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Prepared by: MF O'Keefe, SA McDonald, RW Tucker and PJ Watts
FSA Consulting

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

Bedding material use in cattle feedlots

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Abstract

Meat & Livestock Australia (MLA) is interested in assessing the impacts that bedding materials such as woodchip and straw have on the health and welfare of lot fed cattle. 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 be pen surface stabilisation or pen covering with bedding. This scoping study aims to collate baseline data about the use of bedding materials in North American and Australian feedlots and propose a comparative, observational trial that can be completed at several feedlots during the 2013 winter period. Pen surface amendments have been shown to have a positive effect on cattle health, welfare and performance in North American feedlots and there is also anecdotal evidence supporting bedding use by several Australian lot feeders.

Executive summary

Meat & Livestock Australia (MLA) is interested in assessing the impacts that bedding materials such as woodchip and straw have on the health and welfare of lot fed cattle. In recent years, there has been increasing interest into the use of various types of pen surface amendments (PSA) in Australian cattle feedlots. In the context of cattle feedlots, PSA can be put in two categories:

- *Bedding materials:* distributing bedding materials such as woodchip or straw over the pen surface to provide improved cattle comfort and welfare outcomes.
- *Soil stabilisers:* incorporating stabilising products such as cement or fly ash into the pen surface layer to provide a durable, low permeability pen surface.

While the primary interest relates to the potential for improvements in animal health and welfare, there are many other reasons PSA should be examined e.g. heat load amelioration, dag reduction, and odour and greenhouse gas emissions reduction.

Exposure to a layer of wet manure and mud, or a dry, hard and hot pen surface, can compromise the comfort of lot fed cattle and safety of staff working within feedlot pens. This project has identified the following problems that affect 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').
- *Cold stress:* reduced body temperature as a result of being covered in moist dags 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 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 contribute to hoof and limb injuries. It can also lead to animals and staff slipping, resulting in injury.

This review has considered research outcomes from overseas animal production systems that use bedding materials and soil stabilisers. More specifically, it provides details of:

- The effect of stocking density on moisture content of the feedlot pad
- Pen surface stabilisation
- Pen surface covering with bedding
- Examples of the use of pen surface amendments for cattle
- Outcomes following the use of pen surface amendments.

Pen surface stabilisation aims to create a low-permeability, hard pen surface that optimises pen drainage and minimises the mixing of manure with pen foundations. Pen surface stabilisation has been achieved using fly ash, pond ash, cement-stabilised clay and chemical additions to the soil surface.

Pen surface covering, or bedding, is widely 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. The types of bedding used in various aspects of cattle production include:

- Woodchips
- Sawdust
- Straw
- Rice and almond hulls
- Composted manure
- Sand
- Recycled rubber chips

In general, American research indicates that the use of PSA improves animal welfare, health and performance to varying degrees. However, the effect on environmental issues such as odour generation and runoff quantity and quality is poorly understood. PSA alters the characteristics of the manure harvested from feedlot pens, again to varying degrees depending on the type of PSA used.

Information was collected on the use of bedding in Australian feedlots. Eighteen Australian feedlots that have previously used bedding materials in either their production or sick pens were contacted or visited to obtain data on their experiences with pen surface covering. No feedlots were identified that had trialled pen surface stabilisation in Australia. The responses from all eighteen feedlots were summarised. All of these responses are anecdotal and none of those surveyed using woodchip provided an accurate estimate of woodchip usage rate or changes in animal performance. As far as can be determined, there have been no systematic trials undertaken to quantify any of the responses. In general, the use of bedding was regarded favourably but there remain uncertainties that prevent widespread adoption of the practice.

A series of initial observation trials are proposed to gain a systematic understanding of the use of bedding in Australian feedlots. These trials could be conducted in the winter of 2013 to provide baseline data for more rigorous technical trials the following winter. These proposed trials are to be discussed at a workshop of feedlot managers, nutritionists and veterinarians.

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1 Background

In recent years, there has been an increasing interest in the use of various types of pen surface amendments (PSA) in cattle feedlots. In the context of cattle feedlots, there are two categories of PSA:

- *Bedding materials:* distributing bedding materials such as woodchip or straw over the pen surface to provide improved cattle comfort and welfare outcomes.
- *Soil stabilisers:* incorporating stabilising products such as cement or fly ash into the pen surface layer to provide a durable, low permeability pen surface.

While the primary interest relates to the potential for improvements in animal health and welfare, there are many other reasons PSA should be examined e.g. heat load amelioration, dag reduction, and odour and greenhouse gas emissions reduction. Because of this interest, the ALFA R&D Committee has recommended research be undertaken into the benefits of PSA. As a precursor to detailed research, a scoping study was undertaken.

