically has a moisture content of about 10% to 15%.

A 2011 study found that sawdust and shaving was sold by sawmills in a range around \$10/m$^3$ (\$40/t dry) excluding transport. The low bulk densities of sawdust and shavings make them expensive to transport. Photograph 22 shows sawdust bedding used in a partially-covered feedlot as a part of this trial.

**PHOTOGRAPH 22 – SAWDUST BEDDING USED IN COVERED FEEDLOT**

#### 3.5.1.6 Construction and demolition waste

The disposal of construction and demolition waste is an on-going issue in urban areas. Timber waste is generated during building construction and when buildings are demolished. Depending on the type of buildings being demolished, timber can represent 10% to 30% of the waste. While there is a market for recycled timber, only large straight intact timber is suitable. With the increasing use of large machinery to demolish buildings, the amount of suitable timber for recycling is reducing. It is also difficult to recycle timber products such as particle board and laminated beams.

Most municipal bodies now charge a fee to dispose of construction and demolition waste into landfills. The adoption of the Queensland Waste Management Strategy in 2011 introduced a waste disposal levy of $35/t on landfill.

Unlike timber by-products produced during timber production, which all have established markets, construction and demolition waste produces large volumes of timber that could be used for bedding and this would be a cheaper disposal method than paying landfill charges. To that end, two feedlots in this study were offered construction and demolition waste. In both cases, the timber was contaminated to varying degrees with plastic, cloth and metal fragments (nails, plastic electrical fittings) (Photograph 23 and Photograph 24). In one case, the lot feeder was too concerned about potential injury to the cattle to trial the material. In the other case, the lot feeder used the material. Photograph 25, Photograph 26 and Photograph 27 show the use of the construction waste in a post-washing pen. The construction and demolition waste that they had spread in the pens did have some nails protruding. Although this material was contaminated with non-timber items and included some large pieces of timber, the lot feeder reported that the material had no adverse impacts and worked acceptably as a means of preventing dag development after the cattle had been washed. While this did not result in any injuries, it is important to acknowledge this issue as a potential cause of injury.

**PHOTOGRAPH 23 – BEDDING OPTION – BUILDING CONSTRUCTION WASTE**


**PHOTOGRAPH 24 – BEDDING OPTION – BUILDING SITE WASTE (NOT USED)**


**PHOTOGRAPH 25 – CONSTRUCTION AND DEMOLITION WASTE IN POST-WASHING PEN**


**PHOTOGRAPH 26 – CONSTRUCTION WASTE - POST-WASHING PEN**

**PHOTOGRAPH 27 – CONSTRUCTION WASTE - POST-WASHING PEN**

#### 3.5.1.7 Recycled pallets

Another type of waste that fits under the category of construction waste is pallet waste. One 2011 study looking at potential materials for cogeneration (combustion) reported that about 120 000 tonnes of pallet waste was dumped annually in Sydney landfills at a cost of $120/t in dumping fees. The dumping fees made the material attractive from a cogeneration perspective but there were concerns that the paint and preservatives used in pallets might lead to air pollution issues. Wood pallets and packaging are used in business-to-business trade and logistics throughout Australia. Although businesses exist in wood pallet repair and reuse, these are often located in urban area and large quantities end-of-life wood pallets are still generated and sent to landfill.

Shredded recycled pallets could provide wood chip which may be several centimetres in length, but perhaps only a few millimetres in thickness (Smith et al. 2010). Wood packaging that is used to import or export goods may have been subject to immunisation with heat, sterilisation with fumigant or treatment with permanent preservatives for quarantine purposes (EPA 2012). If immunisation with heat or sterilisation is undertaken with non-residual gas methyl bromide, it is not a barrier to reuse or recycling. However, use of material that has been treated with permanent preservative for use as animal bedding is not recommended (EPA 2012) and is actually not permitted in many jurisdictions, including NSW. Wood packaging may also become contaminated with chemicals spilled during use and transport. Wood packaging that is contaminated should be separated and disposed of appropriately, however this needs to be taken into consideration when sourcing recycled pallets.

No feedlot in this trial used pallet waste although this material may be viable and could be further investigated.

### 3.5.2 Crop reside by-products

There are several crop residue by-products that have been used as PSC materials.

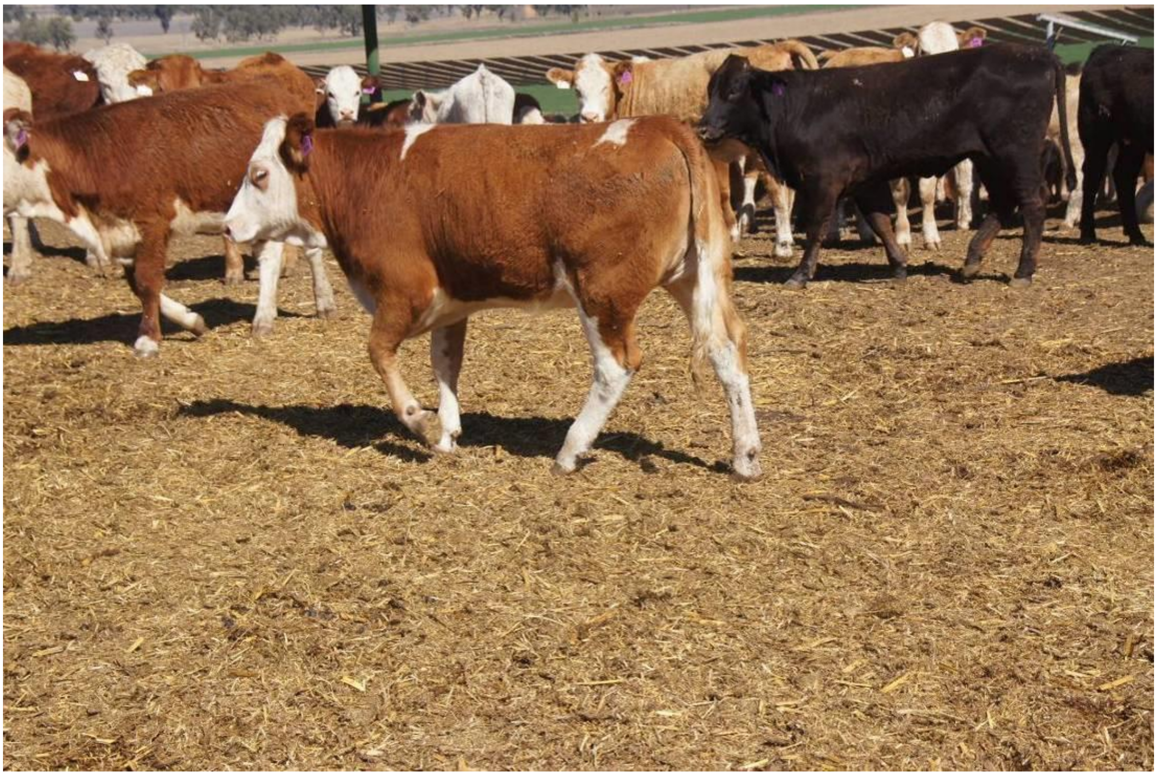
#### 3.5.2.1 Wheat and barley straw

Photograph 5 shows the use of straw in a feedlot pen. Straw is typically baled into large round or rectangular bales, producing a dense bale that is easily stacked and safely transported. Wheaten straw baled into large rectangular bales in northern Victoria achieved an average bulk density of 150 kg/m$^3$, based on a bale 2.4 m long x 1.2 m high x 0.9 m wide; and an average bale weight of 400 kg. Zhang et al. (2012) analysed wheaten straw and determined it had the following properties: moisture content of 5-8%, bulk density range of 98-177 kg/m$^3$ and porosity range of 46-84%. Cereal straw is used widely by the Australian pork industry as a bedding material in deep litter pig sheds.

No feedlots in this trial used wheat or barley straw. However, this material has been used successfully in Australian feedlot hospital pens to provide soft, comfortable and dry lying conditions for sick livestock.

#### 3.5.2.2 Corn stalks

Corn stalks can be used for bedding material as per wheat straw (Photograph 7). This is more common in the USA where corn production is considerably higher. In the USA corn stalks are more commonly referred to as "corn stover". Corn stalks / stover consists of the leaves and stalks of maize plants left in a field after harvest. Photograph 28 shows corn stalks being used at an Australian feedlot during this trial. The bedding was used in induction pens for young cattle that were new to the feedlot and had just finished long road trips. The corn stalks provided a dry, soft surface which encouraged tired cattle to lie down and rest.



**PHOTOGRAPH 28 - CORN STALKS USED IN INDUCTION PEN**

### 3.5.2.3 Rice hulls

Rice hulls are produced in the first step of the milling process. It is the rice husk that has been removed from the grain. Rice hulls contain approximately 20% silica and large percentage of a structural polymer called lignin. The blend of silica and lignin make rice hulls very resistant to water penetration and fungal formation, and an excellent thermal insulator. However, these characteristics mean that rice hulls have limited moisture retention capacity. Rice hulls typically have a moisture content of 5-15% and an average porosity of 85% (within a pile). Rice hulls have a low bulk density of only 70-110 kg/m$^3$, although this can be increased to 145 kg/m$^3$ when vibrated, or 180 kg/m$^3$ when formed into briquettes or bales (Rice Knowledge Bank 2013). Hence, they require large volumes for storage and transport, making transport over long distances uneconomical.

No feedlot in this trial used rice hulls. However, rices hulls have been previously trialled in feedlots in northern New South Wales and were found to be an impractical solution. The hulls quickly blend in with the manure and become embedded in the manure and dag on the animal's coat. Their low bulk density means that they are an expensive material to transport long distances.

#### 3.5.2.4 Almond hulls

Almond hulls are separated from the shell and nut during processing. They typically have a moisture content of 10-30% and bulk density ranging between 400-650 kg/m$^3$. Almond hulls are widely used as animal feed and bedding material in the United States (Ledbetter 2008).

#### 3.5.2.5 Composted manure

The composition of composted manure varies depending on the properties of the raw manure, the composting process and whether any other materials were co-composted with the manure. As a guide, composted manure has a moisture content of around 28% and a bulk density of around 750 kg/m$^3$.

No feedlot used composted manure in this trial. However, it is known that one covered feedlot in Australia has used composted manure as a bedding similar to sawdust as soft flooring in concrete pens.

### 3.5.3 Inorganic materials

#### 3.5.3.1 Sand

The most common constituent of sand is silica or silicon dioxide; usually in the form of quartz. Sand is typically graded into particles sizes such as fine, medium and coarse that range between 0.063-2.0 mm. The bulk density of dry sand ranges from 1100-1600 kg/m$^3$ and its porosity ranges from 20-50% (Curry et al. 2004).

No feedlot used sand in this trial. However, it is known that sand has been successfully used in post-washing pens in Australia.

#### 3.5.3.2 Recycled rubber chip

Car tyres can be cut into rubber chips that are an alternative to organic garden mulches; flooring surfaces for sporting ovals and playgrounds and as an additive to asphalt. They also have potential as a bedding material. There is little research data showing their use or effectiveness in intensive animal facilities. However, recycled tyres have been used to create rubber mats used in the dairy industry to provide bedding in stalls and soft flooring alternatives in areas frequently trafficked by cows and dairy staff (O’Keefe et al. 2010). One disadvantage of rubber chips produced from recycled tyres is that they can contain heavy metals such as zinc and lead (Simon 2010). If they were used as a bedding material in cattle feedlots, it could affect animal health and compromise food safety. This would limit the reuse options for spent bedding.

#### 3.5.3.3 Rubber matting

Perforated rubber matting has a role as a soft, non-slip surface in cattle handling facilities (Photograph 29). However, it has limited application in open feedlot pens.

**PHOTOGRAPH 29– PERFORATED RUBBER MATTING**

### 3.5.4 Availability and cost of bedding materials in Australia

Cost and availability are important aspects of whether bedding materials will be used at a feedlot. The bedding materials described in the previous sections were provided by a variety of suppliers. The availability and prices these materials are subject to volatility and are influenced by market demand, availability of substitute materials, anticipated or perceived shortages due to climatic conditions (such as drought), distance from the supplier to the buyers, and other factors.

For some materials, such as typical wood chip, prices are generally stable as there is a large landscaping market for the product. In other cases, bedding material prices and availability are subject to numerous factors outside of the control of the lot feeder. For example, although wheat and barley straw typically have a relatively low cost ($/m$^3$), during a period of drought, the price would significantly increase and availability decrease. A significant barrier for use of a number of bedding materials is the delivery cost associated with the material. For example, although timber harvest residue has a low cost, it will only be a cost effective product if the feedlot is located close to a forest that produces the residue. A number of the bedding materials single-sourced or have a limited number of suppliers with availability limited to urban areas, such as construction and demolition waste and recycled pallets.

Shortages in supply, increases in the price of bedding materials or high transport/delivery costs for bedding material may adversely impact the adoption of the use of certain bedding materials.

Table 2 gives a summary on the availability and cost of a number of proposed bedding materials that are available in Australia. Data in the table is comprised of data collected during the trials, data collected from lot feeders, personal communications with a range of supplies and literature values.

**TABLE 2 - BEDDING MATERIAL COSTS & AVAILABILITY**

| Product | Bulk density ($kg/m^3$) | Cost ($/t) | Cost ($/$m^3$) | Availability |
|---|---|---|---|---|
| Timber harvest residue | 250 | 30 – 60 | 10-15 | Good close to forest. |
| Timber off-cuts | 300-450 | 35-40 | 35-90 | Limited market, limited availability. Fire wood can be used but this increases cost. |
| Typical wood chips | 300-500 | 50 – 80 | 15-42.50<br>Generally about 20 | Good - generally available from timber mills. |
| Wood mulch | 80-200 | 105-500 | 15-50 | Good availability from timber mills/ landscape suppliers |
| Sawdust | 160-300 | 40 (dry) | 4-10 | Good from sawmills, expensive to transport. |
| Construction & demolition waste | - | - | - | From urban/industrial areas – landfill/recycling companies |
| Recycled pallets | 250 | - | - | Limited in regional areas. Transport would be high cost if delivery required from an urban area. |
| Wheat & barley straw | 98-177 | 70-150 | 10-20 | Good - depends on location. Drought conditions can cause shortages of availability. |

| Product | Bulk density (kg/m$^3$) | Cost ($/t) | Cost ($/m$^3$) | Availability |
|---|---|---|---|---|
| Corn stalks | 90-150 | 32 | 30/bale | Dependent on location |
| Rice husks | 70-110 | 560<br>70/125 kg | 60 – 80 | Dependent on location. Generally produced in Victoria. |

# 4 Feedlot bedding trials

## 4.1 Australian feedlots (covered and uncovered)

In the scoping study (B.FLT.0379 'Bedding material use in cattle feedlots' O'Keefe et al. 2013), completed in 2013, eighteen Australian feedlots were identified that had used bedding materials in feedlot production or sick pens. Five of the eighteen feedlots operated either fully or partially covered feedlot pens. The main reason for using bedding materials in either covered or uncovered feedlots was to provide a clean, dry resting place for cattle to lie on. The provision of bedding also addresses several other cattle comfort issues such as dirty cattle, cold and heat stress, excessive moisture and pen surface hardness.

Covered feedlots cannot use direct solar radiation to dry pen manure. Therefore, bedding materials are used to absorb a percentage of the moisture from manure. Uncovered feedlots in southern Australia use bedding to manage moisture from manure and wet / muddy pens that result from persistent cold, wet weather and low evaporation typically experienced in winter. Northern uncovered feedlots experience the same problems, but typically the problems occur during the summer dominant rainfall period of the year. However, regardless of location within Australia or whether the feedlot is covered, those lot feeders surveyed considered wood chips and straw to be the most effective bedding materials.

Ten feedlots participated in the bedding trial case studies for this project to determine the effects of introducing bedding to feedlot pens. Case study details (e.g. bedding types, experiment layout) have been recorded. Nineteen case studies were undertaken in total, using varying bedding types (typical wood chip, wood mulch, corn stalks, construction and demolition waste, timber mill processing by-products and sawdust) and application of bedding materials (across the entire pen or in a central mound). Standardised questions were asked at each participating feedlot. The questions covered details on animal welfare/behaviour, environmental issues, management issues and any further comments. A summary of the case studies is presented below.

## 4.2 Feedlot locations and case study weather conditions

To ensure the trial was representative of the Australian feedlot industry, case study trial sites were selected across eastern Australia. The selected sites are situated in different climate zones as illustrated in Figure 3. Of the ten participating feedlots, three were located in Queensland with summer-dominant rainfall, four were in New South Wales with winter-dominant or uniform rainfall, two in Victoria with winter-dominant rainfall, and one in South Australia with winter-dominant rainfall.

The trials generally began in August 2013 and continued through to February 2014. During the trial, only two feedlots experienced higher rainfall than annual average and most experienced average temperature conditions. Most feedlots experienced similar temperature as annual average, with one feedlot having 12 days exceeding 35°C and two feedlots having nine days exceeding 35°C. This limited the significance of data collected at most sites.

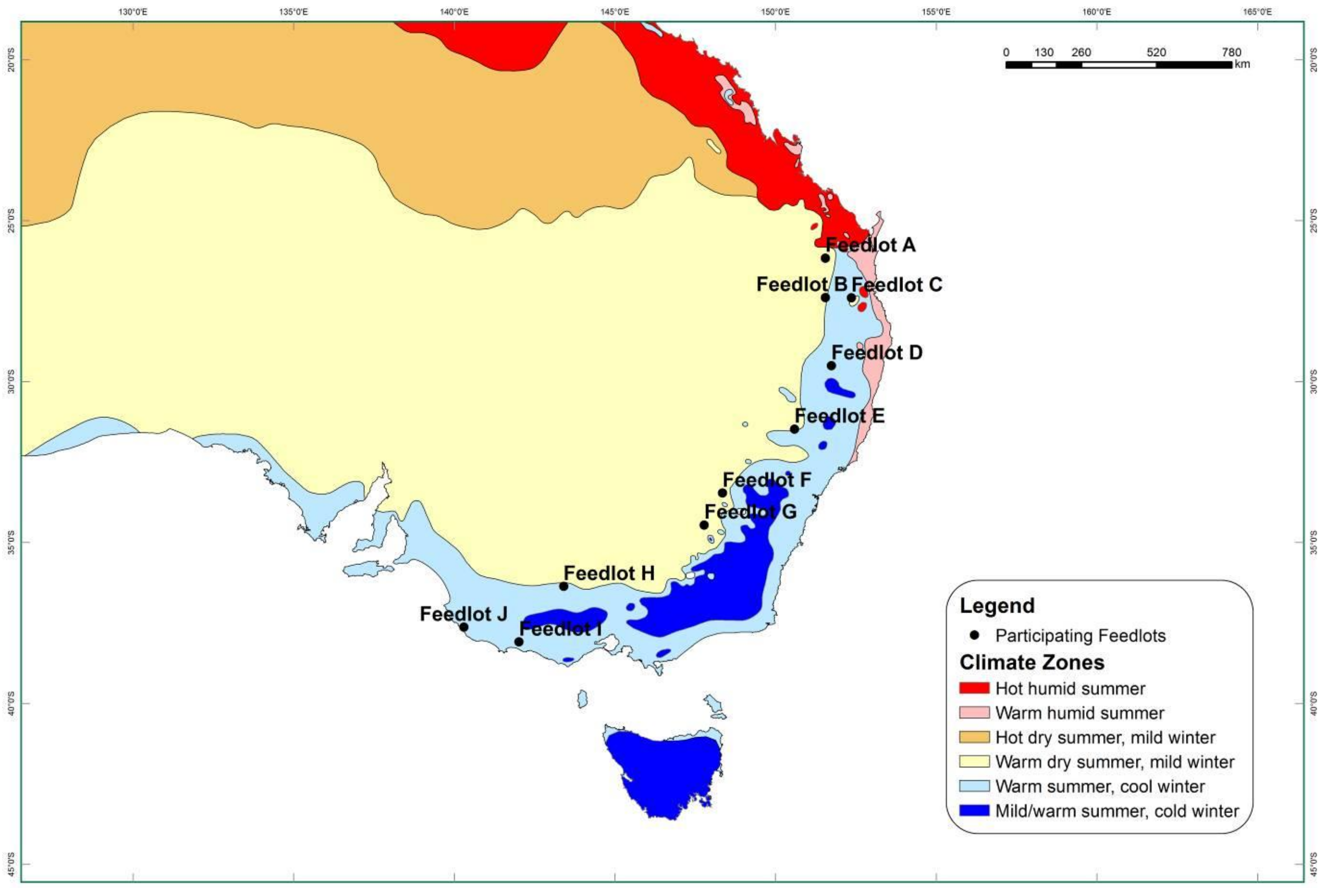



**FIGURE 3 – PARTICIPATING FEEDLOTS AND MAJOR CLIMATE REGIONS**

## 4.3 Bedding types and costs

For each trial, feedlots used locally available bedding materials. Therefore, there was variability in the bedding used across the feedlots. Section 3.5 has provided some information on the different types of bedding used. Although increasing the variability between the trials, it was agreed with MLA at the start of the project to only use locally available products. This would reflect likely future adoption and would reduce transportation costs.

Eight of the ten participating feedlots used typical wood chips (11 trials), with varying sizes from small pieces (typical wood chips; 25 mm x 25 mm - Photograph 15) of soft and hard wood chips to sharp wood mulch (4 trials) and large chunks of timber including off-cuts (1 trial) and construction and demolition waste (1 trial). One feedlot used sawdust (1 trial) and another trial used corn stalks.

The wood chips costs typically varied from \$15 to \$42.50/m$^3$ delivered, whereas sawdust was about \$7/m$^3$. As discussed in Section 3.5.4, the range of price is reflective of type of wood chip, local availability as well as a number of other factors.

## 4.4 General case study information

The following section provides general information about each site. The sites were chosen to provide a range of climatic conditions, cattle types, bedding options and management systems.

### 4.4.1 Feedlot A

**Feedlot location and description**

This feedlot is located in the South Burnett region of Queensland. This feedlot predominately feeds 100-day bullocks and 70-day domestic cattle. Most cattle are *Bos indicus* cross breed.

**Typical and trial weather conditions**

Feedlot A is in a summer-dominant rainfall zone with a mean annual rainfall of 697 mm and a mean annual Class 'A' pan evaporation of 1802 mm. Even after the effect of added moisture from cattle is taken into account, this feedlot does not, on average, experience winter months where there is a net addition of moisture to the pens and they remain wet. During the trial period, the weather was dry where rainfall in August and October 2013 was 87% and 52% lower than average. Highest daily rainfall occurred on 17 September 2013 with 29 mm rain. December was the hottest with three days exceeding 35°C and reached 39.1°C on 29 December 2013. August was the coldest with seven days having temperature below zero and reached -4.4°C on 22 August 2013. There were no extreme cold periods experienced during the case study. Early in the trial, overnight temperatures reached -2°C.

**Reasons for trialling bedding**

This site does not experience wet winters and does not have an issue with dags or cattle cleanliness, as few European cattle are fed. The feedlot manager had discussions with the consulting nutritionist who had indicated that bedding had been shown to improve cattle performance and reduce health issues. It was on this basis that the wood chips were trialled.

**Bedding type and cost**

Two types of bedding material were available from a local timber mill. Typical wood chip was chosen as the product to be used at this feedlot and was available at $20/m^3$ delivered (~$47/t). Wood mulch (Photograph 19) was rejected due to concerns about hoof injuries.

**Bedding application**

Three unshaded pens were set aside for this trial. One additional pen was monitored as a control pen (Pen D8). Three case studies were undertaken at the feedlot.

Each pen was 31 m wide and 60 m deep. The pen slope was measured to be 6.3%. Each pen nominally holds 132 SCU at 12.8 $m^2$/SCU. During the trial, 150 bullocks were held in each pen. The pens were cleaned in mid-August 2013 prior to introduction of cattle and the wood chips were placed on 19 August 2013. Photograph 30 shows Pen D7 after cleaning. Only a thin layer of manure was left across the pen with some areas showing exposed clay. The cattle in each pen were 400 kg bullocks (*Bos indicus* cross) to be fed 100 days.

The bedding treatments were:

Trial 1A: 100 $m^3$ of typical wood chip, spread evenly across the whole pen (approximately 54 mm depth) (Pen D7)

Trial 2A: 100 $m^3$ wood chip placed in a central mound (Pen D9)

Trial 3A: 200 $m^3$ wood chip placed in a mound (Pen D10)

For Trial 1A, the pen where wood chips were spread evenly across the whole pen, no wood chips were spread within the bottom few meters of the pen (see Photograph 31). This was to reduce the amount of wood chip flowing out of the pen into the drain following rainfall.

For Trial 2A and Trial 3A the central mounds were placed at approximately 1-1.5 m in height (see Photograph 32).

**PHOTOGRAPH 30 – TRIAL 1A - PEN AFTER CLEANING AND PRIOR TO WOOD CHIP PLACEMENT**

**PHOTOGRAPH 31 – TRIAL 1A – WOOD CHIP SPREAD EVENLY ACROSS THE PEN (27 AUG 2013)**

**PHOTOGRAPH 32 – TRIAL 3A– 200 M$^3$ WOOD CHIP MOUND (19 AUG 2013)**

### 4.4.2 Feedlot B

**Feedlot location and description**

This feedlot is located in the Darling Downs region of Queensland. This feedlot predominately feeds 100-day bullocks and 70-day Angus cattle.

**Typical and trial weather conditions**

Feedlot B is in a summer-dominant rainfall zone with a mean annual rainfall of 643 mm and a mean annual Class ‘A’ pan evaporation of 1866 mm. Even after the effect of added moisture from cattle is taken into account, this feedlot does not, on average, experience winter months where there is a net addition of moisture to the pens and they remain wet for prolonged periods each year. However, in some winters, wet pens are an issue.

During the trial period, the weather was dry, especially August through to November 2013 where rainfall was about 80% lower than the average. The highest daily rainfall occurred on 12 December 2013 with 21 mm rain. Maximum temperature was slightly higher than average and minimum temperature was close to average. During the last week of December, there were four days above 35 C and it reached 40.3 C on 29 December 2013.

**Reasons for trialling bedding**

This site does not experience pronounced wet winters. However, it feeds European cattle (Angus) and can have issues with the formation of dags and the cleanliness of cattle in winter.

**Bedding type and cost**

The wood chips used in this trial were Cypress pine of a similar size to those shown in Photograph 15 (typical wood chips). The wood chips cost $22/m^3$ delivered (~$51/t). It was difficult to obtain sufficient volume of wood chip at this site and consequently, the start of the trial was delayed.

**Bedding application**

Two shaded pens were set aside for this trial. Two control pens were also monitored during the trial period. Each pen was 31 m wide and 60 m deep. The pen slope was measured to be about 3%. Each pen nominally holds 132 SCU at 15-16 m$^2$/SCU.

The bedding treatments were:

Trial 1B: 100 mm of wood chip spread evenly across the whole pen (280 m$^3$) (see Photograph 20). (Pen F4)

Trial 2B: 200 mm of wood chip spread evenly across the whole pen (560 m$^3$). Pen F3)

In the pens where wood chips were spread, wood chips were spread to the bottom end of the pen. Wooden boards were placed along the bottom fence line to prevent wood chips moving into the cattle lane (see Photograph 34).

**PHOTOGRAPH 33 –TRIAL 1B – 100 MM WOOD CHIP (9 OCT 2013)**

**PHOTOGRAPH 34 –TRIAL 1B - BOARDS PLACED ON BOTTOM END OF PEN TO PREVENT WOOD CHIPS MOVING INTO CATTLE LANE / DRAIN (9 OCT 2013)**

### 4.4.3 Feedlot C

**Feedlot location and description**

This feedlot is located in the South East region of Queensland. This feedlot predominately feeds 100-day bullocks and 70-day domestic cattle. Most cattle are *Bos indicus* cross.

**Typical and case study weather conditions**

Feedlot C is in a summer-dominant rainfall zone with a mean annual rainfall of 865 mm and a mean annual Class ‘A’ pan evaporation of 1708 mm. Even after the effect of added moisture from cattle is taken into account, this feedlot does not, on average, experience winter months where there is a net addition of moisture to the pens and they remain wet.

During the trial period (up to January 2014), the weather was drier than average except in June and November, where rainfall was 67% and 18% higher than average. Highest daily rainfall occurred on 24 January 2014 with 50.1 mm rain. The weather was warmer than average, where there were two days higher than 35°C in October, November and December 2013. January was the hottest month with eight days exceeding 35°C and reached 43.5°C on 4 January 2014.

**Reasons for trialling bedding**

The main reason for participating in the bedding trial was to prevent pen surface damage. Previous experience had shown that a thick covering of wood chips had reduced damage and clay loss from their steep (>8%) slope pens. Animal comfort in the hospital was also a consideration.

**Bedding type and cost**

Three different bedding treatments were trialled at this feedlot. A hardwood typical wood chip from Roma (390 kg/m$^3$) was used as this had been used by the feedlot for a previous trial (**Error! Reference source not found.**). A second hardwood typical wood chip from local upplier (310 kg/m$^3$) was also used (Photograph 36). The third product used was a wood mulch (Photograph 20) from a local supplier (270 kg/m$^3$). The approximate costs for the three products were \$20/m$^3$ of the typical wood chip (\$51/t for the Roma wood chip, and \$64/t for the local wood chip) and an average cost for wood mulch is \$32.50/m$^3$ (~\$83/t).

**Bedding application**

Four pens were used to trial bedding materials. One additional pen without a bedding material was monitored as a control pen. Pens used for the trial were approximately 45 m deep and about 20 m wide. The pens were nominally stocked at 12.5 m$^2$/SCU (capacity about 80 SCU) and there was approximately 250 mm/SCU of bunk space provided. The pen slope was steep (8%).

The bedding treatments used:

| | |
|---|---|
| Trial 1C | 100 mm local typical wood chip spread evenly over whole pen (Pen 2) |
| Trial 2C | Single long mound of local typical wood chip, about 0.5-1.0 m high (seePhotograph 37) (Pen 3) |
| Trial 3C | 200 mm local wood mulch (see Photograph 20) spread evenly over whole pen (Pen 5) |
| Trial 4C | 200 mm Roma typical wood chip over whole pen (see **Error! eference source not found.**) (Pen 6) |


**PHOTOGRAPH 35 –ROMA TYPICAL WOOD CHIP**


**PHOTOGRAPH 36 –LOCAL TYPICAL WOOD CHIP**

**PHOTOGRAPH 37 –TRIAL 2C – WOOD CHIP MOUND (4 SEP 2013)**

### 4.4.4 Feedlot D

**Feedlot location and description**

This feedlot is located in the New England region of New South Wales. Feedlot D runs a 270-day long-fed Angus program with cattle turning off in excess of 800 kg live weight.

**Typical and case study weather conditions**

Feedlot D is in a uniform rainfall zone with a mean annual rainfall of 776 mm and a mean annual Class ‘A’ pan evaporation of 1377 mm. This feedlot does experience winter months where there is a net addition of moisture to the pens and they remain wet.

During the trial period, the weather was dry, with rainfall in December 2013 only 10% of average. Heavy rainfall events were experienced on 17 September 2013 (32.4 mm) and 11 November 2013 (26.8 mm). The maximum and minimum temperatures were similar with the average. There was one day in December and two days in January that exceeded 35°C. August was the coldest month with 18 days having minimum temperature below zero and reached -7.8°C on 21 August 2013.

**Reasons for trialling bedding**

The main reason for trialling bedding treatment at this feedlot was to provide soft flooring for heavy cattle, to reduce stress, lame cattle and leg infections from gravel as well as controlling dags. The surface of one pen with heavy cattle and wood chips was observed in August 2013. Photograph 38 and Photograph 39 shows evidence of dag removal during the trial period. Although hair has been removed from the cattle, the lot feeder noted that this had little effect on the cattle hide.

**PHOTOGRAPH 38 –FEEDLOT D– DAG WITH HAIR REMOVED IN WOOD CHIP PEN**

**PHOTOGRAPH 39 –FEEDLOT D– DAG WITH HAIR REMOVED IN WOOD CHIP PEN**

**Bedding type and cost**

The feedlot used a sharp pine wood chip. Wood chip used for this trial was transported from as far as 250 km. This material was chosen as the product has been used previously at the feedlot and has aided removal of dags. The cost was about $7000 per year per pen. The purchase and delivery cost was $52/t delivered.

**Bedding application**

At this feedlot, bedding treatments had been applied to both covered sheds and uncovered pens. Pens used for the trial were approximately 60 m deep and about 50 m wide. The pens were nominally stocked at 12.5 $m^2$/SCU (capacity about 240 SCU). The pen slope was between 2.5 - 4.0%.

Trial 1D Uncovered pens with 300 mm of wood mulch spread evenly across the pens.

Trial 2D Covered pens with 300 mm of wood mulch spread evenly across the pens.

Note: The lot feeder noted that the depth of wood mulch is required to be 300 mm. They initially trialled using a lesser depth and found a big difference in longevity of chips and overall pen condition. Photograph 40 shows a thin covering of wood mulch on a concrete floor for Trial 2D.

**PHOTOGRAPH 40 –TRIAL 2D– THIN LAYER OF WOOD CHIP OVER CONCRETE FLOOR IN COVERED SHEDS**

### 4.4.5 Feedlot E

**Feedlot location and description**

This feedlot in the Liverpool Plains area in New South Wales.

**Typical and case study weather conditions**

Feedlot E is in a uniform rainfall zone with a mean annual rainfall of 599 mm and a mean annual Class ‘A’ pan evaporation of 1817 mm. This feedlot does experience winter months where there is a net addition of moisture to the pens and they remain wet.

During the trial period, the weather was dry with rainfall in August and October 98% and 82% lower than average except in June, where rainfall was 41% higher than average. There was no daily rainfall higher than 25 mm. Temperature was similar with average. December was very hot with 12 days exceeding 35°C and reached 41.1°C on 29 December 2013. August was the coldest month with 14 days having minimum temperature below zero and reached -6.7°C on 21 August 2013.

**Reasons for trialling bedding**

The main reason for participating in the bedding trial was to reduce the formation of dags in the post washing pens.

**Bedding type and cost**

Three bedding materials were trialled at Feedlot E. This feedlot trialled a crop residue by-product, corn stalks which cost $30/bale (Photograph 28). This cost is ~$10/m$^3$ or ~$80/t. Two timber by-products were also used, typical wood chips (costing $21/m$^3$) and recycled timber from construction and demolition waste ($18/m$^3$). The delivery cost was included in these prices.

**Bedding application**

Bedding materials were only applied in post-washing pens.

Trial 1E: Corn stalks were applied evenly over the pen surface (Photograph 28)

Trial 2E: Typical wood chips (25 mm x 25 mm) were applied evenly across the pen surface of a post washing pen (Photograph 41)

Trial 3E: Recycled timber from construction and demolition waste was used across a post washing pen (Photograph 25, Photograph 26, Photograph 27).

**PHOTOGRAPH 41 –TRIAL E2 - TYPICAL WOOD CHIP USED IN POST-WASHING PEN**

### 4.4.6 Feedlot F

**Feedlot location and description**

This feedlot is located in the central New South Wales.

**Typical and case study weather conditions**

Feedlot F is in a uniform rainfall zone with a mean annual rainfall of 570 mm and a mean annual Class 'A' pan evaporation of 1666 mm. After the effect of added moisture from cattle is taken into account, this feedlot experiences winter months where there is a net addition of moisture to the pens and they typically remain wet for a prolonged period, usually from May through to August.

During the trial period, the weather was drier than average except in June where rainfall was nearly three times higher than average. Highest daily rainfall occurred in 17 September 2013 (32.6 mm). Temperature was similar to the average. December was the hottest month with nine days exceeding 35°C and reached 41.5°C on 22 December 2013. July was the coldest month with nine days having minimum temperature below zero and reached -2.7°C on 6 July 2013. Unfortunately, the trial started later than anticipated and the wet period of winter ended just as the wood chips were placed in the pens.

**Reasons for trialling bedding**

A bedding treatment was trialled at this feedlot as it is located in an area that experiences prolonged wet periods, which do not allow pens to dry out. Bedding treatments were trialled to reduce the formation of dags on cattle as well to reduce cold stress on cattle during wet conditions.

**Bedding type and cost**

One bedding material was used in the trial. The material was a timber by-product similar to typical wood chips. However, it was not of a uniform in size like the typical wood chip usually used as it appeared to include shavings. Photograph 42 shows the wood chip that was used at the feedlot. This wood chip was purchased from a landscaping company and cost \$42.50/m$^3$ (~\$100/t).


**PHOTOGRAPH 42 – WOOD CHIP USED IN PENS AT FEEDLOT F (RANDOM SIZING)**

**Bedding application**

One unshaded pen was used for this trial. An additional unshaded pen was monitored as a control pen. The pens were 32 m wide and 62 m deep. At a nominal stocking density of 18 $m^2$/head, the pen capacity is 110 head. The pen slope is 3.5%.

Trial 1F: Wood chip was spread evenly across an entire pen. An approximately 5 m wide strip of pen near the cattle lane was kept free of wood chips, to stop wood chip entering the cattle lane or being removed with rainfall runoff. Photograph 43 shows the 5 m wide strip.

**PHOTOGRAPH 43 – BOTTOM END OF PEN WITH 5 M FREE OF WOOD CHIPS (FEEDLOT F)**

### 4.4.7 Feedlot G

**Feedlot location and description**

Feedlot G is located in the Riverina region of southern New South Wales.

**Typical and case study weather conditions**

Feedlot G is in a uniform rainfall zone with a mean annual rainfall of 561 mm and a mean annual Class 'A' pan evaporation of 1580 mm. After the effect of added moisture from cattle is taken into account, this feedlot experiences winter months where there is a net addition of moisture to the pens and they can remain wet for a prolonged period, usually from May through to August.

During the trial period, the weather was slightly drier than average with the exception in June and November, where rainfall was 113% and 54% higher than average. Heavy rainfall events occurred on 2 June 2013 (43.4 mm) and 17 November 2013 (61.6 mm). The weather was slightly warmer than average. December was the hottest month with nine days exceeding 35°C and reached 42°C on 21 December 2013. July was the coldest month with ten days having minimum temperature below zero and reached -2.9°C on 27 July 2013.

**Reasons for trialling bedding**

As pens can remain wet for a prolonged period of time, the feedlot chose to trial bedding materials in post-washing pens to stop the re-formation of dags on cattle. Bedding was also trialled in hospital pens and laneways.

**Bedding type and cost**

Typical wood chips were used at the site, similar to those shown in Photograph 15. The cost of wood chips was \$80/t delivered (~\$34/$m^3$).

**Bedding application**

Bedding material was trialled in one post-washing pen as well as covered hospital pens. The post-washing pen was uncovered, and was 38 m deep and 70 m wide with a 2% slope. At 13.5 $m^2$/head nominal stocking density, it can hold 197 head. The hospital pen was a covered pen.

Trial 1G: Typical wood chip spread evenly across entire post-washing pen.

Trial 2G: Typical wood chip spread evenly across entire covered, hospital pen.

### 4.4.8 Feedlot H

**Feedlot location and description**

Feedlot H is located in western Victoria.

**Typical and case study weather conditions**

Feedlot H is in a uniform rainfall zone with a mean annual rainfall of 438 mm and a mean annual Class ‘A’ pan evaporation of 1538 mm. After the effect of added moisture from cattle is taken into account, this feedlot experiences winter months where there is a net addition of moisture to the pens and they remain wet for a prolonged period, usually from May through to August.

During the trial period, the weather was slightly drier than average. There was no heavy rainfall event and the highest daily rainfall occurred on 1 June 2013 (14.4 mm). The weather was slightly warmer than average. December was the hottest month with seven days exceeding 35°C and reached 43.6°C on 19 and 20 December 2013. July was the coldest month with four days having minimum temperature below zero and reached -1.8°C on 9 July 2013.

**Reasons for trialling bedding**

The main reason for trialling bedding materials was to reduce cattle stress during wet and cold periods and also for cattle cleanliness.

**Bedding type and cost**

The bedding material used was a timber mill processing by-product, sourced from a local timber mill. The by-product used was off-cuts as described in Section 3.5.1.2 and shown in Photograph 11 and Photograph 12. The off-cuts were up to 300 mm long and 150 mm wide. The purchase cost was \$21/$m^3$ with a \$16/$m^3$ delivery cost. Hence, the total cost was \$37/$m^3$ (~ \$95/t).

**Bedding application**

One pen was used for the trial. The pen was 30 m wide and 60 m deep and had about 3% slope. At a nominal stocking density of 15 $m^2$/head, the pen holds 120 head. The pen is shaded.

Trial 1H The off-cuts were put in the pen at a nominal depth of 150 mm evenly across the pen.

### 4.4.9 Feedlot I

**Feedlot location and description**

Feedlot I is located in southern Victoria. It is a small feedlot specialising in high-value Angus cattle for the restaurant market.

**Typical and case study weather conditions**

Feedlot I is in a winter-dominant rainfall zone with a mean annual rainfall of 743 mm and a mean annual Class 'A' pan evaporation of 1281 mm. After the effect of added moisture from cattle is taken into account, this feedlot experiences winter months where there is a net addition of moisture to the pens and they remain wet for a prolonged period, usually from April through to September.

During the trial period, the weather was very wet, with rainfall in August, October and November more than 50% higher than average. The highest daily rainfall occurred on 23 October 2013 (45.4 mm). Temperatures were similar to the average. December was the hottest month with one day exceeding 35°C (19 December 2013, 39.2°C). July was the coldest month with two days having minimum temperature below zero and reached -2.1°C on 9 July 2013.