This scoping study collates baseline data about the use of PSA in feedlots and proposes comparative, observational trials that can be completed at multiple feedlots during the 2013 winter period. As part of the scoping study, a review of literature also investigated the use of PSA in different sectors of the cattle industry.

This scoping study will conclude with a workshop of lot feeders and ALFA R&D Committee members to select the most suitable components for the observational trials, identify collaborating feedlots, and determine if MLA will provide funding to develop and manage the trials. At the end of the observational trials MLA will be better placed to initiate future detailed R&D projects.

2 Project objectives

As per the contract, the objectives of this scoping study were to develop a suite of R&D projects to examine the benefits of, and to address any issues arising from the use of, bedding materials in feedlots.

After this project commenced, MLA requested that the scoping study also investigate suitable methods and products to stabilise pen surfaces, e.g. fly ash.

For clarity, the term '**pen surface amendment**' (PSA) has been used in this report to account for two separate treatments within the pen:

1. ***Pen surface stabilisation (PSS)*** where soil stabilisers are used to create a durable, low permeability surface.
2. ***Pen surface covering (PSC)*** where bedding materials are distributed over the surface of the pen to improve cattle comfort and welfare outcomes.

The contract methodology required that several R&D projects be developed. However, after visiting and/or interviewing feedlots and industry specialists (e.g. feedlot veterinarians, nutritionists, researchers), it was decided that the initial research should focus on assessing the pros and cons of PSA through observational trials. A major challenge with initiating detailed R&D projects is the lack of Australian experience and research into the use of PSA at feedlots. There are no Australian published data for the effectiveness of different PSA types; how PSA should be distributed or applied within the pen; and whether or not PSA treatments provide better welfare and performance outcomes for lot fed cattle. Secondly, to ensure rigour through R&D projects, up to 30-40 pens at a single feedlot would be required to accommodate the various in-pen treatments (3-4 replications per treatment to provide a statistically valid assessment). It is very unlikely that any feedlot would be willing to accommodate such a request without first knowing that cattle performance was likely to benefit.

MLA agreed for the project objectives and methodology to be modified to accommodate these changes.

3 Methodology

According to the contract, the scoping study methodology included the following elements:

1. A brief literature review of the use of PSA in feedlots overseas. This will include the types bedding and soil stabilisers used, and the reasons why bedding and soil stabilisers are used.
2. A collation of the current experience of Australian lot feeders and veterinarians with the use of bedding materials. This will include documentation of the reasons why bedding was used, the types of materials used, successes and failures and the willingness of lot feeders to participate in a future R&D program.
3. A collation of the cost and availability of potential bedding materials and soil stabilisers.
4. A list of the proposed benefits of using bedding materials and soil stabilisers (e.g. animal welfare, dags, animal health, reduced heat stress, reduced pen maintenance, improved OHS, improved winter performance) and an outline of R&D projects that will document these benefits.
5. A list of environmental concerns (e.g. changes to odour, dust, runoff quantity & quality, manure management, greenhouse gas emissions, nuisance flies) and an outline of the R&D projects that will quantify these changes and address the concerns.
6. A preliminary costing of these R&D projects including suggestions for participating R&D organisations and co-operating feedlots.
7. A workshop attended by selected lot feeders and industry participants to agree on a future R&D program. This workshop will be held in May 2013 so that recommended projects can commence in the winter of 2013.

As explained in the Project Objectives (see Section 2), MLA agreed that it was difficult to scope and cost the R&D projects referred to in Elements 4-7 of the contracted Methodology. This was due to the lack of Australian research into the use of PSA at Australian feedlots. As a result of this change, FSA Consulting concentrated on scoping observational trials at Australian feedlots with the primary focus on the use of bedding materials, and the secondary focus on soil stabilisers. There is a high likelihood that observational trials could be established at feedlots this winter (2013) using bedding materials, based on feedback from lot feeders surveyed as part of this project. However, trials to assess the use of soil stabilisers would require the enlistment of a feedlot in the process of major pen renovations or undertaking the construction of new pens. This was considered less likely to be achieved in the short lead time between the MLA workshop and the commencement of the 2013 winter.

4 Overview of PSA used in intensive animal facilities

Pen surface amendment (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. 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 reduces an animals willingness to lie down and/or causes discomfort to animals that lie down.

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 mitigated, through the use of PSA. This report investigates the effectiveness of using PSS additives such as fly ash and cement; and PSC materials such as woodchip, straw, sawdust, rice and almond hulls, composted manure, sand and rubber chip to address the key issues that affect comfort. PSC can also provide a safe, stable non-slip surface for animals and staff.