**Reasons for trialling bedding**

The site has a relatively high and strongly winter-dominant rainfall which results in pens being wet for several months throughout the winter. During wet winters, the pen manure becomes a wet slurry. This not only causes a heavy dag load on the cattle but reduces animal comfort in cold windy conditions as the cattle do not like to lie in the wet, cold manure slurry. The bedding has been used for several years now to provide a dry, comfortable area for cattle to lie in each pen.

**Bedding type and cost**

The bedding that was trialled was blue-gum residue and pine post peelings that has been tub-grinded (Photograph 8). The bedding is very similar to the bedding described as wood mulch in Section 3.5.1.4. The bedding was sourced directly from the blue-gum company at \$10 - \$15/$m^3$ (~ \$40-60/t).

**Bedding application**

Feedlot I used bedding across their feedlot. This is normal practice for the feedlot in winter months. They had previously used typical wood chip as their bedding material. For this trial, Feedlot I placed a mound of blue-gum residue and pine post peelings as bedding longitudinally in the centre of each pen with enough area for the cattle to rest on the mound (Photograph 10). Fresh bedding is added throughout the winter depending on the weather conditions. The feedlot had 10 pens each with 200 head capacity and stocked at about 15 $m^2$/head.

### 4.4.10 Feedlot J

**Feedlot location and description**

This feedlot is located in the limestone coast of south-east South Australia.

**Typical and case study weather conditions**

Feedlot J is in a winter-dominant rainfall zone with a mean annual rainfall of 749 mm and a mean annual Class 'A' pan evaporation of 1335 mm. After the effect of added moisture from cattle is taken into account, this feedlot experiences winter months where there is a net addition of moisture to the pens and they can remain wet for a prolonged period, usually from April through to September. To counter this wet weather, about 36% of the feedlot pen area is covered (Photograph 44). Sawdust is used as bedding in the covered section.

During the trial period, the weather was much wetter than average, with rainfall in July, August and October more than 50% higher than average. Heavy rainfall events occurred on 7 June 2013 (27.8 mm), 5 July 2013 (32.6 mm) and 22 October 2013 (26.2 mm). The weather was slightly colder than average. December was the hottest month with two days exceeding 35°C and reached 40.2°C on 19 December 2013. June was the coldest month with two days having minimum temperature below zero and reached -0.9°C on 20 June 2013.

**Reasons for trialling bedding**

Sawdust bedding is applied to the covered section to absorb moisture and provide soft flooring (Photograph 22). Odour reduction and pen surface protection were also considerations. Animal comfort is improved as animal prefer to lie on the sawdust. There are no issues with dags, flies or odour when using the sawdust.

**Bedding type and cost**

Sawdust was sourced from local timber mills. The cost including delivery was $14/t (~$3.15/$m^3$). This price is low as this feedlot is close to a timber mill and plantation forests.

**Bedding application**

Sawdust bedding was applied to the undercover section of feedlot at a thickness of 150-200 mm across pen floor. The top layer of bedding (approximately 50% of total) was removed approximately 6-8 weeks after initial application. Remaining sawdust was removed 6-8 weeks after first cleaning. Replacement of sawdust layer was applied at a thickness of 150-200 mm across pen floor occurs about four times per year. This lot feeder noted that they had trialled wood shavings being the most absorbent and long-lasting medium but the product is very light and can blow around. Wood chips was their least preferred medium as it was not as absorbent as sawdust and needs to be replaced more often. The deodorising effect of wood chips does not last as long as sawdust. The use of straw was a "disaster".

**PHOTOGRAPH 44 – FEEDLOT J COVERED PENS AND OPEN PENS**

## 4.5 Animal production, health and welfare

### 4.5.1 Animal performance

Where possible, animal performance was evaluated through changes in feed consumption between bedded and unbedded pens. Most of the feedlots provided details suggesting that there was no change in intake. Two feedlots (Feedlot E and Feedlot G) felt that there was a slight intake increase for cattle on the bedding, while a third (Feedlot I) had witnessed a definite intake increase of 0.2-0.3 kg/head/day. Feedlots that used bedding treatments in post-washing and hospital pens stated that there was limited opportunity to observe changes in animal performance or feed consumption over such a short period of time. Feedlot J estimates an increase of 10% in ADG when using the sawdust in the partially-covered pens.

In summary, change in animal performance seems anecdotal but over time lot feeders felt that the use of bedding could have a positive effect under certain conditions and no negative effects were reported. Unfortunately, the climatic conditions experienced during the trial did not cause the bedding to have much of an effect.

Some feedlots did provide detailed animal performance data. These details are given below.

Table 3 gives the data from Feedlot A.

**TABLE 3 – ANIMAL PERFORMANCE – FEEDLOT A**

| Item | Units | Pen D7 | Pen D8 | Pen D9 | Pen D10 |
|---|---|---|---|---|---|
| Pen layout | | 100 $m^3$ even | control | 100 $m^3$ mound | 200 $m^3$ mound |
| No cattle in | hd | 150 | 150 | 150 | 150 |
| Date in | | 28 Aug 2013 | 21 Aug 2013 | 28 Aug 2013 | 21 Aug 2013 |
| No cattle out | hd | 149 | 30/119/1 | 14 / 136 | 150 |
| Date out | | 15 Dec 2013 | 8 Dec 2013/ 9 Dec 2013/ 16 Dec 2013 | 9 Dec 2013/ 15 Dec 2013 | 8 Dec 2013 |
| Mean LWT in | kg | 400 | 427 | 400 | 419 |
| Mean LWT out | kg | 612 | 678/668/604 | 676/611 | 672 |
| Average day on feed | days | 109 | 110 | 108 | 109 |
| Average gain per day | kg/hd/d | 1.94 | 2.21 | 2.00 | 2.32 |
| Feed conversion (% DM) | | 5.26 | 5.09 | 5.31 | 4.97 |
| Mortalities | % | 0.67 | 0 | 0 | 0 |
| Medicine cost | $/hd | 1.55 | 1.14 | 0.59 | 0.62 |
| Pulls | | 1 – respiratory (5 Oct 2013) | 0 | 0 | 0 |
| Wood chip cost (supply only) | $/pen | 2000 | 0 | 2000 | 4000 |
| Wood chip cost (supply only) | $/hd | 13.33 | 0 | 13.33 | 26.67 |

1. Both groups (control and bedding) in the trial have recorded similar intakes throughout the trial period. Due to the cattle type (smooth skinned *Bos indicus*) and weather conditions, dags were not an issue during the trial. No differences in hoof or foot injuries were noted during the trial. The differences in respiratory disease are as follows:

| | |
|---|---|
| Control | – Respiratory: 3.3% treatment rate including one animal treated 3 times; Non-eater: 2%; Bloat 0.66% |
| 100 $m^3$ spread | – Respiratory: 2% |
| 100$m^3$ pile | – Respiratory: 1.33% |
| 200$m^3$ pile | – Respiratory: 1.33%; Buller: 0.66% |

Table 4 gives data on animal performance for Feedlot B.

**TABLE 4 – ANIMAL HEALTH AND PERFORMANCE DATA – FEEDLOT B**

| Pen | F3 | F4 | F5 | F6 |
|---|---|---|---|---|
| Treatment | 200 mm | 100 mm | Control | Control |
| Date Opened | 9/12/2013 | 27/09/2013 | 25/11/2013 | 11/11/2013 |
| Date Closed | 20/07/2014 | 27/04/2014 | 13/07/2014 | 15/06/2014 |
| Ave DOF | 213 | 201 | 213 | 207 |
| No cattle in | 180 | 177 | 180 | 180 |
| Deaths | 7 | 4 | 1 | 4 |
| Culls | 4 | 0 | 0 | 2 |
| Entry weight (kg) | 431 | 475 | 447 | 473 |
| Weight Out | 754 | 752 | 768 | 750 |
| AFI (wet), kg/d | 14.6 | 14.57 | 14.57 | 14.39 |
| AFI (dry), kg/d | 10.56 | 10.51 | 10.56 | 10.42 |
| Morbidity% | 5.6 | 4.5 | 4.4 | 6.1 |

AFI = as fed intake

For Feedlot B, The deaths in each pen are as follows:

F3 deaths – 1 x cast under fence (11/12/13), 1 x cast in pen (1/3/14 - not autopsied and suggest was respiratory influenced), 1 x pneumonia (7/2/14), 1 x Tracheitis (4/3/14), 1 x cast (19/04/14), 1 x cast under fence (13/06/14), 1 x BRD (16/07/14)

F4 deaths – 1 x buller (2/12/13), 1 x pen injury (26/12/13), 1 x pneumonia (12/2/14), 1 x cast in pen (14/04/14)

F5 deaths – 1 x cast in pen (22/05/14)

F6 deaths – 1 x bloat (22/12/13), 1 x pen injury (20/1/14), 1 x pen injury (29/01/14), 1 x cast (18/04/14)

The cause of illness in each pen is as follows:

F3 – 100% resp. pulls

F4 – 63% resp, 13% structural (infection), 24% structural (non infection)

F5 – 88% resp, 12% blight

F6 – 55% resp, 9% blight, 9% bloat, 27% structural (non infection)

Feedlot F provided the following animal performance information. As at 2 October 2013 (after 44 days on feed), the following feed intake (as-fed) information was provided.

- Pen 33 Wood chips pen ( steers)
    - Averaged 15.3 kg/hd/day for last 5 days (windy and rain).
    - Averaged 14.8 kg/hd /day for last 14 days
- Pen 43 Comparison pen (same days on feed and steers)
    - Averaged 13.8 kg/hd/day for last 5 days
    - Averaged 14.8 kg/hd/day

Feedlot F experienced higher than average rainfall at the end of the trial period, over a windy and rainy period of 5 days at the end of cattle feeding, feed intake in the Trial 1F pen was 15.0 kg/head/day as opposed to 13.8 kg/head/day in the control pen. Over the entire trial period at Feedlot F, the average feed intake in the trial and control pen was similar.

### 4.5.2 Animal behaviour

Throughout the trial cattle behaviour was monitored by pen riders and other staff at each feedlot. Five of the ten participating feedlots reported that cattle were more playful when entering the pens with fresh wood chips. These cattle were reported kicking, jumping around and rubbing their heads in the wood chips.

Only one site (Feedlot H) witnessed cattle purposefully avoiding the bedding materials. Trial 1H used a timber processing mill by-product, off-cuts which were large pieces of wood similar in size to fire wood. However, after a period of time the cattle became accustomed to the bedding and were content to lay on it, especially during wet periods (Photograph 14). During wet weather, cattle in the Trial 1H pen appeared to be more content than cattle in the control pens at Feedlot H.

Those trialling typical wood chip in mound formation found that cattle preferred to stand/lay on the wood chips area, while other respondents trialling entire bedded pens saw an increase in cattle laying and sitting on the pen surface as well as spreading out across the whole pen. Feedlot G reported that the number of cattle lying down was as high as 85% in the bedded pens. Several of the feedlots reported that cattle on bedding materials seemed more content and comfortable in wetter/colder conditions than the cattle in regular pens. One site (Feedlot B) did not record any differences in cattle behaviour. Feedlot E trialled three bedding materials (corn stalks, wood chips and construction waste) in post-washing pens and found that the cattle were less responsive to the construction waste as they were required to establish their own tracks through the material.

### 4.5.3 Hoof and limb injuries

The effect of bedding on hoof and limb injuries was not documented by a number of the feedlots. The lack of response data was likely due to the short length of the trial period and therefore objective conclusions could not be made. Two feedlots (Feedlot D and Feedlot I) reported that cattle housed on bedding resulted in decreased incidents of lameness and footsore/leg infection. Feedlot D noted that the most obvious reductions in lameness/leg infections are witnessed when long-fed cattle over 200 days are placed on the wood chips. A safety concern that was alluded to by one feedlot (Feedlot E) was that the construction and demolition waste that they had spread in the pens did have some nails protruding. While this did not result in any injuries, it is important to acknowledge this issue as a potential cause of injury. Feedlot I (using wood mulch) compared the cattle in their trial pen to cattle from their custom fed feedlot that does not use bedding. Cattle from the custom fed feedlot were transferred to Feedlot I during the trial period and the respondents noted a considerable difference in the number of foot sore cattle. They also commented that in addition to a central mound of wood mulch, allowing a 25 mm cover of wood mulch across the pens slightly improved the lameness problems, even when cattle are put onto a concrete floor.

### 4.5.4 Bovine respiratory disease

Bovine respiratory disease (BRD) is the most common cause of illness and death in Australian feedlot cattle. It is most common in the first four weeks after entry to the feedlot. The majority of feedlots that participated in this trial used bedding in post-washing pens, hospital pens or finishing pens. A drop in the rate of respiratory disease was witnessed at one feedlot (Feedlot A) from 3.3% in the control to 2.0% for the pens with an even spread of wood chips and reduction to 1.33% for the two pens with bedding mounds. No other feedlots recorded differences between pens with and without beddings. However, based on the positive animal behaviour response that animal comfort is increased with bedding, it is likely that bedding could have a positive effect on reducing the stress on cattle (heat stress, cold stress, stress of injury etc.). BRD is more likely to occur under stressful conditions.

### 4.5.5 Cold stress

Energy requirements for cattle increase during periods when temperatures fall below the animal’s normal body temperature. Rain or wind chill can also cause an increase in the required energy for cattle. Bedding can be used as an effective method of alleviating cold stress on feedlot animals by providing insulation. Cold stress events are likely to happen in the southern feedlots and also in hotter areas, after rainfall. None of the feedlots reported cold stress events throughout the duration of the trial. As a result no comment can be made on the bedding effect under these conditions. Only two feedlots (Feedlot I and Feedlot J) experienced significantly higher rainfall than annual average. In periods of wetter weather, it was noted that the wood chips pens appeared to dry faster and cattle had a preference to stand on the wood chips rather than uncovered pen surfaces.

### 4.5.6 Heat stress

Similarly to the cold stress, bedding can act as an insulator from the pen floor to prevent heat stress. Pen floors can act as a reservoir for heat, but by using a lighter coloured bedding material there is less solar heat gain. The majority of feedlots did not experience any periods of extreme heat. Two of the feedlots (Feedlot B and Feedlot G) did experience short periods of extreme heat and both noted that the pen riders felt the wood chipped pens were cooler than the uncovered pens. However, no conclusive animal behaviour observations were made.

### 4.5.7 Dags and animal cleanliness

It was proposed to assess the presence of dags on cattle was compared between cattle on the bedded pens and cattle in regular pens. To ensure consistent marking between trial sites a dag scoring sheet was provided (Table 1). Unfortunately, little quantitative data was collected. Two feedlots (Feedlot A and Feedlot B) did not report any difference, but this was due to smooth skinned animals or weather being dry and therefore there were no dags on any cattle. All other sites, with the exception of one feedlot, found that if the cattle entered the bedded pens after being washed, the cattle remained dag free for longer. If the cattle entered the pen with dags, there was a visible reduction on dags on the cattle housed on wood mulch or typical wood chips. One site (Feedlot I) witnessed the opposite effect of the wood chips. As the feedlot is located in a particularly wet environment and the cattle had an increased tendency to lay down on the wood chips, the dags then formed higher up on the back, rather than being confined to the legs and belly.

## 4.6 Environmental issues

### 4.6.1 Odour

The response from several feedlots was that the pens have an initial pleasing smell of fresh timber when the bedding is placed. After the trial period, two sites (Feedlot A and Feedlot G) reported a reduced odour from the use of wood chips, while the remaining sites did not observe any differences. Feedlot J, which used sawdust in a covered pen, noted than the manure tended to mix/blend with the sawdust and hence, reduce the odour.

### 4.6.2 Dust

Only two sites (Feedlot A and Feedlot G) witnessed a decrease in dust from pens with bedding. This was particularly evident after rainfall events. It is thought that as the wood chips absorb moisture they also adsorb fine particulates to the chip surface. Throughout the first week of the trial at Feedlot F, it was reported that the cattle were coughing more than usual. It is thought that the fines contained in the wood chips may have been disturbed and released into the air, resulting in increased coughing.

### 4.6.3 Runoff

Several trends relating to drainage and runoff were witnessed for pens containing wood chips. The general trends found that for pens with an even spread layer, the rain fall passed through the wood chips and drained out from underneath the layer. As the wood chips got old (particularly in the mounded pens) the wood chips formed an impermeable surface and the water drained across the surface without penetrating. This caused ponding of runoff around the mound (Feedlot A, Trial 3A; Feedlot E). One feedlot (Feedlot D) commented that, by screening the wood chips and removing fine like sawdust and other rubbish, the infiltration can be improved which decreased this impermeable effect. It was also found that the wood chips in the top surface layer dried out much fast than conventional pen surfaces (Feedlot B). Although the top layer was dry, moisture was retained deeper down in the wood chips layer. Feedlot D also experienced this. Photograph 45 shows the top dry layer of wood mulch with an underlying wet layer.

**PHOTOGRAPH 45 –FEEDLOT D– DRY WOOD MULCH SURFACE WITH UNDERLYING WET LAYER**

## 4.7 Feedlot management issues

### 4.7.1 Pen manure management

Most feedlots did not provide feedback to this topic. Feedlot A found that the manure from the bedding pens was drier and the pen floor had less holes forming where wood chips were spread evenly across the pen surface. However, pens with a central mound showed a greater incidence of holes forming, generally concentrated around the edge of the mound. Feedlot A also noted the need to ensure bedding remains within the pens. While this is not an issue when bedding is mounded in the centre of the pens, it is important for pens with wood chips up to the fence. To prevent wood chips leaving the pens, Feedlot B placed timber boards along the bottom of the pen (Photograph 34). It was proposed that runoff would be able to flow underneath the boards, while the larger wood chips would be retained within the pen. Photograph 46 shows a pen at Feedlot C where runoff has caused the wood chips to spill beyond the pen. It was noted at several sites that under-fence manure with wood chips tended to dry into a more rigid structure than under-fence manure with no bedding. Hence, this under-fence manure prevented any drainage from the pens and required more frequent under-fence cleaning.

Feedlot B found that while the bedded pens were in a better condition than uncovered pens, they were not devoid of potholes and the pen surface required re-levelling during the trial. Feedlot B also noted that cleaning of the pens with wood chip took significantly longer than pens without wood chip (4 times longer to clean the pen with 100 mm of wood chip and 6 times as long to clean the pen with 200 mm wood chip). Feedlot G found there was almost no pen surface damage in high traffic area with bedding.

**PHOTOGRAPH 46 –FEEDLOT C, TRIAL 4C– WOOD CHIPS UNDER BOTTOM FENCE**

### 4.7.2 Wood chip reuse

One of the key requirements of wood chips use was recycling of the bedding material for a second use. However this was not attempted by any of the participating feedlots. The feedlots treated the material removed during pen cleaning the same for both bedded and unbedded pens. Stockpiling was the most common practice, followed by composting. Feedlot A reported that wood chips recycling was not considered as the wood chips were small and the substrate was generally very clumpy. Feedlot I reported that the wood chips were composted along with the pen manure. The wood chips improve the quality of the compost and when combined with the low cost of wood chips, there is little incentive to consider the option of recycling.

A trial was conducted on recycling wood chips from the pen cleaning product from Feedlot B and Feedlot C. Details are included in Section 6.

### 4.7.3 Workplace health and safety

Six feedlots provided positive comments and said that bedding pens tended to be less muddy and slippery. The bedding reportedly improved the confidence of pen riders when working on the surface and pen riders at Feedlot A expressed a preference in riding the pen with the evenly spread out wood chips. Feedlot D noted that pen riding in pens with bedding was safer for riders than riding in muddy pens. Feedlot I had staff walking the pens and reported that pens with bedding were not as flat as those without but noticed no safety concerns. Feedlot E found that the bedding they used (construction and demolition waste) contained some protruding nails, while no incidents were reported this is an issue that must be addressed in future applications. Pen riders from Feedlot B noted that the wood chips were slippery underfoot when it was fist applied, but again no incidents were reported.

## 4.8 Additional comments

Feedlot D reported that having long-fed cattle on wood chips once they are over 200 days greatly reduced cast cattle, lame cattle and leg infections from gravel. Feedlot F found occasional incidences where cattle were coughing in the wood chip pen. No other additional comments or observations were made by the feedlots.

# 5 Pen surface repair and maintenance costs

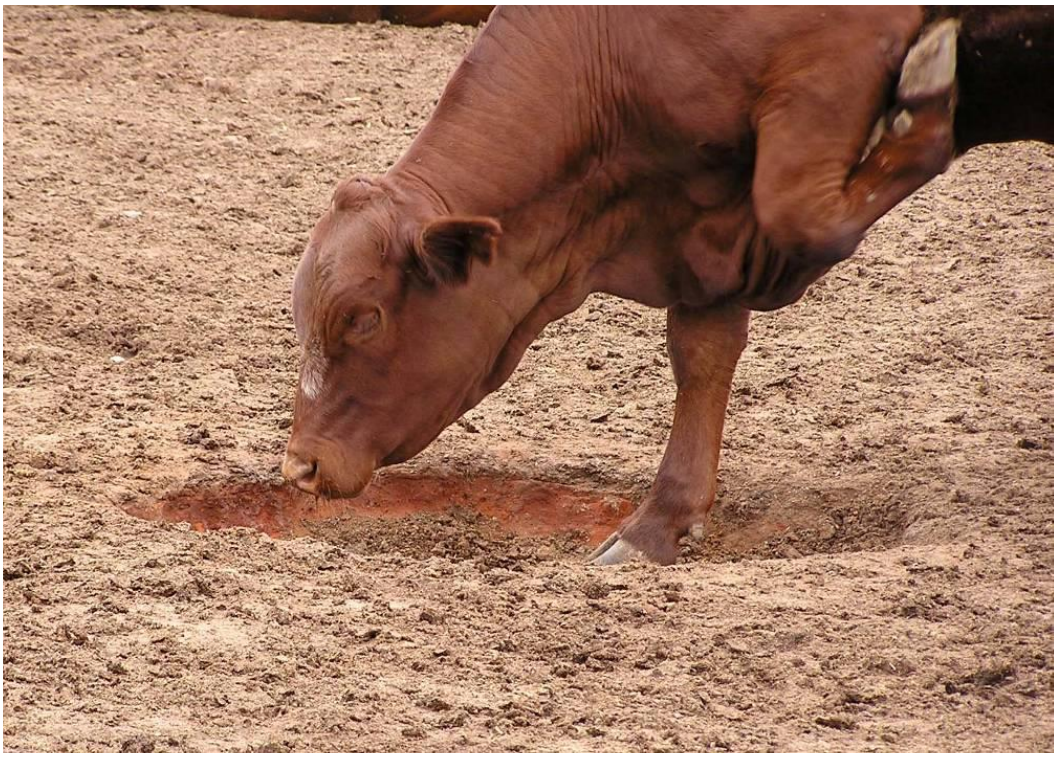
## 5.1 Background

Feedlot pens require on-going maintenance. Pen surface material can be removed during pen cleaning and holes in the pen surface can develop due to cattle digging holes or wear adjacent to high traffic areas such as feed bunks and water troughs.

Cattle can simply dig holes in the pen surface (Photograph 47). Areas behind feed bunks can become eroded (**Error! Reference source not found.**) and potholes develop in the pen urface (Photograph 49). Pen surface material can be removed during pen cleaning if the interface layer is disrupted.

It is speculated that the use of bedding materials will protect the pen surface and thus reduce the cost of on-going pen surface maintenance. This would off-set the cost of the bedding material. However, there is no published data available on the cost of pen surface maintenance.

It was agreed that this project would include an attempt to quantify the cost of pen surface maintenance. This would be done by surveying major feedlots to obtain data on factors that contribute the pen maintenance costs and, if possible, actual costs on a per head basis.



**PHOTOGRAPH 47 – ANIMAL DIGGING A HOLE IN A BARE PEN SURFACE**

**PHOTOGRAPH 48 – PEN SURFACE EROSION BEHIND FEED BUNK APRON**

**PHOTOGRAPH 49 – POTHOLE DEVELOPMENT IN FEEDLOT PEN SURFACE**

## 5.2 Survey

The 22 largest feedlots in Australia were identified and contacted to obtain data on the causes of pen surface damage, the nature and costs of pen surface repair and maintenance works and the effect of bedding on pen surface wear. Of these, data was collected from 13 feedlots whose combined pen capacity was about 350 000 head (about 25 % of total industry capacity).

A survey form was provided to each lot feeder to standardise the data collected. Data was collected via telephone interviews. The form addressed the following:

- Cattle types
- Pen construction
    - Stocking density
    - Pen slope
    - Pen surface construction – clay v gravel
    - Heat stress management – shade vs no shade, type of shade (shade cloth vs iron)
- Pen manure management
    - Manure interface
    - Pen cleaning frequency

- Pen repair processes
- Frequency of repair
- Equipment used
- Cost of pen repairs
- Differences in pen surface damage between bedding pens and non-bedding pens.

## 5.3 Results and discussion

### 5.3.1 Overview

The most frequent pen surface repair and maintenance activity reported was pothole repair. Pen surfaces developed potholes due to wet weather, manure removal, accumulation of moisture on the pen surface and by the actions of cattle pawing and licking.

There was limited quantitative data provided on pen surface repair and maintenance costs. This data was either not recorded by feedlot operators or these costs were incorporated in pen cleaning costs. Estimates of pen repair and maintenance costs varied widely and ranged from $16 to $60/head of pen capacity/year.

The feedlots surveyed had little experience with bedding in pens. Observational data suggested that bedding greatly reduced pen surface wear, but, for one feedlot, it caused a six-fold increase in routine pen cleaning time (see Section 4.7.1) although the pen was cleaned less frequently.

### 5.3.2 Effect of cattle type and age on pen maintenance

Cattle type and their lot feeding stage were found to influence pen surface damage. Most respondents reported a strong difference in the degree of pen surface damage caused by *Bos indicus* and European breeds. European breeds, in particular Angus, had a greater tendency to paw the pen surface which accelerated pothole development. The motivation for this is unknown. It is speculated that it is either a symptom of boredom or cattle are seeking salts contained within the clay surface of the pen.

Starter cattle appeared to cause less pen surface damage than cattle which had been lot fed for some time. Most respondents placed starter cattle in renovated pens first, as starter cattle had fewer tendencies to paw the pen surface when compared to cattle that had been on feed for some time.

#### 5.3.2.1 Stocking density

The stocking densities of the surveyed feedlots ranged from 12 to 16 $m^2$/head. Respondents with previous experience at other feedlots stated that there was no discernible difference in pen surface wear or maintenance costs under different stocking densities. They considered factors such as climate, cattle congregation and shade structures to have a greater influence on pen surface deterioration than stocking density.

#### 5.3.2.2 Pen slope

Pen slopes varied at each feedlot that was surveyed and ranged between 2 and 8%. Respondents stated that pen slope had no discernible influence on pen surface repair and maintenance requirements and costs which is contrary to the assumption that steeper pens would result in more erosion during heavy rain. All feedlots stated that there were more dominant factors effecting pen surface wear than pen slope *per se*. These factors are discussed in other sections.

#### 5.3.2.3 Pen surface construction

In the feedlot industry, there has been a long standing debate concerning the surfacing of feedlot pens. Some prefer a complete gravel cover over the whole pen surface. Other lot feeders prefer a clay surface (covered with manure and an interface layer) with gravel only in high traffic areas. This is due to the high cost of gravel capping and the problem of rocks harvested in pen manure as well as concerns over sharp gravel causing hoof injuries.

The surveyed feedlots included pens constructed from clay with no gravel capping, clay with gravel surfacing, and one feedlot that was sited on a natural gravel ridge. Thus, a range of pen surface options were surveyed.

The opinions of the survey respondents on pen surface construction materials were mostly in relation to feedlot operations and animal welfare rather than pen surface maintenance. The effect of pen surface materials on pen surface repair and maintenance costs could not be established due to a lack of quantified data.

Clay-surfaced pens were reported to have the following benefits over gravel-surfaced pens:

- Reduced lameness in cattle
- Cheaper manure removal and processing for sale. Manure from gravelled pens needed to be screened to remove rock which imposed an additional cost (~$5.00/t) on manure management.
- Easier to repair as a more effective bind could be achieved between the clay and the pothole backfill material.

However, one issue that was identified with clay-surfaced pens was that the surface wore rapidly, particularly under wet conditions if the manure interface was not maintained. Clay-surfaced pens require greater volumes of material for on-going pen maintenance and many of the feedlots with clay surfaces had a clay borrow pit, adjacent to the feedlot, open at all times.

#### 5.3.2.4 Heat stress management

Eleven of the surveyed feedlots had structures to provide full or part shading of cattle to reduce heat stress. The respondents from these feedlots were unanimous in their opinions that shade was a significant contributing factor to pen surface wear.

The survey found that the pen surface of shaded areas was more susceptible to damage than unshaded areas for two main reasons. Firstly, cattle congregated in the shaded areas which concentrated surface wear and moisture from cattle wastes. Secondly, the shade structures restricted drying of the pens and this softened the pen surface making it easier for cattle to dig holes. It was reported in the survey that 80% of pen surface wear occurred where water pooled or in areas that remained wet or moist.

The respondents acknowledged that, although pen shading increased surface repair and maintenance, shade was necessary for heat stress management in their cattle. They made the following key suggestions to reduce pen surface damage related to feedlot shading:

- **The shadow cast by a shade structure must move significantly across the pen.** This allows wet areas to dry and increases the area of pen surface over which cattle congregate. One feedlot reported up to a 50% reduction in pen surface wear after transitioning to a shade structure that allowed the shadow cast to move across the pens.
- **Permeable shade materials reduce pen surface wear associated with rainfall.** Most respondents stated that permeable materials, such as shade cloth, reduced rain drop impact and allowed the moisture to distribute evenly across the pen. Runoff from solid shade materials, such as iron, caused moisture to concentrate and created wet areas of the pen surface that were more susceptible to damage (Photograph 50).

**PHOTOGRAPH 50 – POTHOLES DUE TO IRON SHEETING SHADE DRIPPING ONTO THE PEN SURFACE IN THE SAME PLACE**

#### 5.3.2.5 Pen cleaning frequency

All surveyed feedlots managed pen cleaning in a manner consistent with the *National Guidelines for Beef Cattle Feedlots in Australia* (MLA 2012) by ensuring that the maximum pen cleaning interval did not exceed 13 weeks. Pen cleaning frequency of the surveyed feedlots ranged from 50-64 days (7-8 weeks) up to 84 days (12 weeks) for feedlots in drier areas.

Most of the feedlots that participated in the bedding trial noted that they would clean pens with bedding material much less frequently than standard pens. They wanted to maintain the expensive bedding surface intact for as long as possible, and this was generally possible as the bedding protected the pen surface from pothole development and absorbed moisture from the manure. Problems with deep wet manure did not occur. Hence, there was less need to clean the bedding pens as frequently as normal pens. However, when pen cleaning was eventually undertaken, the time taken to clean the bedding pens was much longer (see Section 4.7.1).

#### 5.3.2.6 Manure interface

At each feedlot, the lot feeders noted that the manure interface layer (Photograph 51) was critical for protecting the pen surface from wear and damage as it deterred cattle from digging, licking or eating the pen surface material. All respondents surveyed aimed to maintain a manure interface of between 25-50 mm as part of their manure management strategy. After major or minor pen repairs, the survey respondents re-introduced a layer of pen manure as an interim measure to protect the pen surface.

**PHOTOGRAPH 51 – EXAMPLE OF A MANURE INTERFACE LAYER MAINTAINED ON A PEN SURFACE**

### 5.3.3 Pen surface repair processes

All respondents stated that their pen surface repair and maintenance works included both targeted minor repairs and whole-of-pen rehabilitation works. Targeted minor pen surface repairs included:

- Filling potholes or low spots that commonly developed where the pen surface was softened by intense cattle traffic and moisture accumulation such as around feed bunk aprons, water troughs and shade. Low spots were identified as weak points in the pen surface as they accumulated moisture and wore more rapidly.
- Filling drop-offs that formed behind concreted apron areas (**Error! Reference ource not found.**). Surface wear was accelerated around the interface of concreted areas and the pen surface as the pen surface often had high moisture content from runoff from the concrete apron, water splash from troughs and concentration of cattle wastes.

Major repairs to the whole pen surface, which typically included regrading and surfacing, were undertaken to reverse the gradual reduction in pen surface levels caused by the actions of cattle and pen cleaning.

#### 5.3.3.1 Frequency of repair

Each feedlot aimed to undertake targeted minor pen surface repairs after each pen cleaning event. However, most respondents noted that this rarely occurred because surface repair works were a lower priority to pen cleaning and other feedlot maintenance activities. In practice, minor surface repairs and maintenance were only carried out if staff, equipment and time were available after pen cleaning.

The frequency of undertaking major repairs to the pen surface ranged from 3 years to 10 years. Corporate feedlots generally conducted major pen surface more frequently than privately-owned or custom feedlots.

#### 5.3.3.2 Materials

Materials for repairs to pen surfaces were usually sourced locally (i.e. within 2 km of the feedlot) from the feedlot property or a related entity. Methods for winning the material varied by the type of material and the capability of a feedlot's on-site resources.

Clay-surfaced pens were repaired with materials from on-site borrow pits. Feedlots with gravelled pens usually engaged a contractor to rip, crush, screen and stockpile supplies of rock and gravel. Two feedlots used their own equipment to source rock and gravel as their local resource (e.g. pea gravel or soft white rock) could be removed from the gravel pit with lighter machinery. Rock was usually crushed to less than 40 mm, with the most common fraction being 10-20 mm, as larger sizes increased the incidences of lameness and was difficult to bind. Two feedlots blended gravel and clay to form an engineered material that could be compacted and bound together.

Only one feedlot purchased material from an off-site source that was not associated with the feedlot. Gravel was delivered to the feedlot in a form that could be directly placed on the pen surface. The respondent noted that this was an expensive option but there was no suitable material on-site.

#### 5.3.3.3 Process followed

The typical pen surface repair process described by the respondents is below:

- Manure removal from the repair site
- Scarification (i.e. ripping or scuffing) of the area to be repaired and the surrounding pen surface to bind the repair material with the existing surface material
- Placement of the repair material. For large repairs and whole-of-pen repairs, layers were limited to a thickness of 150 mm thickness to achieve the required compaction
- Watering the repair material to assist with compaction. All respondents were aware of the need for moisture control to achieve a tight pack. One respondent discussed this process in technical terms (i.e. optimum moisture content and maximum dry density) while most used generic terms for achieving a 'tight or good bind'
- Compaction of the repair material, gradually building it up in layers and then grading it to the required surface level
- Re-introduction of a layer of pen manure prior to cattle entry to deter cattle from pawing, eating or licking the repaired surface.

#### 5.3.3.4 Plant and equipment used

The following range of plant and equipment was used for pen surface maintenance:

**Trucks** - trucks were used to cart pen surface materials from the material stockpile, quarry or borrow pit to the pen. The trucks used for manure removal were used for pen surface maintenance. Most feedlots owned trucks but two feedlots used contractors for this purpose.

**Loaders** – Front-end loaders were used to load stockpiled materials into the trucks. All feedlots had a front-end loader on-site which was used for pen cleaning and pen surface maintenance activities.

**Excavators –** Hydraulic excavators come in a wide variety of sizes from large heavy machines to small compact ones. Buckets of various sizes and configurations can be fitted such as ones fitted with teeth or straight edge. Attachments can be fitted for ripping, boring, crushing, lifting, compacting etc.

**Skid-steer loaders** – All feedlots had a small, compact, rigid-frame loader on-site for activities such as under-fence cleaning and pen surface repair.

**Water cart** – All feedlots had a water cart on-site for dust suppression that was used to apply moisture to the pen surface material prior to compaction.

**Roller** – All feedlots had some form of roller on-site to compact the pen surface material and for road maintenance activities. The configurations present within the feedlots surveyed included:

- Tractor-drawn and self-propelled
- Three-point roller steel drum
- Single drum roller non vibrating
- Single drum vibrating
- Smooth drum and sheepsfoot roller
- Special attachments to excavators.

Most rollers were in the 14-16 t weight range. Four larger feedlots also had a smaller roller (around 2 t) for compacting areas around feed bunks and water trough aprons.

**Grader** – Most feedlots also owned a grader that was used for road maintenance and for levelling pen surface material. No respondents used GPS machine control on any equipment, but one used laser level to level pen surfaces after major repair works.

### 5.3.4 Cost of Pen Surface Repairs and Maintenance

Very limited quantitative information was provided for the costs of pen surface repairs and maintenance. Ten respondents stated that they did not separate the cost of pen surface repairs from the costs associated with pen cleaning. Three feedlots provided approximate costs related to pen surface repairs and maintenance.

One feedlot estimated that approximately $400,000 was spent each year on pen surface repairs and maintenance which equated to about $16/head of pen capacity/year. Another feedlot reported that the machinery cost for general pen maintenance was about $2000 per 250 head pen per year. Gravel cost $10.50/t delivered and it took 12 t of gravel per pen. After compaction of the gravel, the total pen maintenance cost was about $20/head of pen capacity/year. Another feedlot of 7000 head capacity estimated that annual pen maintenance costs were about $200,000.

Two feedlots provided rates for the supply of pen surfacing materials. From their head-on-feed capacities and indicative gravel demand (~2 t/head/year), their annual pen surface repair and maintenance costs were crudely estimated to range from $16 to $60/head of pen capacity/year. It should be noted that these estimates did not include labour, equipment, fuel or other costs.

### 5.3.5 Surface damage in bedding and non-bedding pens

Three feedlots surveyed used some form of bedding material. Two feedlots had only used bedding (wood chips) for a short period (<6 months) and could offer only limited comment on differences in pen surface wear between bedding and non-bedding pens. One respondent made the following observations:

- A pen with 200 mm deep bedding appeared to be in better condition than a pen with 100 mm bedding and the control pens.
- The surface of 200 mm bedding pens required re-levelling to remove potholes in the wood chip layer. Interestingly, the potholes did not extend into the pen surface.

- The pen surface was in better condition in bedding pens compared with non-bedding pens.
- The bedding pens took significantly longer to clean than the non-bedding pens. The 100 mm bedding pen took four times longer to clean and the 200 mm bedding pen took six times longer to clean.

A third feedlot provided observational data of pen surface wear based on three years of experience with bedding pens. This feedlot used hardwood chip bedding with a 50 mm particle size to reduce dags on Wagyu cattle. The respondent reported that the bedding protected the surface from wear and preserved its integrity. No potholes had formed in the surface of the pens after three years of continued use of hardwood chip bedding.

## 5.4 Summary

The survey clearly demonstrated that there is little quantifiable or reliable data for pen surface repair and maintenance costs at the surveyed feedlots. This is because these costs were generally absorbed in pen cleaning costs. The lack of rigour around cost accounting for pen surface repair works was considered to reflect the ad-hoc basis on which they were conducted and their low priority compared to other routine feedlot maintenance activities. However, annual costs are highly variable and can be significant.

The survey results suggested that bedding does reduce pen surface wear and limit the formation of potholes. However, there were insufficient data to determine the cost benefit of reduced pen surface repairs and maintenance due to the use of bedding. A notable comment received from one respondent suggested that bedding actually resulted in a six-fold increase to the time, and presumably the costs, of routine pen cleaning.

The cost - benefits of bedding with regards to pen surface repairs and maintenance could not be determined from this survey. The true value of bedding pens to feedlot operations would require strict cost accounting for pen cleaning and surface maintenance works (labour, plant and materials), an evaluation of the cost impacts of bedding on routine pen cleaning and other feedlot operations and determination of the cattle productivity benefits of bedding.

## 5.5 Pen surface stabilisation (PSS)

Throughout the survey of pen surface management, no respondent mentioned using any type of pen surface stabilisation (cement stabilised or fly ash). However, several feedlots commented that they did not have a close source of good quality gravel and had used on-site clay to build and/or repair pens. Unstabilised clay wears quickly and this is an on-going cost.

It seems probable that PSS could have a role in feedlots where weak and / or dispersive clay is used on the pen surface (and gravel is expensive). However, there is no experience on its use in Australia but it has been used in a feedlot in New Zealand (Photograph 52). It would be beneficial to develop a PSS demonstration site on a feedlot with clay pen surfaces and to document the installation and on-going performance of the pen surface so that other lot feeders could make an informed decision about its use.

PHOTOGRAPH 52 – FEEDLOT WITH CEMENT-STABILISED PEN SURFACE

# 6 Wood chip recovery from pen manure

Wood chip bedding will almost certainly need to be recycled and reused to make this practice economically and environmentally sustainable for extensive use in feedlots. Recycling involves separating the wood chip from the cleaned pen manure so it can be reused on the pens.

As discussed in Section 3.5.1, there is no single 'wood chip' product. Consequently, the wood chip accessible for feedlot bedding varies by region and is available in many shapes and sizes with varying physical characteristics (i.e. density and PSA). These physical attributes potentially allow for the implementation of recycling/separation techniques. The recycling techniques for separating wood chip from pen manure are detailed in the following sections.

## 6.1 Common separation approaches

Solids separation methods can be grouped into two categories: gravitational separation and mechanical separation.

### 6.1.1 Gravitational separation in liquids / floatation

Gravitational separation relies on density differences between two media. The material with the higher density will eventually, under the force of gravity and time, settle to the bottom of the liquid stream. A common example of this within the feedlot setting is sedimentation ponds, which are designed to remove soil and manure particles entrained in the feedlot runoff.