4.1 Typical problems addressed by PSA

Exposure to a layer of wet manure and mud, or a dry, hard and hot pen surface, can compromise the comfort of lot fed cattle and safety of staff working within feedlot pens. This project has identified the following problems that affect 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’).
- *Cold stress:* reduced body temperature as a result of being covered in moist dags 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 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 contribute to hoof and limb injuries. It can also lead to animals and staff slipping, resulting in injury.

4.2 Possible solutions

The possible solutions considered in this project to address the problems that affect animal health and welfare; and the safety of staff working in feedlot pens can be grouped into two main categories; PSS and PSC.

PSS and PSC can be used to solve a range of problems. However, the use of either solution may solve one problem but 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 and lying down. In this situation, the use of PSS may also require the use of PSC such as woodchip 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.

4.2.1 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 soil 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 used successfully in the United States, but it is only one of several stabilisers that can be used to achieve the same outcome (i.e. a solid pen surface).

4.2.2 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 feedlots). Bedding materials, such as woodchip, straw, sawdust, rice and almond hulls, composted manure, sand and rubber chip, can be 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 offers different physical attributes that determine its suitability and effectiveness. The physical attributes considered in this project are absorbency, durability, porosity and recyclability.

5 Review of literature

5.1 Review scope

There are no Australian published data for the effectiveness of different PSA types; how PSA should be distributed or applied within the pen; and whether or not PSA treatments provide better welfare and performance outcomes for lot fed cattle. There is also no published Australian research on the use of soil stabilisers like fly ash.

This review has considered research outcomes from overseas animal production systems that use bedding materials and soil stabilisers. More specifically, it provides details of:

- The effect of stocking density on moisture content of the feedlot pad
- Pen surface stabilisation
- Pen surface covering with bedding
- Examples of the use of pen surface amendments for cattle
- Outcomes following the use of pen surface amendments.

5.2 Impact of stocking density 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 through manure (faeces and urine) deposition. Figure 1 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.

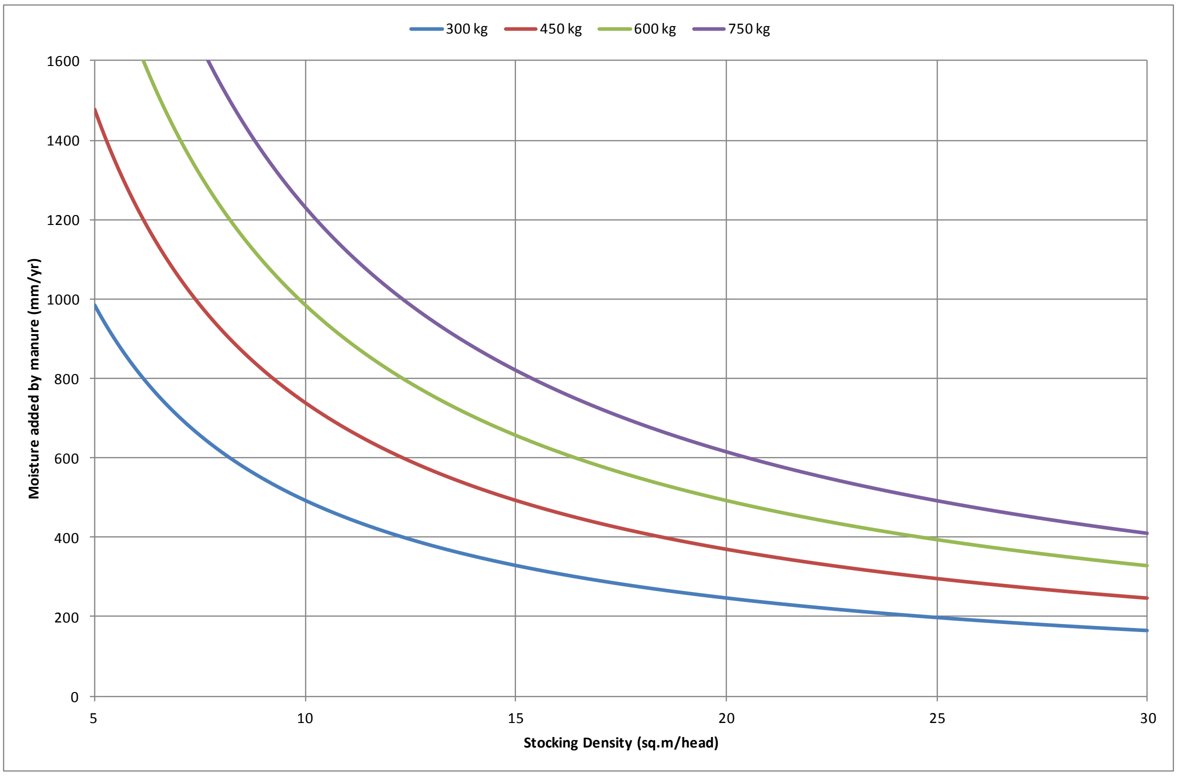


Figure 1 – Effect of stocking density and cattle liveweight on moisture added to pen surface

5.3 Pen surface stabilisation (PSS)

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.