The majority of dry wood chips have a lower density than water and therefore they will float in water. By mixing the harvested wood chips and manure with water, the wood chips should theoretically rise to the top of the water column. The separated wood chip could then be skimmed from the top of the water column. A gravitational separation system would require large volumes of water and proper mixing to reduce the chances of wood chips being trapped within manure clods. Wood chips separated in this way would then require drying before they could be re-spread onto pens. Small scale (30 L) testing was undertaken to determine the effectiveness of gravitational separation (Photograph 75). Cleaned wood chip pen manure from Feedlot B and Feedlot C were used. The wood chip manure was placed in the 30 L tank and thoroughly mixed. Some wood chips floated to the surface after mixing stopped but the large proportion did not. This was because the wood chip was saturated (wet). It had an increased density after being used for bedding due to exposure to moisture in manure and rainfall. Furthermore, most wood chips had wet manure attached to them. These wood chips sank to the bottom of the tank and could not be removed by floatation. On this basis, and given the volume of water required for separation, it was concluded that gravitational separation is not a viable way of recycling wood chip bedding from feedlots.

### 6.1.2 Mechanical separation

Mechanical separation includes screening and centrifugal separating (Birchall et al. 2008). Material screening is a size classification separation approach which relies on grading a material by size. Screening units can be operated as ‘static’, ‘vibrating’ (lateral movement) or ‘rotating’. This technique can utilise one or more mesh screens of varying size to separate materials. Centrifugal separation, in particular hydrocylcones, are another mechanical separation technique. This process is used to separate or sort particles in a liquid suspension based on the ratio of their centripetal force to fluid resistance or in a solid phase such as grain cleaning. Dense and coarse (wood chip) particles tend to have a high ratio while light weight and fine particles tend to have low ratios. Based on the experiences with pen manure wood chips, centrifugal separation does not seem viable.

### 6.1.3 Screening

Due to the solid status of both wood chips and manure, screening was considered the most likely option for separating wood chip from manure. There are three general classifications of screens: static, rotating and vibrating. In this study, wood chip separation trials were conducted using rotating and vibrating screens.

#### 6.1.3.1 Static screens

Static (run-down) screens are commonly used at piggeries and abattoirs to separate solids from liquid effluent. Static screens often have small screen openings (e.g. 6 mm) and due to their lack of movement can clog quickly if the waste stream contains a high fraction of material greater than the screen pore size. Therefore, as the harvested manure/wood stream is solid, this approach would be unsuitable for separating wood chips from manure.

### 6.1.3.2 Rotating screens

Rotating screens (trommels) are used in the municipal waste and mining industries to separate solids from either solid or liquid feed streams. Trommels consist of a perforated cylindrical drum (screen) and sometimes, a fixed scraper which dislodges material stuck in the screen. The system can also be fitted with a water jet to ensure the screen remains free of debris. The fixed scraper and/or water jet may aid in the breakup of large manure clods (Birchall 2010). However, a more usual solution is to use an external brush to clean the trommel screen (Photograph 53). The trommel screen allows smaller particles (<sieve size) to pass through to screen into a collection tray, while material greater than the pore size are passed through the drum and ejected at the end. The screening time of a trommel can be adjusted by increasing the length of the screen, or by altering the inclination of the screen. An increase in screening time means that particles are retained within the rotating trommel for longer periods. With manure, this means that manure clods are more broken down and more material passed through the fine screen. Photograph 54 shows a small trommel with a fine (5 mm) screen that had been trialled to separate wood chips from dry pen manure.

**PHOTOGRAPH 53 – TROMMEL WITH EXTERNAL BRUSHES WORKING AT A FEEDLOT**


**PHOTOGRAPH 54 – A TROMMEL (ROTATING SCREEN)**

#### 6.1.3.3 Vibrating screens

Vibrating screens (shakers) consist of a static frame, with one or more vibrating screens (Photograph 55). The screens decrease in aperture from top to bottom. This vibrating screen process is used for particle size differentiation in the mining and quarry industries.

**PHOTOGRAPH 55 – AN EXAMPLE OF VIBRATING SCREENS**

### 6.1.4 Limitations with screening manure

Screening separation is dependent on the moisture content of the manure. Extremely wet manure (fresh manure) is likely to clog the screens, resulting in poor separation. A solution to this would be to include a water jet to clean the screens.

The lower the moisture content, the more effective the screening will be. If the manure substrate is extremely dry, the manure clods should breakup, releasing the wood chips and allowing them to be recovered. The worst case scenario for screening operations is likely to be if the manure is slightly wet with a 'tacky' or clay-like state. Manure at this moisture level may stick to the screen and even with the use of sprayers may be difficult to break down the clods to keep the screen free of debris.

In practice, manure should be in a dry condition at the point of screening as pen cleaning is generally undertaken in dry periods. However, during the separation trials for this study, when the 'dry' manure was screened, one of the trial participants noted that the 'dry' manure moisture content was still too high for effective screening.

## 6.2 Wood chip screening trial

A trial was undertaken to determine if wood chips could be removed from pen manure using equipment normally available at a feedlot. The objective was to remove wood chips that could be reused in a pen a second time, thus reducing the cost of wood chip bedding.

The trial was undertaken at a commercial composting facility that had both a trommel and a dual-screen vibrating shaker. Pen manure from wood chip trials set up at Feedlot B and Feedlot C was harvested after about six months of occupation by cattle. The harvested manure was weighed at the feedlot and transported to the composting facility where it was screened using both types of machinery. Samples of the different screened materials were then wet-sieved to manually separate the remaining wood chip from the pen manure to determine the recovery rate of wood chips.

In this trial, both rotating and vibrating screens were tested to determine their effectiveness at recovering wood chips from pen manure. An additional scenario combing both types of screens was run to determine if combining the different screening motions (rotational and lateral) could increase wood chip recovery rates. For the combined screening trial, the manure feedstock was initially fed through the trommel and the reject material was then fed into the shaker to determine if the combined separation was greater than the individual screening processes.

## 6.3 Materials and methods

### 6.3.1 Feedlot B

Feedlot B is described in Section 4.4.2. Four pens were used for the trial, consisting of two control pens and two trial pens. All of the trial pens at Feedlot B were shaded (Photograph 57 and Photograph 58) with pen dimensions of 50 m width and 60 m depth. The pen slope was about 3%. Details of the trial pens, bedding techniques and cattle are detailed in Section 4.4.2 and Table 4.

The wood chip used in both bedding trial pens at Feedlot B was Cypress pine with a particle size of 10-40 mm (Photograph 56). The wood chip cost was $22/m^3$ delivered and had a bulk density of 300 $kg/m^3$ as delivered. Both wood chip pens (F3 and F4) were cleaned in mid-August 2013, with the intention of spreading the wood chip on 19 August 2013. The required volume of wood chip could not be obtained initially, therefore the start of the trials were delayed until the wood chip became available. Pen F4 was setup first, and in-pen spreading was completed on the 27 September 2013. Cattle were placed on wood chip the following day. The 200 mm deep bedding layer in Pen F3 took six weeks to complete. Spreading began on the 11 October 2013 and was finished on the 10 December 2013. Cattle were moved onto the wood chip the day of completion.

In both bedding trial pens, the wood chip was spread from the edge of the feed apron to the bottom fence line. During periods of rainfall, wood chip was observed to be washed from the pen into the cattle lane. In response, Feedlot B placed wooden boards along the bottom fence line prevent wood chips moving into the cattle lane (Photograph 34).


**PHOTOGRAPH 56 – TYPICAL WOOD CHIP - FEEDLOT B**

**PHOTOGRAPH 57 –FEEDLOT B – PEN F4 – 100 MM WOOD CHIP (9 OCT 2013)**

**PHOTOGRAPH 58 – FEEDLOT B – PEN F4 – CATTLE USING SHADE (20 NOV 2013)**


**PHOTOGRAPH 59 – FEEDLOT B – PEN F3 – SPREADING 200 MM WOOD CHIP (20 NOV 2013)**

### 6.3.2 Feedlot C

Feedlot C is described in Section 4.4.3. Five trial pens were used which were 20 m wide and 45 m deep. The pens were stocked at 12.5 $m^2$/SCU (72 SCU/pen) and an average bunk space of approximately 278 mm/SCU was provided. Pen slopes were steep, ranging from 5% - 8% and there were no shade structures in the trial pens. Details of the trial pens, bedding techniques and cattle are detailed in Section 4.4.3.

Three different wood chip products were used for the trial at Feedlot C:

| | |
|---|---|
| Product 1 – hardwood chip from Roma | 390 kg/$m^3$ |
| Product 2 – hardwood chip from local supplier | 310 kg/$m^3$ |
| Product 3 – shattered, splintered mulch from local supplier | 270 kg/$m^3$ |

Feedlot C started receiving wood chip loads from 12 July 2013. Due to availability of supply issues, the wood chip was stockpiled until the required quantities were received by 4 September 2013. Wood chip spreading was completed on the 4 September 2013.

**Photograph 60 –Feedlot C– Pen surface before spreading wood chip (4 Sep 2013)**


**Photograph 61 – Feedlot C – Placement of 200 mm wood chips – Pen 6 (4 Sep 2013)**

**PHOTOGRAPH 62 – FEEDLOT C – PEN 5 (200 MM SPLINTER) ON LEFT, PEN 6 (200 MM CHIP) ON RIGHT (4 SEP 2013)**

**PHOTOGRAPH 63 – FEEDLOT C – PEN 3 – WOOD CHIP MOUND (4 SEP 2013)**

**PHOTOGRAPH 64 – FEEDLOT C – PEN 5 ON LEFT (SPLINTER), PEN 4 ON RIGHT (CONTROL) – 5 FEB 2014**

### 6.3.3 Feedlot Pen Cleaning

Pen cleaning was conducted at Feedlot C on 11 March 2014 (Photograph 65) and at Feedlot B on 17 March 2014. The total mass of material removed from the trial pens was recorded and sub-samples of the material (approximately ten tonnes) were delivered to the recovery trial site the following day. During pen cleaning, pen surface manure samples were taken from the control pens. These samples were later analysed from agronomic properties (see Section 0).


**PHOTOGRAPH 65 – PEN CLEANING AT FEEDLOT C (11 MARCH 2014)**

### 6.3.4 Screening of Manure

Manure screening trials for harvested pen manure from Feedlot B and Feedlot C were conducted on 12 March and 19 March 2014 respectively. The two screening units used were a trommel (rotating screen) and a shaker (vibrating screen). The following three screening trials were completed

- Trommel only (TO)
- Shaker only (SO)
- Shaker following trommel (ST).

During each trial, three front-end loaders (FEL) loaded one full bucket of the harvested manure into the screening machines intake section. After manure delivery, the loaders were repositioned to collect the screened material from each of the shaker output streams. The screening machines were then started. Throughout the screening operation, which only took a few minutes, multiple samples were taken from the output streams to ensure a representative composite sample (approximately 30 – 50 kg) was kept. The composite samples from each stream were individually stored in covered containers (wheelie bins) to prevent sample contamination, spillage and water infiltration. All input and output weights, including tare weight of the front-end loaders, were determined and recorded by four (Haenni® WL 103) weigh pads.


**PHOTOGRAPH 66 – RECORDING LOADS BY WEIGH PADS DURING SEPARATION TRIAL**

### 6.3.4.1 Trommel

The trommel used in the trials was fitted with a 20 mm aperture rotating screen (Photograph 67). Material that was smaller than 20 mm passed through the mesh and was collected by a conveyor located below the rotating screen (Photograph 68). Solids greater than 20 mm were rejected by the screen and passed through the machine before being collected at the front of the trommel by a FEL (Photograph 68). Screened material that was missed by the FEL was manually shovelled into the FEL bucket.

**PHOTOGRAPH 67 – TROMMEL SCREEN - 20 MM SCREEN**

The UHF radio is approximately 150 mm long


**PHOTOGRAPH 68 – TROMMEL WITH A 20 MM SCREEN USED AT TRIAL SITE**

Material collected from the <20 mm and >20 mm outlets contained a mix of manure and wood chip (Photograph 69, Photograph 70). Visually, it was immediately obvious that the trommel was unable to separate the wood chips from the pen manure due to the small size of the wood chips.

**PHOTOGRAPH 69 – MANURE AND WOOD CHIPS SCREENED FROM TROMMEL WITH THE SIZE >20 MM**


**PHOTOGRAPH 70 – MANURE AND WOOD CHIPS SCREENED FROM TROMMEL WITH THE SIZE <20 MM**

### 6.3.4.2 Shaker

The shaker used in the second trial (SO) was fitted with two vibrating screens. The top screen had a larger aperture of 40 mm, while the secondary screen had a reduced aperture of 10 mm. Therefore, the shaker generated three output streams with particle sizes: <10 mm, 10-40 mm, and >40 mm (Photograph 71).


**PHOTOGRAPH 71 – VIBRATING SCREEN WITH THREE OUTLETS USED AT THE RECOVERY TRIAL SITE**

The three output streams from the shaker contained a mix of wood chip and manure. Material from the <10 mm stream contained a high fraction of manure and splintered timber products (Photograph 72), the 10-40 mm stream appeared to contain the highest wood chip to manure ratio (Photograph 73), while the > 40 mm stream had obvious wood chip, but contained a large fraction of solid manure pads (Photograph 74). The shaker operator suggested that large manure clods meant that the moisture content of the manure was still too high to get a complete and effective screening. All input and output loads were weighed as per the trommel only trial.


**PHOTOGRAPH 72 – MANURE AND WOOD CHIPS SCREENED FROM VIBRATING SCREEN -<10 MM**

**PHOTOGRAPH 73 – MANURE AND WOOD CHIPS SCREENED FROM VIBRATING SCREEN - 10 TO 40 MM**

**PHOTOGRAPH 74 – MANURE AND WOOD CHIPS SCREENED FROM VIBRATING SCREEN >40 MM**

#### 6.3.4.3 Shaker following trommel

The third trial combined both screening technologies to produce the shaker and trommel (ST) test. Three loader buckets of raw substrate were initially fed into the trommel and material that passed through the screen (<20 mm) was collected and fed into the shaker for additional size separation and classification. All input and output streams from both the trommel and the shaker were recorded.

#### 6.3.4.4 Mass balance of screen inputs and outputs

A mass balance was undertaken to check that the weight of manure delivered to the screen was recovered in the separated components. Table 5 shows the mass balance of inputs and outputs for the trommel only trial. A mass balance error of 18% was found for Feedlot B manure, while a 6% error was recorded for the raw manure from Feedlot C.

Table 6 shows similar data for the vibrating screen only trial. There was a 19% mass balance error for Feedlot B and a 4% error Feedlot C. Table 7 shows similar data for the combined trommel and screen trial.

The mass balance errors occurred due to the inaccuracies associated with measuring the loaders plus manure on weigh scales in the field (Photograph 66). For small loads, the tare weight of the loader was much greater than the load of manure in the bucket. The manure from Feedlot B was screened first. The data clearly shows that the experimental method had improved considerably by the time that the Feedlot C manure was screened as the mass balance errors had reduced to only a few percent. Mass balance of the screening highlighted variability between the feed input and output from each of the screening treatments. These errors may be explained by random spill during screening and transportation to the weighing, variability in the FEL position at weighing and accepted the weigh pad error. Random spills occurred when the wind was strong, or when the outlet was not properly captured by the loader. Although unavoidable, this is considered a minor component of the error.

The weigh pads error, on the other hand, may be more significant and could explain the large errors witness (19%). Each of the weigh pads used in the trial is designed for a load up to 15 t with an inaccuracy of ± 50 kg. As four weigh pads were used in the trial, this suggests a maximum load of 60 t with a potential inaccuracy of up to ± 200 kg (http://www.haenni-scales.com/fileadmin/redakteur/datenblaetter/Radlastwaagen/W2_106_E.pdf). During the trial, the tare weight of FEL was 12 to 17 t, while the loads varied from only 300 to over 2000 kg. Therefore, the maximum load weighed by the four pads was only 19 t. This is well within the load limit, but not within the ideal weight ranges, suggesting a potentially high error in measuring small loads. Furthermore, if the load was not evenly placed across the pads and the FEL bucket was positioned differently at the time of measurement, this may also influence the recorded weight.

**TABLE 5 – MASS BALANCES OF TROMMEL SCREENING TRIAL**

| **Trommel Only (TO)** | **Units** | **Feedlot B** | **Feedlot C** |
|---|---|---|---|
| Pen | | Pen 4 | Pen 6 |
| Bedding treatment | | 100 mm wood chip | 200 mm wood chip |
| Raw harvested manure entering screen | kg (wb)* | 6 117 | 6 050 |
| Raw harvested manure < 20 mm | kg (wb) | 4 839 | 5 793 |
| Raw harvested manure > 20 mm | kg (wb) | 361 | 672 |
| **Raw harvested manure exiting screen** | **kg (wb)** | **5 200** | **6 466** |
| **Mass error of screening** | **%** | **-18** | **6** |

*wb refers to wet basis

### TABLE 6 – MASS BALANCES OF SHAKER TRIAL FOR THE TWO FEEDLOTS

| Shaker Only (SO) | | Feedlot B | Feedlot C |
|---|---|---|---|
| Pen | | Pen 4 | Pen 6 |
| Bedding treatment | | 100 mm wood chip | 200 mm wood chip |
| Raw harvested manure entering screen | kg (wb)* | 6 100 | 3 150 |
| Raw manure < 10 mm | kg (wb) | 2 531 | 1 696 |
| Raw manure 10-40 mm | kg (wb) | 1 466 | 1 191 |
| Raw manure > 40 mm | kg (wb) | 1 108 | 147 |
| **Total raw manure out** | **kg (wb)** | **5 106** | **3 035** |
| **Mass error of raw manure** | **%** | **-19** | **-4** |

*wb refers to wet basis

### TABLE 7 – MASS BALANCES OF SHAKER FOLLOWING TROMMEL TRIAL FOR THE TWO FEEDLOTS

| Shaker following Trommel (ST) | | Feedlot B | Feedlot C |
|---|---|---|---|
| Pen | | Pen 4 | Pen 6 |
| Bedding treatment | | 100 mm wood chip | 200 mm wood chip |
| Raw harvested manure entering screen | kg (wb)* | **2 350** | **5 793** |
| Raw manure < 10 mm | kg (wb) | 2 130 | 3 997 |
| Raw manure 10-40 mm | kg (wb) | 598 | 1 639 |
| Raw manure > 40 mm | kg (wb) | NA | NA |
| **Total raw manure out** | **kg (wb)** | **2 727** | **5 636** |
| **Mass error of raw manure** | **%** | **14** | **-3** |

*wb refers to wet basis

### 6.3.5 Wood chip recovery determination

After completion of the on-site manure screening, measurements were taken to determine the amount of wood chip in each screened sample. This involved the following steps: representative sampling; water addition and stirring; removal of floating wood chips using a sieve; and by screening wood chip from the manure sludge (Photograph 75).

1. Representative sampling

During the on-site screening, samples of each manure category were collected in wheelie bins with a collected mass ranging from 30 – 50 kg. The procedure for wood chip recovery determination only required 3 kg of screen substrate. Therefore, to ensure representative samples were tested the 'quartering and sub-sampling' approach was used. During the quartering, large manure clods were manually broken apart to create a homogenous sample. The sample was then split into four equal parts. Three quarters were disposed leaving a final quarter which was mixed further. Finally, a 3 kg representative sub-sample was obtained from the remaining quarter.

2. Water addition and stirring

Each 3 kg sub-sample was placed into a 30 L bucket of water. The samples were stirred for 1 minute using a mechanical mixer (paint stirrer) to break down the manure clods and dislodge as much wood chip as possible.

3. Separation of wood chips

After the stirring process, manure-free, floating wood chip was collected using a sieve. It was observed that a significant amount of wood chip was retained in the manure sludge or was too saturated to float. This wood chip could not be recovered from the water surface with the sieve. To remove wood chip from the manure sludge, the sludge plus manure was washed through a 4.75 mm sieve which allowed collection of wood chip and removal of gravel. All particles (including wood and gravel) that passed through the 4.75 mm sieve were considered 'manure'. Wet weight of wood chips and gravel were recorded to determine the compositional breakdown of each harvested manure sample. Gravel was manually separated out from wood chip.

For both feedlots, gravel comprised only 1-2% of the harvested manure (Figure 7). This seems to be a low percentage for pen manure, perhaps indicating that the wood chips had protected the pen surface from mixing with the bedding / manure while in the pen.

Using this method, "wood chip" is effectively defined as any particles (excluding gravel) that did not pass through a 4.75 mm screen. All manure had broken down into much finer particles. However, it is clear that 4.75 mm particles are too small to be recycled back into the feedlot pen. Hence, a particle size analysis of the screened wood chip was undertaken to determine how much of the recovered wood chip was re-useable (Figure 8).