5.3.1 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 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'.

5.3.2 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).

5.3.3 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 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, 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. (2004) 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. (2004) 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

5.4 Pen surface covering (PSC)

Pen surface covering, or bedding, is widely 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).

5.4.1 Types of bedding material

Different types of bedding are used in animal production. They include organic or inorganic materials. Organic bedding materials include woodchip, including post peel and bark; cereal straw; sawdust; rice and almond hulls; recycled manure (composted) and recycled rubber chip. Woodchip and sawdust, mostly from Radiata pine and blue gums, are the waste residues from timber processing. Post peel is another 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. Inorganic bedding materials include manufactured rubber mats and sand, which are used in freestall dairies in Australia, United States and Europe.

5.4.1.1 Woodchip

Woodchip can hold as much as 200% of its weight in water, depending on the kind of timber used, its moisture content and chip size. A batch of well-graded, smaller woodchip has a higher surface area to volume ratio and better water holding capacity (i.e. increase absorbency) than woodchip 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 woodchip ranges from 50-60% (Ragland et al. 1991).

The typical bulk density of pine and blue gum woodchip in Australia ranges between 350-500 kg/m^3. The bulk density can vary widely depending on moisture content and particle size. Bulk density will increase with smaller particle sizes and/or higher moisture content.

5.4.1.2 Straw

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 (Damian O'Keefe, pers. comm., 25 March 2013). 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.

5.4.1.3 Sawdust

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. Unpublished data from the former Queensland Department of Primary Industries and Fisheries estimated that softwood sawdust / shavings had a moisture content of 10% Tucker et al. (2010). Sawdust with smaller particle sizes retains more water than batches with larger particle sizes. Particle density essentially influences porosity, and particle size influences the capacity of sawdust to retain moisture (Maharani et al. 2010).

5.4.1.4 Rice and almond 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. 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.

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).

5.4.1.5 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 (Tucker et al. in Preparation)

5.4.1.6 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 density of dry sand ranges from 1100-1600 kg/m^3 and its porosity ranges from 20-50% (Curry et al. 2004).

5.4.1.7 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 limit the reuse options for spent bedding.

5.4.2 Important bedding material attributes

According to the survey completed as part of this scoping project, woodchip and straw have been trialled most widely by Australian feedlots. Feedback from the bedding material survey is discussed in Section 6 and completed surveys for eight feedlots are shown in Appendix 1. Feedback from surveys concluded that woodchip and straw are the most suitable bedding materials for Australian covered and uncovered feedlots, as they provide a clean, comfortable, and a dry resting environment for confined cattle.

The following characteristics were 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.
- *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).

Other important considerations reported in the bedding material survey that influenced the use (uptake) of bedding materials by Australian feedlots were availability and cost. Bedding material bulk density has a significant bearing on transport costs. Several feedlots provided availability and cost data for the bedding materials they have trialled and this is discussed in Section 6.2.

5.4.3 Bedding suitability assessment for Australian feedlots

Table 1 provides a comparative summary of each bedding material's suitability for use in Australian feedlots based on the attributes listed in Section 5.4.2 and feedback from the lot feeders surveyed as part of this scoping project (see Section 6). Each bedding material was assessed for each attribute and ranked as either poor, average or good. Table 1 also provides an overall assessment of each bedding material.

Woodchip and straw were assessed as the most suitable bedding materials for Australian covered and uncovered feedlots based on the following:

- *Screened woodchip* 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.
- A well-graded batch of *woodchip* can provide a high degree of porosity that allows for drainage of rainfall, urine and manure slurry. This can then exit the pen as runoff. Very wet sawdust or straw can lose their structure after exposure to heavy machinery and animal loadings, which can reduce porosity and inhibit drainage.
- *Woodchip* from post peeling is inferior for durability and recyclability compared with well graded *woodchip.*
- *Straw* has good absorbency and porosity. However, it is unsuitable for recycling and has only average durability.
- *Sawdust* (small particles) and *chopped straw* are likely to have a greater absorbency potential than woodchips (adult finger size). However, *sawdust* has poor durability, porosity and recyclability.
- *Sand* was trialled at a covered feedlot. They 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 hull* rated poorly for absorbency (rice hull), durability and recyclability. However, the 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. Rice hull 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. 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 1 – Bedding type suitability assessment for Australian feedlots

Type	Absorbency	Durability	Porosity	Recyclability	Key factors that influence the suitability and uptake of bedding materials based on the bedding survey feedback (see Section 6)
Woodchip (screened chip)	*Avg.	Good	Avg.	Good	➢ More durable than straw and sawdust. ➢ Porosity within a woodchip bedded area typically lasts longer than a straw or sawdust bedded area. ➢ Larger woodchip pieces can be recycled (i.e. screened from spent bedding). ➢ Easier to handle, transport, distribute and remove from feedlot pens than straw. ➢ Sharp woodchip pieces assist in removing / wearing dags off cattle.
Woodchip (Post peeling)	Avg.	Avg.	Avg.	Poor	
Straw	Good	Avg.	Good	Poor	➢ Good absorbency and provides softer, more comfortable lying surface for cattle than woodchip. ➢ 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 woodchip. ➢ 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 which reduces transport efficiencies and difficult to handle due to their 'fluffy' consistency. ➢ Almond hulls have average absorbency and porosity, they may be considered palatable by cattle. ➢ Availability and uptake limited by processing locations in north western Victoria and NSW Riverina.
Almond hull	Avg.	Poor	Avg.	Poor	
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. ➢ 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. ➢ Potential concerns of heavy metal contaminants from the recycled tyres.

* Avg.= average

5.5 Examples of bedding use for cattle

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

5.5.1 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 woodchip, woodchip / 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 woodchip 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 woodchip (at least 75 mm as the minimum) with a maximum chip length of 100 mm
- >75 mm depth of woodchip 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. Suitable flooring is the key to decrease foot soreness and lameness in stock. 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.

5.5.2 Live export

Australian cattle are routinely transported short and long distances by sea to markets such as Indonesia and Pakistan. These journeys can last up to 25 days so the welfare of livestock must be monitored and protected to prevent high numbers of injuries and mortalities. The cramped conditions and listing (swaying) of the ships carrying the livestock creates a dangerous 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, on the animals.

Cattle weighing 450 kg can produce approximately 26 kg of manure per day (≈85% moisture) per day (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.

5.5.3 Dairies

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

5.5.3.1 Freestalls and loose housing

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).

5.5.3.2 Wintering systems

In the high rainfall regions of New Zealand, some dairy and beef farms restrict grazing over the wettest months of the year. There are two main reasons that farmers use wintering systems. To:

- increase winter productivity through better pasture management and animal health
- reduce impacts on surface water from the loss of uncontrolled dairy effluent.

The New Zealand wintering systems that could provide useful design and management data for Australian lot feeders are called ‘standoff pads’ and ‘wintering pads’. Both of these systems are designed and managed similarly to an Australian dairy feedpad with an adjacent loafing area. The main differences between the design and management of Australian feedpads and New Zealand standoff pads are that New Zealand farmers:

- provide a greater depth of bedding material (0.5-1.0 m), due to the high winter rainfall that ranges between 1400-2400 mm/yr in the main dairying regions
- may confine cows to the standoff pad for up to six months of the year in high rainfall regions that are prone to soil pugging (with access to a partial or total mixed ration).

The bedding materials most commonly used in New Zealand are woodchip, bark, post peeling, sand, lime and soft rock (DEC 2006).

Dairy NZ conducted research trials in 2012 to examine the environmental and welfare impacts of confining dairy cattle to standoff pads. One trial at a Jordan Valley farm included a 650 cow herd confined to a feedpad with a standoff pad in the winter. The standoff pad was constructed over agri-pipe drainage, with 1.0 m of pine peelings on top, and stocked at 4.8 m^2/cow. The standoff pad was fenced into four quadrants to separate the treatments:

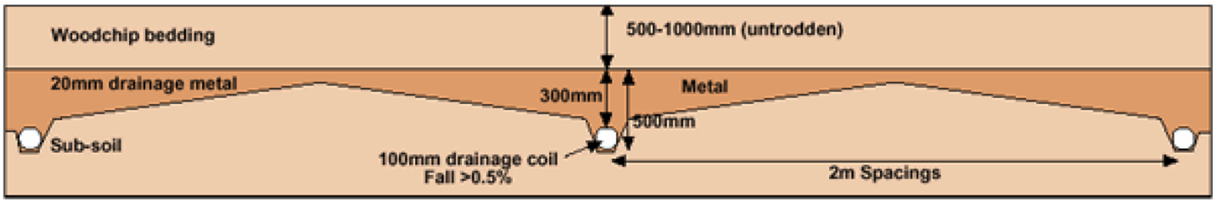
- Quadrant 1 left undisturbed for the 6 week trial period
- Quadrant 2 had its surface ripped weekly
- Quadrant 2 and 4 has their surfaces ripped twice per week