Washed wood chips were dried by microwave. Each wood chip sample was placed in four to eight plastic containers (microwave safe), containing up to 250 g of wet wood chips. To prevent burning, the drying time was one to five minutes. Containers were taken out of the microwave and air cooled before further drying. Clean wood chips (unused) from Feedlot B and C were also dried by microwave using a shorter drying time of two minutes. This drying determined the approximate moisture content of the wood chips when originally placed in the pens.

(i) Sub-sampling

(ii) Mixing

(iii) – Sieving

(iv) - Floating

**PHOTOGRAPH 75 – WOOD CHIPS WASHING PROCEDURE**

(Clockwise): (i) representative sampling of materials from bins; (ii) mixing manure with water by stirring; (iv) floating wood chips after mixing; (iii) washing and sieving wood chips from sludge.

### 6.3.6 Wood chips properties

Bulk densities of unused (clean) wood chip samples from the two trial recovery feedlots were measured. Samples were placed in a calibrated 5.4 L container and slightly compacted before weighing. This method was used to determine most of the bulk densities given in Table 2. Hence, the bulk density of clean wood chip products is given at an as-supplied moisture content, not dried. Moisture content of these samples was determined using microwave drying.

A sub-sample of the raw harvested and screened streams from the trommel and shaker were analysed at an accredited laboratory for moisture content (MC), total solids (TS) and volatile solids (VS). Additional testing for nutrient and mineral composition was undertaken on the control pens and the <10 mm ST samples. The <10 mm ST samples were considered to represent the pen manure that would have been spread as fertiliser. The additional testing was undertaken to allow comparisons between the agronomic content of the control pen manure and the manure fraction contained within the trial pens (see Section 0).

## 6.4 Results

### 6.4.1 Wood chip separation by trommel only

Trommel screening separated 93% of Feedlot B and 90% of Feedlot C raw pen manure / wood chip mix into the <20 mm outlet (wet based, Figure 4). This indicates that, in the process of pen cleaning, transport and then tumbling in the trommel, over 90% of the pen manure / wood chip was less than 20 mm in size.

After separation of the recovered wood chip from the manure, it was determined that 88% and 93% of the available wood chip fraction from Feedlot B and Feedlot C was screened to <20 mm, respectively.

This shows that only a few percent of the original wood chips remained at a size that could be separated by a 20 mm screen. This is partly because about 50-60% of the original wood chips were smaller than 20 mm (see Figure 8) and because it was observed that many of the larger wood chip pieces had split laterally while in the feedlot pen. This allowed them to pass vertically through the 20 mm screen.

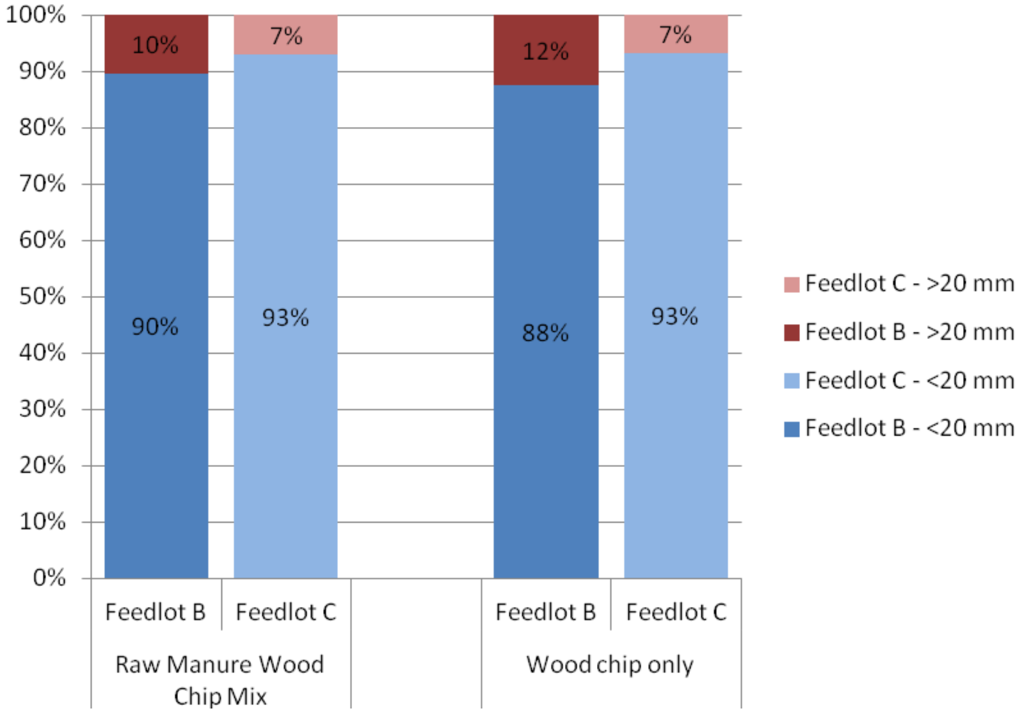



**FIGURE 4 – TROMMEL SCREENING PROPORTIONS (<20 MM AND >20 MM)**

### 6.4.2 Wood chip separation by shaker only

Shaker screening separated 50% of Feedlot B pen manure and 56% of Feedlot C pen manure into the <10 mm outlet (wet based, Figure 5). Only 5% of the pen manure / wood chip from Feedlot C was greater than 40 mm.

While at least half of the total manure / wood chip mix was sieved into the <10 mm stream, the majority of wood chip from Feedlot B (48%) and Feedlot C (55%) was screened into the >10mm to <40mm stream.

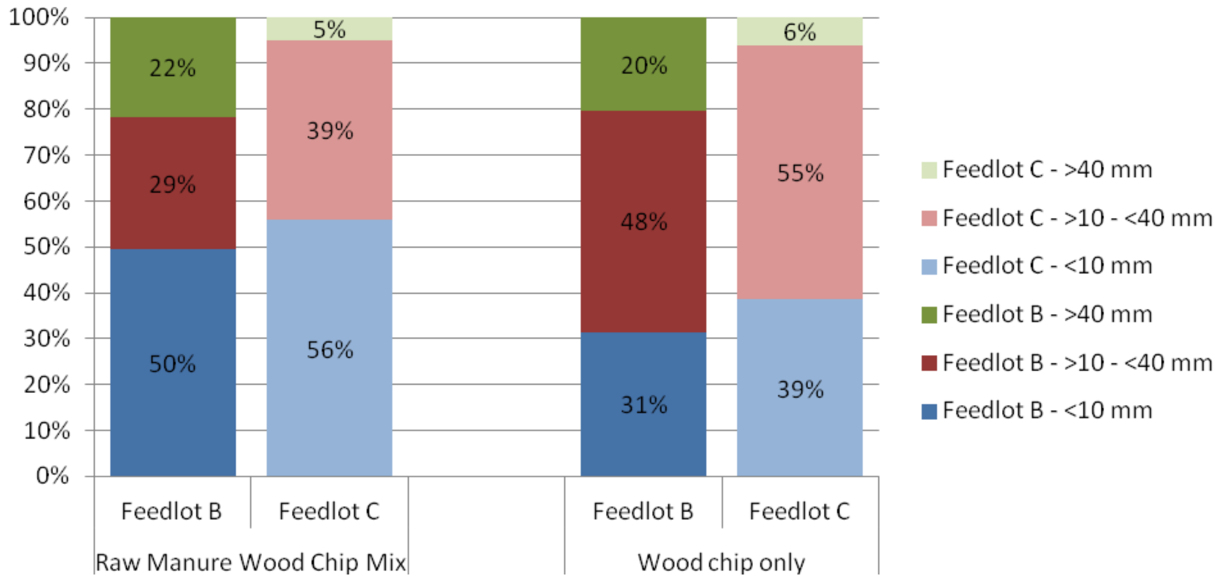



**FIGURE 5 – SHAKER ONLY SCREENING PERCENTAGES**

### 6.4.3 Wood chip separation by trommel and shaker

Shaker following trommel screening (ST) separated 78% of Feedlot B pen manure and 71% of Feedlot C pen manure into the <10 mm outlet (wet based, Figure 6). The wood chip fraction was split evenly between <10 mm and >10 - <40 mm fractions.

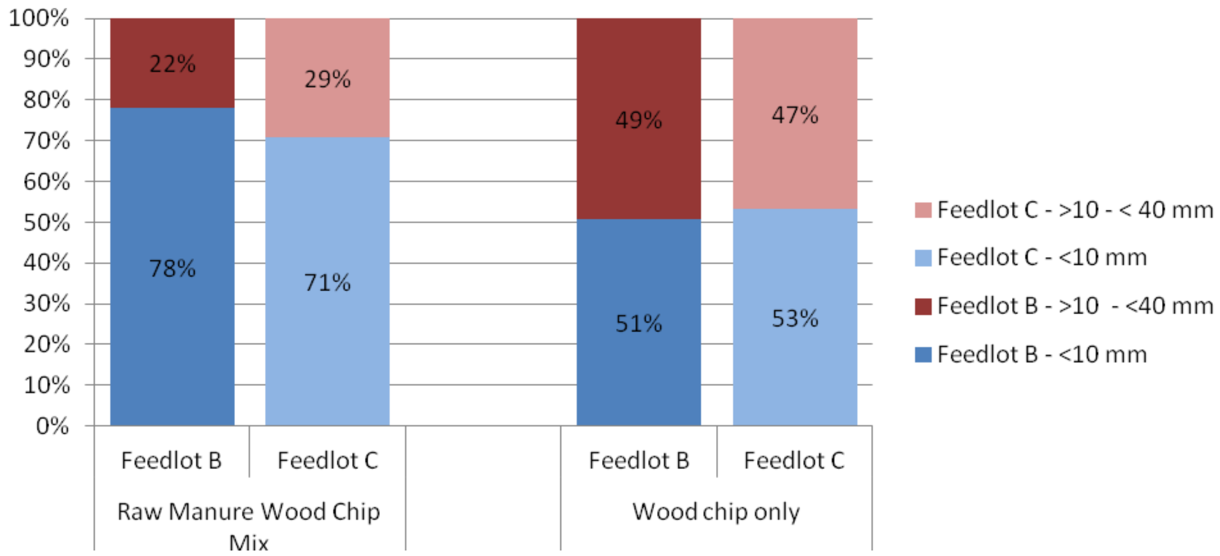



**FIGURE 6 - TROMMEL AND SHAKER SCREENED PERCENTAGES**

### 6.4.4 Overall screening results

Throughout the duration of screening tests, samples were collected from each screened output. Samples were analysis to determine the percentage of each component found in harvested pen manure (manure, wood chip and gravel). Figure 7 shows the complete analysis for each trial. It shows that the SO and ST 10-40 mm streams had the highest wood chip fraction. The 10-40 mm stream at both feedlots had the highest wood chip contents, ranging from 45% - 58%. These screen streams also had the highest percentage of gravel at both feedlots.

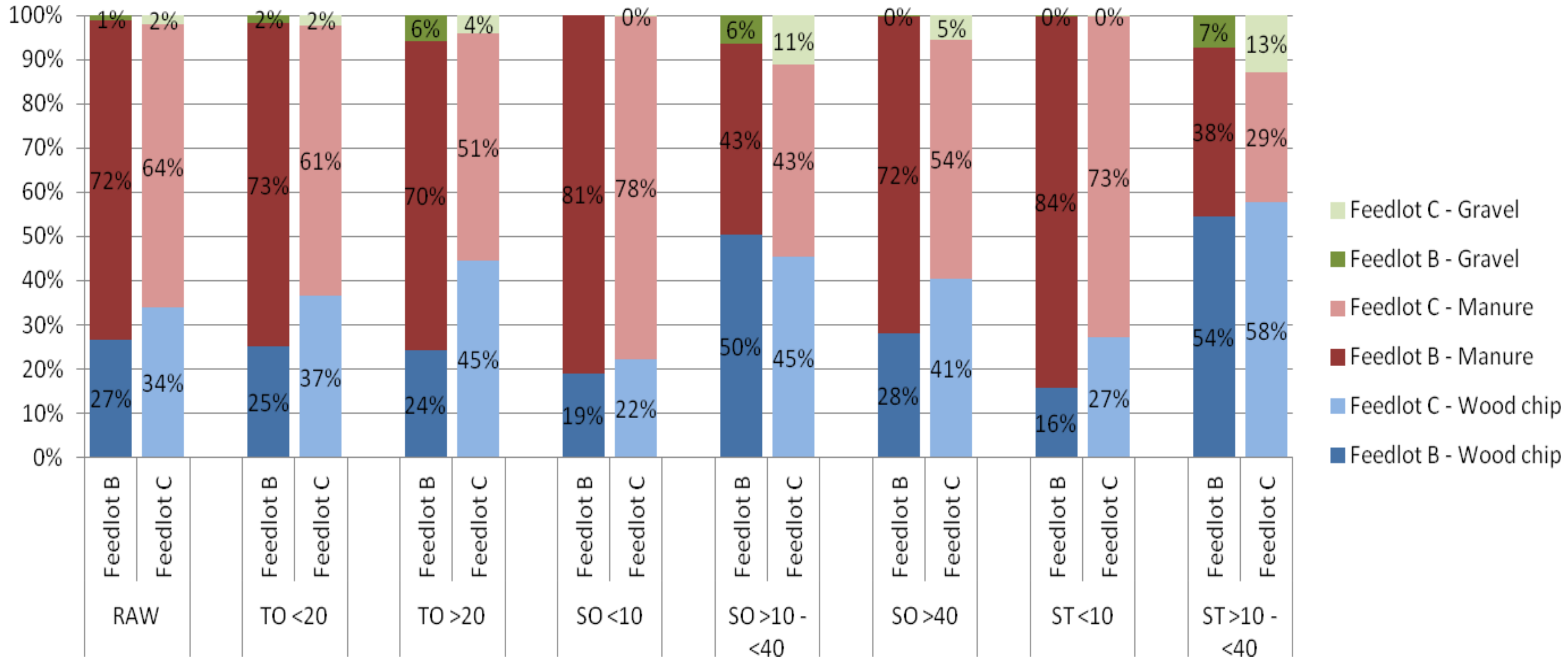



**FIGURE 7 – MANURE, WOOD CHIP AND GRAVEL CONTRIBUTIONS OF RAW AND SCREEN BY-PRODUCTS**

### 6.4.4.1 Particle size analyses of wood chips

Clean wood chips and the wood chips within the harvested pen manure were separated, washed and shaken through a series of sieves to perform particle size analyses (PSA). The seven selected sieve sizes (2.36, 6.7, 13.2, 19, 37.5, 53, 75 mm) were adopted from the European Standards for solid biofuels (CEN 2006). Although the vibrating and trommel screens are able to provide an initial particle distribution based on the 10, 20 and 40 mm screens, the increased range of the seven screens sizes provided a more precise breakdown required for the PSA of the harvested material.

In the unused wood chip samples, virtually no particles were retained by the 37.5 mm screen indicating that the manufacturing process ensures that few large particles are supplied. About 50-60% of clean wood chips passed through the 19 mm screen indicating that these wood chips have a significant proportion of smaller particles.

Particle size analysis of used wood chips shows a significant change when compared to the clean wood chips. The most significant size reduction occurred between 13.2 mm and 19 mm. Observations of wood chips before and after use in the pens suggests that many of the larger chips had spilt laterally and broken down into small particles. Similar results were witnessed in both Feedlot B and C (Figure 8). Less than 10% of the recovered wood chips was of a size considered useful as recycled material.

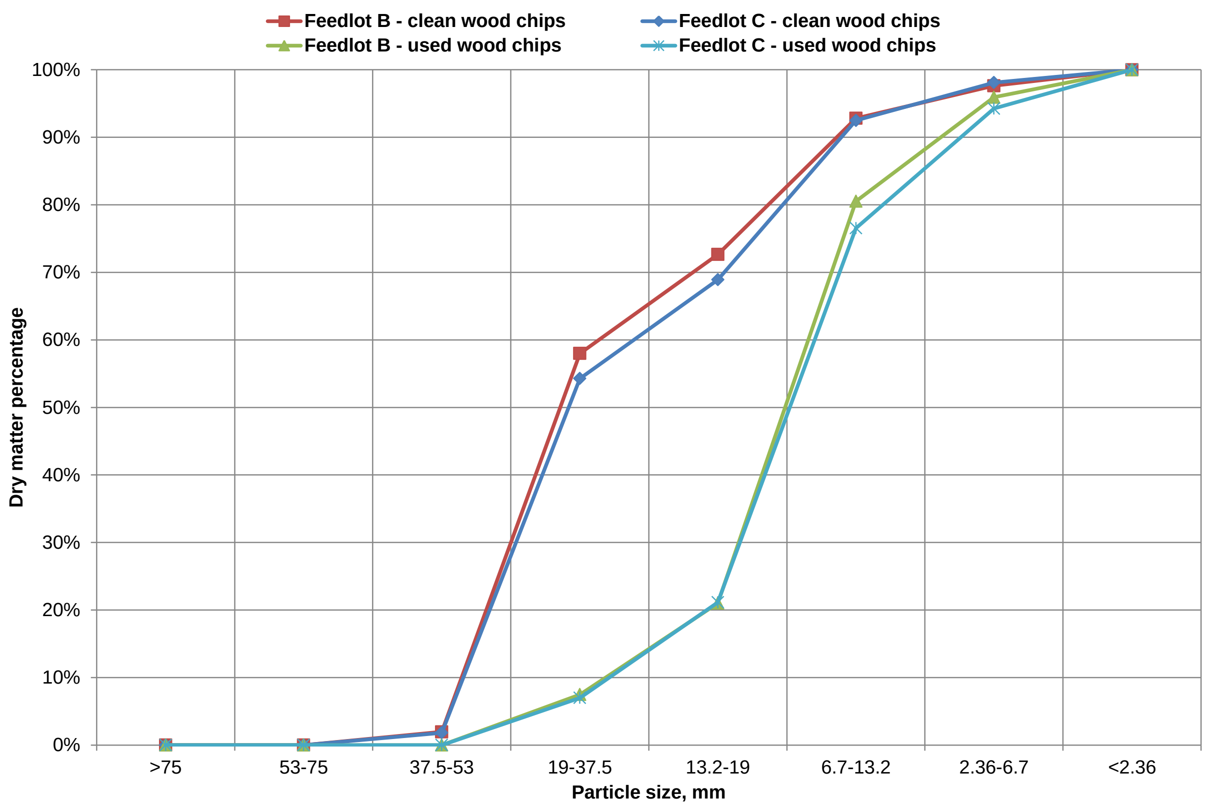



**FIGURE 8 – AVERAGE PSA OF CLEAN WOOD AND USED WOOD CHIPS**

### 6.4.5 Overall wood chip recovery from pens

A mass balance was used to estimate the wood chip recovery at Feedlots B and C. Wood chip recovery is the percentage of wood chip that was placed in the pen that was recovered in the screening and washing process.

Table 8 shows that, at Feedlot B, 66.4 t of wood chip dry matter (78.1 t of as-supplied wood chip) was added at the beginning of the trial. Only 32.7 t of wood chip TS (57.2 t of wet wood chip) was recovered at the completion of the trial. This is 48% of the initial wood chip used. Of the recovered material, only 48% of the wood chip was within the >10 – 40 mm screened category. The total recyclable wood chip dry matter was therefore 15.8 t, equivalent to 24% of the initial wood chip.

Table 9 shows similar data for Feedlot C. It was found that, of the 59.7 t of wood chip dry matter (70.2 t of as-supplied wood chip) added at the beginning of the trial, only 23.9 t of wood chip dry matter (47.6 t of wet wood chip) was recovered at the completion of the trial. This is 55% of the initial wood chip used. Shaker testing found 50% of the wood chip in the raw manure could be screened into the >10 – 40 mm stream kept for potential reuse. The total recyclable wood chip dry matter was therefore 13.3 t, equivalent to 22% of the initial wood chip.

As mentioned previously, most of the recovered wood chip had a small particle size and was unsuitable for reuse.