The trial:

- was stopped at the end of week 5 due to the dirtiness of the cows. The farmer said "they looked like armadillos, but after 3 weeks back on pasture they cleaned up well".
- resulted in the bedded pack compacting to an average thickness of 0.9 m.
- resulted in the top 0.25 m of bedding being heavily fouled with wet manure, Some drier mounds of bedding formed through natural subsidence (and they remained drier than the rest of the standoff pad).
- demonstrated no noticeable difference in cow behaviour between the ripped and non-ripped quadrants.
- produced average daily lying time of 4.5 hours on concrete (laying on the feedpad, not desirable); and 5-8 hours on the post peelings.

Figure 2 shows a typical cross section of a New Zealand standoff pad. The main design principles used in the construction of a standoff pad are that it:

- is capable of housing cows (24 hours) for at least three months
- includes a drainage system to divert contaminated runoff into an effluent system – the most common drainage system is ridge and furrow with perforated agri-pipe to divert runoff from underneath the bedding
- provides a woodchip bedding thickness at least 0.5 m, preferably 1.0 m.



Source: Dexcel Farm Fact 3-14: Standoff pads

Figure 2 – Cross section of typical New Zealand standoff pad

5.5.3.3 Recommended stocking density in confined dairy systems

Dexcel (2005) recommended the following stocking densities for confined dairy systems based on best practice in New Zealand, Australia and the United States:

- feedpads 3.5 m^2/cow; 9-12 m^2 if cows spend greater than 12 hrs/day on a feedpad with access to a loafing area
- if cows will be permanently housed:
  - in loose housing they require at least 11 m^2 per mature cow
  - in a freestall: one stall and one feeding spacing per cow should be provided

5.5.4 Northern US uncovered feedlots

Bedding materials are widely used in Canadian beef feedlots because the colder climatic conditions are uncomfortable for the cattle (Miller et al. 2006). Bedding materials are typically either cereal straw or woodchip. 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).

5.5.5 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 stover have been used successfully in covered feedlots.

5.5.6 Australian feedlots (covered and uncovered)

FSA Consulting identified 18 Australian feedlots that have used bedding materials in feedlot production or sick pens. Feedback was collected from all these feedlots and comprehensive survey responses for eight feedlots (‘Feedlots A-H’) are provided in Appendix 1. The survey data collected is discussed in Section 6.

Five of the eighteen feedlots operated either fully or partially covered feedlot pens. Feedlot A operates a combination of fully covered and uncovered pens, and F is a fully covered feedlot.

The main reason for using bedding materials in either covered or uncovered feedlots is 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, they use bedding materials to adsorb 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 surveyed considered woodchip and straw to be the most effective bedding materials.

5.6 Outcomes from the use of PSA in cattle feedlots

When pen surface amendments 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 section provide data on these outcomes.

5.6.1 Animal production, health and welfare outcomes

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

5.6.1.1 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 (Anderson et al. 2007, 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 again 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. (2007) 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. 2007). 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 woodchips. Incomplete consumption of their full ration may impact cattle performance.

Kalinski & Hippley (2005) investigated the use of fly ash as an amendment in feedlot pens. This improved daily gain and reduced hoof disease in cattle. NFACC (2012) reported that the use of fly ash improved the integrity of the pen surface, subsequently improving pen drainage conditions which resulted in less hoof injuries, disease, mud distribution and depth, and allowed better access to feed bunks and water troughs.

5.6.1.2 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).

Woodchips can prevent muddy conditions developing on pen surfaces and 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 excess use of energy 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 woodchip 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 woodchips.

5.6.1.3 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. Surfaces should not be excessively abrasive, slippery or continuously heavily contaminated with mud or manure (Cook et al. 2004). Surfaces may be compacted earth, gravel, concrete or artificial compounds (e.g. rubber coated concrete). New concrete and grooving is often very abrasive and may need to be abraded and cleaned prior to use.

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. (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. 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.

5.6.1.4 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 abattoirs 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 nonmotile variant of *E coli 0157* was prevalent on cattle pre and post processing, and also on carcasses 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).

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).

5.6.1.5 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.

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.

Woodchip is another bedding material that can be used to eliminate or mitigate the formation of dags. Like straw, woodchip 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 woodchip to clean manure and mud from cattle without penetrating the hide. Woodchip 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 woodchip.

5.6.1.6 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. 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.

5.6.1.7 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 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 (BOM 2013b) 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 (BOM 2013a). 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.

5.6.2 Environmental and manure management outcomes

The use of PSA 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 PSA 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 PSA is to be routinely adopted in Australia, evidence of successful environmental outcomes will need to be provided to regulatory agencies to gain licensing acceptance.

5.6.2.1 Odour

Odour and dust are persistent problems at 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 to moisture gain and loss characteristics of the feedlot surface. This will probably later odour emissions. PSA treatments that promote pen surface drying and encourage runoff (e.g. PSS) are likely to reduce odour emissions. PSA treatments that absorb and retain manure moisture on the surface are likely to increase odour emissions. 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, woodchips, 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, despite with a diurnal variation on some of the days. 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 woodchips 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 do not appear to be any studies completed that have used olfactometry methods accepted in Australia.

5.6.2.2 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 an air-borne dust particle 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 woodchip 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 within pens that is known to contribute to dust generation (Fisher et al. 2003, Tuomisto et al. 2009).

5.6.2.3 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 woodchip, 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 woodchip, respectively. The differences between straw and woodchip 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 woodchips. 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 woodchips. Greater woodchip density meant that three times the weight of woodchips was added compared to straw, but woodchips 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 woodchip 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. 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 (woodchip 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 pen surface amendment will alter the quantity and quality of runoff from an open feedlot pen surface. Pen surface stabilisation is likely to increase runoff volumes. Pen surface coverings are likely to retain moisture on the surface and thus reduce runoff. No data exists in Australia to quantify these changes. Pen surface amendments are also likely to alter runoff quality but no data exists to predict these changes.

5.6.2.4 Harvested manure quality

Many older feedlots in the United States have uncompacted or poorly compacted pen surfaces. During wet conditions or when the soil thaws out, soil and manure mix together. This results in soil being harvested from the pen during periodic cleaning and eventually the removed soil must be replaced during pen renovations. US feedlots have used soil stabilisers such as fly ash and cement to increase the strength and durability of the pen surface, with a subsequent improvement in manure quality.

Woodbury et al. (2013) found that renovating pen surfaces in the central Great Plains provided a solid pen surface that minimised the mixing of manure and soil, and subsequently improved the quality of manure harvested from the stabilised pens. The stabiliser used was ‘pond ash’. The Woodbury et al. (2013) experiment included eight separate feedlot pens (four resurfaced with pond ash only, and four control pens with in-situ silty-loam soil). Firstly the resurfaced pens were excavated to a depth of 0.5 m. Pond ash was then added in 0.15 m layers, and each layer watered and compacted using a sheep-foot roller and finished to the same grade as the soil only pens. The key results were:

- There was no significant difference in cattle ADG from all pens.
- Approximately 34% less mass (mixture of manure and soil) was harvested from the pond ash pens and it contained 46% less ash which infers significantly less soil contamination of the harvested product.
- The manure harvested from the pond ash pens contained 70% more volatile solids (VS) than compared to manure harvested from the soil only pens.

Overall, the findings concluded that the pond ash stabilised pens required less time to clean, as there was less soil contamination of the manure and the harvested manure quality was superior due to its greater nutrient and energy density. Woodbury et al. (2013) also reported that the manure harvested from the pond ash pens could be used as fuel for direct combustion or co-combustion in coal-fired power plants.

Sweeten et al. (2013) examined the combustion fuel properties of manure and compost from paved and unpaved cattle feedlots as modified by annual rainfall. The paved pens were treated with fly ash. Research was conducted to determine the effects of feedlot surfacing materials (soil/unpaved vs. fly-ash paved), partial composting and/or storage in windrow or greenhouse, and wet year (2005) vs. dry year (2006) feedlot conditions on cattle feedlot biomass (FB) (manure) characteristics pertinent to combustion or gasification processes involving re-burn or co-firing with coal or lignite as described elsewhere.

Bulk quantities of FB were harvested from 12 fly-ash paved pens and six soil-surfaced pens in a 400-head research cattle feedlot near Bushland, Texas. FB was windrow-composted, and samples were analyzed using proximate, ultimate, and elemental ash analyses. Higher heating value (HHV) before composting (termed raw manure, RM) was significantly higher for FB harvested from paved pens (termed low ash, or LA-FB) vs. soil-surfaced pens (termed high ash, or HA-FB) on a dry basis and dry ash-free (DAF) basis for both study years. Ash content (dry matter basis) was significantly lower and volatile matter (VM), carbon (fixed and total), and hydrogen were significantly higher for LA-FB (paved pens) vs. HA-FB (unpaved pens) for both years of the study.