### TABLE 8 - WOOD CHIP RECOVERY - FEEDLOT B

| Parameter | Unit | Value |
|---|---|---|
| **Pre trial** | | |
| Volume of DRY wood chip added | $m^3$ | 280 |
| Bulk density of dry wood chips | $kg/m^3$ | 279 |
| Total mass of wood chip added | kg | 78 120 |
| Total solids (TS) of wood chip | % TS | 85 |
| kg TS of wood chip added | kg | 66 402 |
| **Post trial** | | |
| Harvested raw manure + wood chip (wet mass) | kg | 188 550 |
| Percentage of wood chip in harvested raw manure | % | 30 |
| kg of WET wood chip available in harvested WET manure | kg | 57 206 |
| TS of WET wood chip | % TS | 57 |
| kg TS of wood chip available | kg TS | 32 730 |
| Percent of wood chip screened into >10 & <40 mm | % | 48 |
| TS of wood chip in >10 & <40 mm stream | kg TS | 15 783 |
| Percentage of wood chip recovered | % | 24 |

**TABLE 9 – WOOD CHIP RECOVERY FEEDLOT C**

| Parameter | Unit | Value |
|---|---|---|
| **Pre trial** | | |
| Volume of DRY wood chip added | $m^3$ | 180 |
| Bulk density of dry wood chips | $kg/m^3$ | 390 |
| Total mass of wood chip added | kg | 70 200 |
| Total solids (TS) of wood chip | % TS | 85 |
| kg TS of wood chip added | kg | 59 670 |
| **Post trial** | | |
| Harvested raw manure + wood chip (wet mass) | kg | 129 220 |
| Percentage of wood chip in harvested raw manure | % | 37 |
| kg of WET wood chip available in harvested WET manure | kg | 47 627 |
| TS of WET wood chip | % TS | 50 |
| kg TS of wood chip available | kg TS | 23 935 |
| Percent of wood chip screened into >10 & <40 mm | % | 55 |
| TS of wood chip in >10 & <40 mm stream | kg TS | 13 252 |
| Percentage of wood chip recovered | % | 22 |

## 6.5 Discussion

### 6.5.1 Wood chip separation by screening

Different wood chip separation was demonstrated by each of the screening trials. Not only did the manure, wood chip and gravel proportions differ between screening approaches, the variability in samples was documented between Feedlot B and Feedlot C.

### 6.5.2 Wood chip losses in pen

The particle size analysis comparing fresh wood chip entering the pen and used wood chip exiting the pen saw a similar profile at both feedlots. The most significant size reduction occurred between 13.2 mm and 19 mm. On average, 54-58% of the clean wood chips had particle sizes greater than 19 mm, while only 7% of the used wood chips recovered from pen manure were greater than 19 mm. The degradation of wood chip was a result of natural weathering and degradation, with the aid of physical breakdown for the continual impact of cattle within the pen. One obvious issue is the longitudinal splitting of the chips.

The size distribution of used wood chip was reflected in the wood chip recovery rates of the screening trials. As expected from the PSA, only 7-12% of wood chip was found in the >20 mm output from the trommel. Therefore, the optimal wood chip stream to harvest is the shaker 10-40 mm as 48% - 55% of available wood chip is found is recovered in this stream.

### 6.5.3 Wood chip recovery

Wood chip recovery calculations found similar results between Feedlot B and Feedlot C. With the results of the screen testing and PSA, the decision was made to limit the potential wood chip recovery and reuse to the shaker only, 10-40 mm stream. This screening option does not require two passes and hence, doubling material handling is eliminated. Of the single pass options, this output stream has the highest wood chip fraction of 45-50%. The total anticipated wood chip recovery rate at Feedlot B is 24%. This 24% represents that of all wood chip entering the feedlot at the commencement of the trial, only 24% was recovered in the 10-40 mm stream. It is important to note that this wood chip is combined with approximately 43% manure and 6 – 11% gravel. This result was reflected at Feedlot C, which recorded a wood chip recovery of 22%.

### 6.5.4 Lower moisture content of manure

During the screening trials, the screening plant operator stated that the manure moisture content may be too high to get effective screening. This suggests that a drier manure may break apart by the forces of the screening, resulting in a break up of manure clods and a greater release the wood chip. During the feedlot trials, some lot feeders suggested that stockpiling pen manure with wood chips would provide sufficient time for the manure to dry and thus improve wood chip recovery. This is not the case. If moist manure is stockpiled for an extended period of time, the anaerobic decomposition will cause the stockpile to heat up. This is a commonly observed process and, in some cases, manure stockpiles catch on fire. At one trial feedlot, pen manure with wood chips was stockpiled for later screening. This stockpile did heat up and, effectively, the wood chips were burned. Photograph 76 shows the broken open manure stockpile. The white areas indicate the ash remains of wood chip within the stockpile. No recoverable wood chip remained.

**PHOTOGRAPH 76 – DECOMPOSITION (ASHING) OF WOOD CHIP IN MANURE STOCKPILE**

## 6.6 Conclusions and Recommendations

While this trial showed that some conventional wood chip remains in the pen manure after removal from the pen, it did show that it would not be economically feasible to recover enough wood chip of a suitable size to re-use in pens. However, during the screening process, a few larger pieces of wood were recovered (Photograph 77). These large pieces were in the clean wood chip. They represent a small loss of quality control in terms of standard wood chip size. However, from the feedlot bedding perspective, they represent the best option for bedding in pens. Unfortunately, no supplier was found who can supply large quantities of this “reject” material.

If this material was available at a reasonable cost, wood chip recovery by screening would be feasible and these pieces of timber could be reused several times in the pens.


**PHOTOGRAPH 77 – LARGE WOOD CHIPS RECOVERED FROM PENS**

# 7 Influence of wood chip on pen manure chemical properties

Following removal of the wood chip manure mix from pens, the characteristics of screened manure-wood chip material was compared with manure from the control pens. Analysis of characteristics took into consideration the usability of the wood chip and manure mix for land application or composting compared to the control.

As discussed in Section 6, manure screening trials were undertaken at Feedlot B and Feedlot C on harvested pen manure and wood chip mixes removed from the pens. These were compared with manure only samples collected from the control pens. Following screening of pen manure, a sample of the screened wood chip and manure mixture

(<10 mm) was also taken from each feedlot. This sample represents the product that would be available for land application or composting following recycling of the wood chip. The two groups (manure and wood chip and manure only) were analysed for N, P, K, C, DM, ash and C:N ratio. Table 10 shows the mean results for each of the parameters analysed.

**TABLE 10 – MEAN RESULTS FOR MANURE & WOOD CHIPS VERSUS CONTROL MANURE**

| | Manure & wood chip | Control manure | Statistical results |
|---|---|---|---|
| **Parameter analysed** | **Value (Mean ± 2 SD)** | | |
| Dry matter (DM) | 59.1 ± 12.0 | 57.9 ± 33.5 | p>0.05, ns |
| Ash, % of DM | 28.2 ± 3.0 | 18.9 ± 5.1 | p<0.05, s |
| Organic carbon, % of DM | 37.4 ± 10.0 | 42.4 ± 14.5 | p>0.05, ns |
| Nitrogen, % of DM | 1.7 ± 0.3 | 2.5 ± 0.5 | p<0.05, s |
| Phosphorus, % of DM | 0.5 ± 0.1 | 0.6 ± 0.2 | p>0.05, ns |
| Potassium, % of DM | 1.3 ± 0.5 | 1.2 ± 0.7 | p>0.05, ns |
| C:N ratio | 23.6 ± 0.1 | 18.5 ± 0.1 | p>0.05, ns |

Comparison of means determined using an independent t-test.
(s=significant, ns=not significant)

For the two trial feedlots, the screened manure and wood chip mix showed lower levels of nitrogen and higher levels of ash, while other factors were not significantly different. Carbon, phosphorus and potassium levels did not differ between the two samples. The lower level of carbon present in the screened manure plus wood chip sample was unexpected but was partly explained by the higher ash levels present in this sample. Carbon-to-nitrogen ratios were not significantly different and both were within the acceptable range for composting.

Anderson et al. (2007) found the addition of bedding to cattle pens resulted in higher nutrient retention in the mixed material. These authors suggest that the additional carbon may sequester nutrients, improving fertiliser value. However, in the present study, no difference was found in nutrient potassium and phosphorus concentration, and lower concentrations of nitrogen. The different ratios of nutrients between the two samples suggests that the wood chip pens may have experienced higher nitrogen losses. These differences may have been influenced by the screening process, which also removed some larger lumps of manure and may have biased nitrogen levels in the screened material. This noted, it unlikely that the addition of wood chips will improve nutrient levels.

Higher C:N ratios were observed in the screened wood chip manure mix, though again, the screening process removed a significant proportion of the highly carbonaceous material. As C:N ratios were both within the target range for manure composting, it is considered both materials are suitable feed stock for the composting processes without addition of further materials. Where manure has lower C:N ratios, others (i.e. Potts and Casey (1999)) have found that it is beneficial to add carbonaceous material to feedlot manure to increase C:N ratios and retain higher levels of nitrogen but this does not appear necessary with either the manure or screened samples in the present study. Further analysis would be required to confirm the characteristics of the manure wood chip mix as removed from the pen, but it is expected that this material would have a satisfactory C:N ratio for composting. At some feedlots where composting is conducted and additional carbon material is added, applying wood chip to the pens may offer an alternative means of improving feedstock quality for composting, though further trialling would be required to confirm this.

Miller et al. (2000) compared the effect of fresh manure versus compost, straw versus wood bedding and high versus medium application rates on soil physical properties for a feedlot study in Alberta, Canada. It was determined that for all treatment types the physical condition of the soil was improved due to a lowering of the bulk density. Fresh manure improved the soil quality when compared with compost, wood slightly more than straw, and the high rate more than the medium rate of application. It is expected that similar improvements to soil bulk density would be found when land applying the screened manure + wood chip mix, though this is not expected to be different to application of the control manure product from the feedlots sampled.

A significant negative yield response was observed in a silage crop following increasing application of spent timber bedding, based on a single season with several silage cuts (Augustenborg et al. 2008). The authors suggested that this was because the relatively coarse timber particles shaded the sward and inhibited grass growth, at least for first cut silage. Using finer wood chips increased crop yield as the impact of sward shade is reduced, and fine wood chips are now commonly used in the surface layer of the bedding at Irish out-wintering pads (Smith et al (2010)). Yield declines in response to shading are not expected with screened material, though this may be a consideration if material was spread straight from the pens. Another consideration would be the risk of nutrient draw down with wood chip manure mixes, if higher C:N ratios were observed with unscreened material. Considering the screened manure wood chip sample showed lower nitrogen levels compared to manure, poorer crop yield responses could be expected from this material and higher application rates may be beneficial, provided other nutrient levels are not applied at excessive rates.

Considering these results, no significant difference was found between the two products as a feed stock for composting. The higher ash levels in the wood chip manure mix was unexpected but may be related to the screening process or due to wood chip break-down while on the pen surface. Lower nitrogen levels reduce the value of the screened manure wood chip sample for land application.

# 8 Viable options for bedding usage

The following problems affect animal performance, animal health and welfare and the safety of staff working in feedlot pens:

- *Dirty cattle:* manure and mud covering the sides and bellies of cattle (i.e. formation of ‘dags’);

- *Fatigue:* all livestock need to rest. However, in some circumstances, this is not possible (e.g. during transport) or when the livestock do not prefer to lie on a surface that is too hot, too cold and wet, too muddy or too sharp and uneven. Bedding can provide a comfortable surface for resting.

- *Cold stress:* reduced body temperature as a result of being covered in moist manure and no provision of a clean, dry lying area;

- *Heat stress:* increased body temperature as a result of no pen shade and a dark, hot pen surface that radiates heat;

- *Excess pen surface moisture:* moisture added to the pen surface from manure, which is heavily influenced by stocking density. Rainfall also adds moisture to uncovered feedlot pens; and

- *Pen surface hardness:* hard surfaces, such as compacted gravelly-clay mixes and concrete, can lead to hoof and limb injuries. It can also lead to animals and staff slipping, resulting in injury.

The feedlot trials conducted in this project and other contact with the feedlot industry has demonstrated that each problem requires different solutions and that different bedding materials have different characteristics that may or may not assist in solving these problems.

Different types of bedding can be used in different applications around a feedlot. The following section discusses the suitability of different bedding materials for Australian feedlots and proposes best-bet usage guidelines for different applications. A number of case-studies have also been provided in the section assessing the suitability of bedding materials for different applications in Australian feedlots.

## 8.1 Bedding material suitability assessment for Australian feedlots

Table 11 provides a comparative summary of each bedding material's suitability for use in Australian feedlots based on the attributes listed in Section 3.2 and feedback from the lot feeders surveyed as part of a previous scoping project (O'Keefe et al. 2013) and this study. Each bedding material was assessed for each attribute and ranked as either poor, average or good.

Typical wood chip and straw were assessed as the most suitable bedding materials for Australian covered and uncovered feedlots based on the following observations:

- *Timber harvest residues*: This product rated well as a deep bedding material to provide comfortable lying conditions in winter (similar to straw) but can only be used once.

- *Timber off-cuts*: This product is too large and angular to provide comfortable lying conditions for cattle. However, it does appear to remove dags and is highly recyclable.

- *Screened wood chip* attracted no poor ratings. Overall, it rated better than *sawdust* and *straw*, as it is more durable and can withstand frequent animal loadings (physical weight and manure deposition) without breaking down. Wet *straw* and *sawdust* can be moulded and shifted when force is exerted which affects the performance of the bedding. The problem with this product is cost and availability and it cannot be recycled.

- *Wood mulch*: This product is similar to timber harvest residue. It can contain sharp splinters and can only be used once.
- *Straw* has good absorbency and porosity. However, it is unsuitable for recycling and has only average durability. It can only be used once.
- *Sawdust* (small particles) and *chopped straw* are likely to have a greater absorbency potential than *wood chips*. However, *sawdust* has poor durability, porosity and no recyclability.
- *Sand* was trialled at a covered feedlot (not monitored during this trial period). It was reported that the surface became heavily manured after a short period of time and this prevented drainage of wet manure and urine through the bedded area. The low porosity of fine screened sand significantly reduced its suitability as a bedding material. Sand used in uncovered feedlots would increase the likelihood of the bedding surface sealing over with manure, especially after rainfall when manure slurry could block the void spaces within the bedded area.
- *Rice and almond husks* rated poorly for absorbency (rice husks), durability and recyclability. One feedlot that trialled these said they were relatively effective. This was a unique situation as the feedlot was located in a region that experiences hot dry summers and low annual average rainfall of approximately 370 mm. Other feedlots said that they did not reduce dags and quickly blended in the manure. *Rice husk* is light and fluffy which makes is difficult to handle with machinery, expensive to transport (low mass to volume ratio) and tends to blow out of pens when dry.
- *Composted manure (including sawdust spent bedding)* was trialled in a covered feedlot. They reported that it was highly absorbent. Unfortunately, this meant that it turned into a soft manure slurry that could be moulded and shifted when force was exerted. Cattle quickly became dirty and it was deemed ineffective. Presumably, if *composted manure* were used in an uncovered feedlot, it would deteriorate even more quickly when exposed to rainfall. It would be little different to pen manure. Mounding manure may be more feasible than bringing composted manure back into the pen as a separate bedding material.
- No data was found on the use of *recycled rubber chip* in cattle feedlots. The risk of heavy metal exposure to the cattle and contamination of the spent bedding would limit its suitability.

### TABLE 11 – BEDDING TYPE SUITABILITY ASSESSMENT FOR AUSTRALIAN FEEDLOTS

| Type | Absorbency | Durability | Porosity | Recyclability | Comments |
|---|---|---|---|---|---|
| Timber harvest residues | Good | Poor | Good | Poor | ➢ Similar to straw and sawdust |
| Timber off-cuts | Poor | Good | Good | Good | ➢ Off-cuts are uncomfortable to lie on |
| Wood chips (screened chip) | *Avg. | Good | Avg. | Poor | ➢ More durable than straw and sawdust.<br>➢ Porosity within a wood chips bedded area typically lasts longer than a straw or sawdust bedded area.<br>➢ Larger wood chips pieces can be recycled (i.e. screened from spent bedding).<br>➢ Easier to handle, transport, distribute and remove from feedlot pens than straw.<br>➢ Sharp wood chips pieces assist in removing / wearing dags off cattle. |
| Wood mulch | Avg. | Poor | Avg. | Poor | ➢ May have sharp splinters to harm hooves |
| Straw | Good | Avg. | Good | Poor | ➢ Good absorbency and provides softer, more comfortable lying surface for cattle than wood chips.<br>➢ Longer straw particles create a stronger, more durable bedded area that allows better drainage than chopped straw. |
| Sawdust | Good | Poor | Poor | Poor | ➢ Good absorbency and provides softer, more comfortable lying surface for cattle than wood chips.<br>➢ Poor durability once wet / saturated. Longevity reduced through interaction with rainfall. |
| Rice hull | Poor | Poor | Good | Poor | ➢ Rice hulls have good porosity and thermal insulation properties. However, low bulk density reduces transport efficiencies and difficult to handle due to their 'fluffy' nature |
| Almond hull | Avg. | Poor | Avg. | Poor | ➢ Almond hulls have average absorbency and porosity, they may be considered palatable by cattle.<br>➢ Availability and uptake limited by processing locations in north western Victoria and NSW Riverina |

| Type | Absorbency | Durability | Porosity | Recyclability | Comments |
|---|---|---|---|---|---|
| Composted manure | Good | Poor | Poor | Poor | ➢ Very absorptive, however not considered suitable as a bedding material in Australian feedlots. |
| Sand | Poor | Avg. | Poor | Avg. | ➢ Low porosity reduces its effectiveness and high bulk density makes it expensive to transport.<br>➢ Hard to recycle (unless washed) and can be abrasive on soft hooves. |
| Recycled rubber chip | Poor | Poor | Avg. | Avg. | ➢ No data found on use in cattle feedlots.<br>➢ Potential concerns of heavy metal contaminants from the recycled tyres. |

* Avg.= average

## 8.2 Best-bet options for different applications of bedding materials

Based on the experiences in this trial, there are several applications where bedding has been shown to be cost-effective in Australian feedlots. These applications are given below.

### 8.2.1 Post-washing pens

Two of the ten feedlots (Feedlot E and Feedlot G) applied bedding materials in post-washing pens. It is known that other feedlots now do this. Feedlot E noted that the wood chips did a better job of removing dags than corn stalks and construction waste. Feedlot G noted that the wood chips maintained the cleanliness of the cattle better than the other post-washing pens without bedding. Depending on the size of the bedding materials, water has been found to be trapped on the surface of wood chips, or filters down through the chips easily and the bedding provided a dry surface after rainfall.

Based on the feedback from current project and literature data, it is believed that using bedding in post-washing holding pens is helpful to reduce the re-formation of dags on cattle after washing, provided that the sizes of bedding materials are carefully chosen to facilitate pen drainage. It also provided a pen surface for cattle to lie down and rest after having been washed. Wood chips should be spread at 100-200 mm depth across the pen as per Figure 10. To prevent movement of wood chips into the cattle lane / drain, no wood chips should be spread in the bottom 5 m of the pen. Given the low manure production in these types of pens and that they are only used during winter (wet periods), it is likely that they only need to be cleaned once per year.

### 8.2.2 Hospital / sick pens / induction pens

Three of the ten feedlots (Feedlot C, Feedlot G and Feedlot F) applied bedding materials to hospital pens. Feedlot G found that wood chips created a more acceptable pen surface from a welfare perspective. Water was found to filter down through the chips easily and the bedding provided a dry surface after rainfall. Feedlot F made no comments regarding the effect of straw on hospital pens or sick animals. Feedlot C continues to use wood chips in their hospital pens as it provides a comfortable, soft surface for cattle to lie on.

Based on the feedback from current project and a previous survey of Australian feedlots (O'Keefe et al. 2013), it is believed that placing bedding materials in hospital pens has benefits for cattle comfort during wet winters and prolonged cold weather, for provision of soft flooring for cattle with hoof injuries and can enhance cattle recovery in sick pens.

Similarly, it has been found that the use of bedding in feedlot induction pens encourages fatigued cattle that have been transported long distances to rest and lay down where otherwise they might remain standing in a wet or hot or rough-surfaced pen.

### 8.2.3 Production pens - cold, wet winters (animal comfort)

During the trial, none of the feedlots reported cold stress events, and only two feedlots (Feedlot I and Feedlot J) experienced significantly higher rainfall than annual average. Feedlot I noted that the cattle clearly prefer the bedding. Animal performance was reported to have improved in the bedded pens by 0.2-0.3 kg/head/day. Feed conversion was better at Feedlot I as the cattle spend less energy standing and are less affected by the cold. Lameness problems have improved "out of sight" since the introduction of bedding to the depth of 25 mm across the whole pen floor as well as a central mound. Feedlot J found that bedded areas are the animals preferred choice and tend to be where animals congregate. Feedlot A noted that during a few instances of small rainfall (10-25 mm), the animals appeared most comfortable in the spread bedding pen, where the greatest number of animals were observed sitting/lying. Comparatively, the piled bedding pens were observed to have fewer cattle sitting/lying than the spread bedding pen, with these cattle concentrated on the piles. There was not enough room for all animals to sit/lay on the piles.

Based on the feedback from current project and literature data, it is believed that placing bedding materials can reduce cold stress of animals during wet winters, and spreading bedding materials would provide more benefits than piling/mounding them in the pens. Figure 9 shows the suggested usage. At least 2 $m^2$ of bedding should be provided for each animal. The central mound should be built up above the pen surface (500 mm+) and provision for pen drainage be allowed on either side of the bedding mound. Cattle should be able to access the feed bunk from the mound.

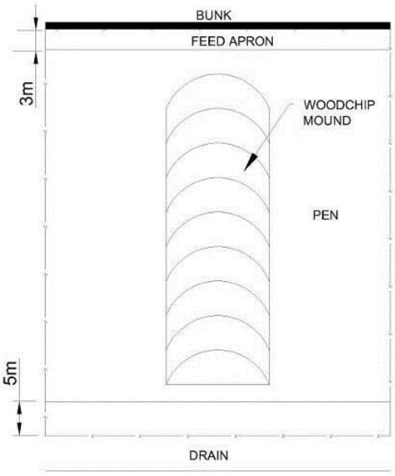



**FIGURE 9 – SCHEMATIC OF USE OF BEDDING AS RESTING MOUND IN PEN**

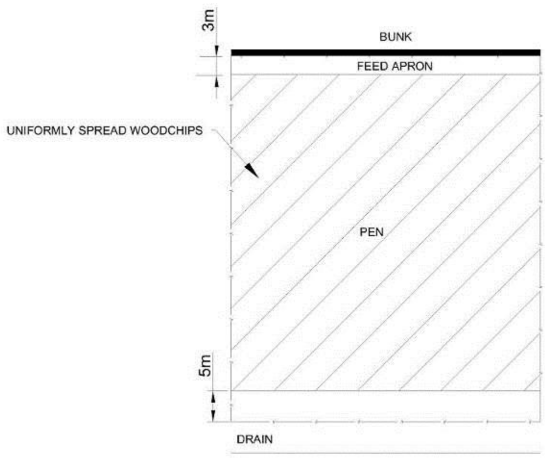



**FIGURE 10 – SCHEMATIC OF USE OF BEDDING ACROSS WHOLE PRODUCTION PEN**

### 8.2.4 Production pens - wet manure (dags, soft flooring)

Of the ten participating feedlots, only Feedlot A had no issue of dags due to smooth skinned cattle. Feedlot B did not notice the difference in dags due to dry weather during trial. Feedlot D thought that dags are dependent on the amount of rainfall received, the timing of the rain and the relationship to how cold it gets, rather than solely dependent on the use of bedding. Five feedlots made positive comments about the benefits of bedding materials in reducing dags on cattle hides. Feedlot E commented that the wood chips did a better job of removing dags than corn stalks and construction waste. Feedlot I noted that, due to the high winter rainfall, dags remain a problem even in the bedded pens, and the more time cattle spend lying, the higher up the dags and mud gets up on the backs of the cattle.

Based on the feedback from the current project and a previous survey of Australian feedlots (O'Keefe et al. 2013), it is believed that bedding materials can help reduce dags on animals, provided that enough is available for animals during high rainfall periods. Figure 10 shows how the bedding should be spread. Unfortunately, this application requires a large volume of wood chip and would only be economically viable in circumstances where wood chip are cheap and readily available and / or cattle are of a high value. Wood chips spread across the whole pen surface significantly increase pen cleaning time and costs but decrease its frequency.

### 8.2.5 Pen Surface Protection

Three feedlots noted improvement of pen surface with bedding materials while the others made no comment. Feedlot A pointed out that there was less incidence of holes forming in the pen floor on the spread bedding pen than the piled bedding pens. Feedlot B noted that wood chips pens did have potholes develop in the wood chips but these did not go through the pen surface, and pen surface was thus maintained better after cleaning in the wood chips pens. Feedlot J found almost no pen surface damage in high traffic area with bedding, while obvious damage to pen surface was found where no bedding existed. Feedlot B also pointed out that wood chips pens took a significantly longer time to clean than standard pens.

Based on the feedback from current project and literature data, it is believed that placing bedding materials can help prevent or reduce pen surface damage. However, pen surface stabilisation would probably achieve a similar or better outcome. There is no experience with pen surface stabilisation in Australia.

### 8.2.6 Covered feedlots

Three feedlots applied bedding materials to covered pen areas. No specific comments were given to applying bedding materials to shaded pens. Feedlot I thought that it is difficult to determine the effect of bedding on temperature because the bedding is also shaded and is cooler than the outside pens exposed to direct sunlight.

Clearly, bedding is required in covered feedlots to provide a soft flooring for both standing and lying, as well as absorbing moisture in the manure. Deep sawdust is the best option.

## 8.3 Case studies

# DAG CONTROL


Feedlot Location: **Northern Tablelands, NSW**

Average Rainfall**:** **776 mm**

Bedding Material: **Sharp pine wood chip (wood mulch)**

Size Grading: **Random**

Availability: **Locally sourced**

Cost: **$52/t delivered**

Bedding Application: **200 mm across production pen**

Feedlot D successfully trialled sharp pine wood chip. There was notable dag removal due to the wood chip. Feedlot D also noted that dag formation is highly dependent on the amount of rainfall received and the relationship to how cold it gets. However, the sharp pine wood chip successfully removed dags on cattle in the production pens, as seen in the photographs below which show removed dags on the pen surface.

# DAG CONTROL (continued)

**Benefits:**

- Dag control and removal.
- Cattle comfort - provides soft flooring for large cattle (200 days).
- Definite increase in feed intake for cattle on wood chip.
- Perceived ADG increase.
- Safer environment for pen riders.
- Greatly reduces cast cattle, lame cattle and leg infections compared to gravel surfaces

**Economic Viability:**

Feedlot D sees this as economically viable and have been using wood chip successfully for 3+ years. In their case, the benefits outweigh the costs.

**Limitations of bedding material:**

- Material is not recyclable.
- Wood chip can trap the runoff if the wood chip has not been screened.

# PEN SURFACE PROTECTION

Feedlot Location: **South East QLD**

Average Rainfall**:** **865 mm**

Bedding Material: **Typical wood chip**

Size Grading: **20-100 mm chips**

Availability: **Sourced from Roma**

Bedding Application: **200 mm across production pen**

Feedlot C trialled wood chip in order to maintain the recently graded pen surface. Pen slopes exceed 8%. Typical wood chip was applied across the pen surface to a depth of approximately 200 mm.

Following heavy rainfall, it is clear that the manure remained on top of the wood chip surface. Once the top layer of manure was removed, the underlying wood chip was still intact and it was clear that the pen surface had not been affected by cattle movements, presumably due to the thick covering of wood chip.

**Benefits:** Pen surface protection, soft flooring.

**Economic Viability:** This is a high cost solution for maintaining pen surfaces across all production pens. Wood chips greatly reduced pen surface damage.

**Limitations of bedding material:** Due to the lack of large (>100 mm) wood chip availability this option is a high cost solution that would be expensive to apply across an entire feedlot.

# COVERED FEEDLOT

| | |
|---|---|
| Feedlot Location: | **South east SA** |
| Average Rainfall: | **749 mm** |
| Bedding Material: | **Sawdust** |
| Size Grading: | **N/A** |
| Availability: | **Locally sourced** |
| Cost: | **$14/t delivered** |
| Bedding Application: | **150-200 mm depth across production pen floor (covered feedlot)** |

Sawdust is used at Feedlot I on an on-going basis. Feedlot I is a covered feedlot, located in an area that experiences prolonged wet periods, which do not allow pens to dry out. Sawdust is used on-site as is a highly absorbent material. It also has many additional benefits.


# COVERED FEEDLOT (continued)

**Benefits:**

- Absorbent material.
- Odour reduction.
- Pen surface protection - almost no pen surface damage even in high traffic areas.
- Animal comfort.
- Reduction of dag on hides.
- Estimated increase in ADG of 10%.
- Easier handling during removal of manure from pens.

**Economic Viability:**

Use of this bedding material is economically viable in covered feedlots in winter dominant rainfall areas, provided the bedding material/delivery cost is not inhibiting.

**Limitations of bedding material:**

- No potential for reuse.

# BEDDING MATERIAL IN HOSPITAL PENS

Feedlot Location: **South East QLD**

Average Rainfall**:** **865 mm**

Bedding Material: **Typical wood chip**

Size Grading: **40-100 mm chips**

Availability: **Sourced from Roma**

Bedding Application: **200 mm across production pen**

Feedlot C trialled bedding material in their hospital pens. It was noted that lame cattle appeared to recover better when placed in the wood chip pens. Cattle seemed more comfortable on the wood chip and it encouraged cattle to sit and lay down. Staff at the feedlot were very positive about wood chip in hospital pens and stated that a 100 mm covering of wood chip in all hospital pens would be the preferred option rather than hospital pens without bedding.

**Benefits:**

- Aided cattle recovery.
- Comfortable flooring for cattle.
- Pen riders felt more comfortable on the wood chip (more traction).
- Cattle also appeared to slip less.
- No pooling of rainfall in the pens.

**Economic Viability:**

In order to be economically viable, Feedlot C would recommend placing a 200 mm mound of wood chip in the pen. The cattle would then spread this themselves, rather than having additional labour costs to spread the wood chip evenly across the surface. A second cost saving could be to place wood chip in the top half of the pen only.

# BEDDING MATERIAL IN HOSPITAL PENS (continued)

**Limitations of bedding material:**

- Wood chip did wash out into the laneway when it was placed close to the fence line

# BEDDING MATERIAL IN POST-WASHING PENS

Feedlot Location: **Southern NSW**

Average Rainfall**:** **561 mm**

Bedding Material: **Typical wood chip**

Size Grading: **25 x 25 mm**

Availability: **Locally sourced**

Cost: **$80/t delivered**

Bedding Application: **200 mm across the post washing pen**

Feedlot G placed cattle in post washing pens with a layer of bedding material after being cleaned. The wood chip maintained the cleanliness of the cattle better than the other (non-bedded) post-washing pens. Feedlot G noted a number of other benefits of using wood chips. The photographs show clean cattle in the post-washing pen on a rainy day.

**Benefits:**

- Maintained cleanliness of cattle.
- Increased incidence of playing observed and the length of play also seemed to be prolonged.
- Improved the pen surface from a pen rider safety perspective.
- Higher incidence of laying out flat on their sides vs just sitting, and cattle are more evenly spread across the pen.

# BEDDING MATERIAL IN POST-WASHING PENS
(continued)

**Benefits (continued):**

- The wood chips create a more acceptable pen surface from a welfare perspective.
- Wood chips contribute positively to improving pen odour.

**Economic Viability:**

Feedlot G does not normally use wood chip in their pens. By using a locally sourced wood chip in the post washing pens only, the cost is manageable.

**Limitations of bedding material:**

Feedlot G did not identify any limitations of using wood chips in the post washing pens.

# 9 Summary and conclusions

There has been increasing interest over the past several years in the use of bedding materials in Australian cattle feedlots. While the primary interest relates to the potential for improvements in production and animal health and welfare during the wet winter period, there are many other reasons these options are being examined (e.g. heat load amelioration, dag reduction, odour and greenhouse gas emissions reduction). A scoping study (B.FLT.0379 'Bedding material use in cattle feedlots') found that, although there was strong interest from lot feeders, no formal trials of bedding materials had been conducted in Australia and no information about the use of bedding had been collated. Following a presentation of the findings at a Meat and Livestock Australia (MLA)/Australian Lot Feeders Association (ALFA) Animal Welfare Committee meeting, it was agreed that a series of trials would be conducted at feedlots around Australia, with the aim of determining the most appropriate bedding type and placement for particular situations and quantifying, as best as possible, the benefits obtained from its use.

These trials were undertaken as part of this follow-on study. This report documents the type and cost of regionally available bedding materials and describes the trials using bedding in feedlot pens. These trials compared different types of bedding materials and different ways in which they are employed (e.g. full pen coverage, mounds, different depths of material, etc.). Changes in animal health, performance, animal behaviour, pen repair and maintenance costs, plus any workplace health and safety implications, associated with the use of the different bedding materials were requested to be recorded. Where possible, outcomes were compared to those achieved under normal (no bedding provided) pen conditions across a number of feedlot sites representative of the full range of regional locations and environmental conditions encountered in eastern Australia (Queensland to South Australia). Some observational data on animal use of the bedding and changes in behaviour was also collected at ten feedlots.

To improve the performance, health and welfare of confined animals and to provide a safer working environment for staff, pen surface amendment (PSA) has been used in intensive animal facilities. PSA can be grouped into two main categories:

- **Pen surface stabilisation (PSS)** - incorporating stabilising products such as cement or fly ash into the pen surface layer to provide a durable, low-permeability pen surface; and
- **Pen surface covering (PSC)** - distributing bedding materials such as wood chips or straw over the pen surface to provide improved cattle comfort and welfare outcomes.

Typical problems addressed by PSA include the following:

- *Dirty cattle:* manure and mud covering the sides and bellies of cattle (i.e. formation of 'dags').
- *Fatigue:* all livestock need to rest. However, in some circumstances, this is not possible (e.g. during transport) or when the livestock do not prefer to lie on a surface that is too hot, too cold and wet, too muddy or to sharp and uneven. Bedding can provide a comfortable surface for resting.
- *Cold stress:* reduced body temperature as a result of being wet, covered in moist manure and no provision of a clean, dry lying area.

- *Heat stress:* increased body temperature as a result of no pen shade and a dark, hot pen surface that radiates heat.
- *Excess pen surface moisture:* moisture added to the pen surface from manure, which is heavily influenced by stocking density. Rainfall also adds moisture to uncovered feedlot pens.
- *Pen surface hardness:* hard surfaces, such as compacted gravelly-clay mixes and concrete, can lead to hoof and limb injuries. It can also lead to animals and staff slipping, resulting in injury.

Bedding materials have been used in a number of areas of cattle production including:

- Saleyards
- Bedding on live export ships
- Various applications for dairy production
- Over-wintering pens in New Zealand, Ireland, Scotland and eastern USA
- Fully covered feedlots, and
- Open feedlots in Canada and northern areas of USA.

Numerous studies in the USA and Canada have compared animal welfare, health and performance in bedding and no bedding circumstances. Although the results vary, it is clear that cattle that are provided with clean, dry bedding that they can lie down on perform better and have better welfare outcomes than cattle that are kept in deep, cold, wet manure conditions where they are reluctant to lie down. Bedding can have a positive outcome.

The following attributes can be used to assess the suitability of bedding materials for Australian covered and uncovered feedlots:

- *Absorbency* - the ability or tendency of a bedding material to absorb or soak up liquid;
- *Durability* - the ability of a bedding material to endure constant, regular loadings and resist the stress and force applied, whilst maintaining its structural form;
- *Porosity* - the measure of void spaces (air space) in material which affects drainage;
- *Softness* - the ability of the material to provide a soft standing and lying surface;
- *Recyclability* - the ability of spent bedding (mixture of manure, bedding and soil) to be treated after removal from the pen and reused as 'fresh bedding'. The term, recyclable, can be defined as 'the ability to produce a fresh supply of the same material' (i.e. spent bedding screened to separate manure and bedding, so the bedding can be reused).

- *Availability* – the ability to access the material at an economic value on an on-going basis.

Different types of bedding have been used in cattle housing systems. They include organic or inorganic materials. Organic bedding materials include wood chips, corn stalks, cereal straw; sawdust; rice and almond hulls and recycled manure (composted). Inorganic bedding materials include recycled rubber chip, manufactured rubber mats and sand, which are used in free-stall dairies in Australia, United States and Europe. In Australia, most bedding is "wood chips" but this is a poorly defined term that covers a range of products including:

- Timber harvest residues
- Timber mill processing by-products
- Sawdust
- Timber mill off-cuts
- Wood chips ("typical" wood chips are about 25 mm in length)
- Wood mulch
- Construction and demolition waste
- Recycled pallets

All but recycled pallets were trialled during this study with varying degrees of success. Except for the construction and demolition waste and recycled pallets, markets now exist for all of these timber by-products in Australia. This reduces their availability and increases their costs to the feedlot industry.

Ten feedlots participated in the bedding trials for this project. The aim was to determine the effects of introducing bedding to feedlot pens. Trial details (e.g. bedding materials, experiment layout) have been recorded. Nineteen trial applications were undertaken in total, using varying bedding materials (typical wood chips, wood mulch, corn stalks, construction and demolition waste, timber mill processing by-products and sawdust) and application of bedding materials (across the entire pen or in a central mound). Standardised questions were asked at each participating feedlot. The questions covered details on animal performance, animal welfare/behaviour, environmental issues, manure management issues, workplace health and safety, and any further comments. Due to the relatively short period of the trials and dry conditions, the results of the trials in terms of animal performance and welfare were inconclusive. However, no adverse effects were noted. No negative environmental outcomes were noted. Positive workplace health and safety effects were observed.

Feedlot pen surfaces require on-going maintenance. Pen surface material (clay or gravel) can be removed during pen cleaning and holes in the pen surface can develop due to cattle digging holes or wear adjacent to high traffic areas such as feed bunks and water troughs. Pen surface material can also be removed during pen cleaning if the interface layer is disrupted. It is speculated that the use of bedding materials will protect the pen surface and thus reduce the cost of on-going pen surface maintenance. This could off-set the cost of the bedding material. However, there is no published data available on the cost of pen surface maintenance. It was agreed that this project would include an attempt to quantify the cost of pen surface maintenance. This would be done by surveying major feedlots to obtain data on factors that contribute to pen maintenance costs and, if possible, actual costs on a per head basis. Feedlots with a combined capacity of about 25% of the Australian pen capacity were contacted.

The survey clearly demonstrated that there is little quantifiable or reliable data for pen surface repair and maintenance costs at the surveyed feedlots. This is because these costs were generally absorbed into pen cleaning and manure handling costs. The lack of rigour around cost accounting for pen surface repair works was considered to reflect the ad-hoc basis on which they were conducted and their low priority compared to other routine feedlot maintenance activities. However, annual costs are highly variable and can be significant. Pen surface repair and maintenance costs were crudely estimated to range from $16 to $60/head of pen capacity/year.

The survey results suggested that the use of pen surface covering does reduce pen surface wear and limit the formation of potholes. However, there were insufficient data to determine the cost benefit of reduced pen surface repairs and maintenance due to the use of bedding. A notable comment received from one respondent suggested that bedding actually resulted in a six-fold increase to the time, and presumably the costs, of routine pen cleaning.

The cost - benefits of bedding with regards to pen surface repairs and maintenance could not be determined from this survey. The true value of using bedding in pens would require strict cost accounting for pen cleaning and surface maintenance works (labour, plant and materials), the cost of the bedding material, an evaluation of the cost impacts of bedding on routine pen cleaning and other feedlot operations and determination of the cattle productivity benefits of bedding.

Wood chip bedding will almost certainly need to be recycled and reused to make this practice economically and environmentally sustainable for extensive use in feedlots. Recycling involves separating the wood chips from the cleaned pen manure so it can be reused on the pens. A trial was undertaken to determine if wood chips could be removed from pen manure using equipment normally available at a feedlot such as vibrating screens or trommels used for manure processing. The objective was to remove wood chips that could be reused in a pen a second time, thus reducing the annual cost of wood chip bedding.

The trial was undertaken at a commercial composting facility that had both a trommel and a dual-screen vibrating shaker. Pen manure from wood chip trials set up at two feedlots was harvested after about six months in pens occupied by cattle. The harvested manure was weighed at the feedlot and transported to the composting facility where it was screened in separate trials using both types of machinery. Samples of the different screened materials were then wet-sieved and dried to manually separate the remaining wood chip from the pen manure to determine the recovery rate of wood chips.

In this trial, both rotating and vibrating screens were tested to determine their effectiveness at recovering wood chips from pen manure. An additional scenario combining the trommel and screens was run to determine if combining the different screening motions (rotational and lateral) could increase wood chip recovery rates. For the combined screening trial, the harvested manure was initially fed through the trommel and the reject material was then fed into the shaker to determine if the combined separation was greater than the individual screening processes.

After sampling, washing, weighing and drying the manure and wood chips from different screening options, it was determined that 48-55% of the wood chips that were placed in the pens were recovered. The missing wood chips were either decomposed or broken down into particles too small to be separated from the manure. Of the recovered wood chips, about 50% was of a size that could be recycled. Hence, 22-24% of wood chips could be recycled back into the pens. However, the recovery was only possible by intensive washing, not by mechanical screening. The conclusion is that typical wood chips (~25 mm size) cannot be recovered and recycled. Using both machines did not improve wood chip removal.

Due to the high cost and poor availability of wood chips and the inability to economically recycle wood chips from pen manure, wide spread use of bedding materials across all pens in feedlots is not viable. However, there are some areas where bedding materials clearly are viable. These include:

- Hospital and sick pens
- Induction pens
- Laneways and high traffic processing areas
- Post-washing pens
- Mounds in production pens in cold, wet winter conditions
- Covered feedlots

# 10 Recommendations

The following recommendations are made.

1. The information on the types of bedding materials that are available and their viable roles within a feedlot operation should be extended to industry.
2. Given positive animal performance responses from research in the United States, and the pilot nature of demonstrations in this experiment, further research is recommended to characterise bedding responses and return on investment in Australian feedlots’
3. The practical and economic issues around the use of pen surface stabilisation should be investigated in a commercial feedlot context.

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