As-harvested, HHV averaged 6,304 and 8,190 kJ kg-1 w.b. (2,710 and 3,521 BTU lb-1 w.b.) for HA-FB for the wet and dry years, respectively, and as-harvested HHV for LA-FB averaged 13,407 and 13,224 kJ kg-1 w.b. (5,764 and 5,685 BTU lb-1 w.b.) for the wet and dry years. Partial composting (PC) in windrows (for 51 to 55 days in 2005 or 91 days in 2006) reduced HHV w.b. by an average (both years) of 11.4% for the resulting HA-FB-PC and 14.8% for the resulting LA-FB-PC. The LA-FB-PC was significantly different from HA-FB-PC for all proximate and ultimate analysis parameters for both 2005 and 2006 manure, with the exception of 2006 wet-basis HHV. Heating value on a DAF basis averaged 20,984 kJ kg-1 (9,022 BTU lb-1) for LA-FB-PC and 18,941 kJ kg-1 (8,143 BTU lb-1) for HA-FB-PC. Greenhouse storage for 9 to 12 months of the 2005 harvested LA-FB-RM and LA-FB-PC preserved fuel quality better than did continuous storage of LA-FB-PC in a windrow, probably because lower moisture conditions were maintained under greenhouse storage conditions (7.7% to 13.4% w.b. final range) compared with uncovered windrow storage (17.4% final moisture content).

Elemental analysis of ash from LA-FB was higher than from HA-FB for Ca, P, Cl, K, Mg, Na, and S, but was lower for Si, Al, Ti, and Fe without or with partial composting. Metal contents were similar for both high-ash and low-ash FB.

5.6.2.5 Spent bedding reuse

Cattle feedlots in Alberta typically apply straw spent bedding to surrounding cropland. However, composted manure, as well as fresh manure or compost containing wood bedding, is being increasingly used. Although many studies had investigated the impact of fresh manure on soil physical properties, Miller et al. (2000) was unaware of any studies that had compared the effect of fresh manure versus compost, or straw versus wood bedding on soil physical properties.

Miller et al. (2000) conducted experiments on a clay loam soil at Lethbridge (Alberta, Canada) where several fresh and composted spent bedding soil amendments where applied to land (varying rates of straw or woodchip). Miller et al. (2000) measured the following soil properties to assess the impacts of the various soil amendment products and rates on the receiving soils: texture and organic carbon, intrinsic air permeability, penetration resistance, seasonal changes in bulk density, soil temperature and water, soil water retention and plant-available water, saturated and unsaturated hydraulic conductivity, percentage of total infiltration flux specific pore sizes, and pore-size distribution.

Miller et al. (2000) concluded the following:

- A single annual application at rate of 39 t/ha and 77 t/ha of either: fresh straw or woodchip spent bedding; or composted straw or woodchip spent bedding to a clay loam soil improved the physical condition of the soil by lowering the soil bulk density over four seasons.
- The treatments that had the most overall net benefit on the physical condition of the soil compared to the control plot were (from greatest effect to least effect):
    - medium rate of manure with wood was greater than high rate of compost with straw
    - high rate of compost with wood had similar results to high rate of manure with straw
    - high rate of manure with wood was greater than medium rate of compost with straw
    - medium rate of compost with wood was similar to medium rate of manure with straw.

The treatment type (fresh or composted) had the most significant effects on soil physical properties, followed by bedding type and the application rate (t/ha). Manure improved the soil slightly better than compost, wood slightly more than straw, and the high rate more than the medium rate of application.

Spent timber bedding from standoff pads in New Zealand and the UK has a significant nutrient content, not dissimilar to the levels in manure removed from feedlot pens (Smith et al. 2010). However, more information is needed on the nutrient value of the spent timber bedding and on optimum application rates and timings. 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). It was suggested that this could be because the timber particles shaded the sward which inhibited grass growth, at least for first cut silage. However, the shading effect of timber reduced as the timber decomposed on the sward surface and was not evident twelve weeks after application. Fine woodchips are now commonly used, at least in the surface layer, in standoff pads in Ireland. For example, shredded pallets provide chips which may be several centimetres in length, but perhaps only a few millimetres in thickness (Smith et al. 2010)

Potts and Casey (1999) undertook a co-composting study to determine the practical aspects of composting cattle feedlot manure using timber sawmill wastes. This work was done at Yarranbrook Feedlot in southern Queensland. Although the sawmill wastes were not used as bedding in the feedlot, the results of this study provide insight into the changes in composted manure characteristics for manure only compared to manure with woodchips. One objective of this study was to alter the carbon to nitrogen (C:N) ratio of the compost from 10 for manure only to 15 to 30 so as to reduce nitrogen loss from the compost. Both cypress pine and eucalyptus hardwoods were used. The composting process worked well but watering and turning improved compost quality. More nitrogen was retained in the cypress-based compost.

5.6.3 Feedlot operational outcomes

Feedback collected from the bedding survey of Australian lot feeders indicated that bedding materials such as woodchip and straw:

- reduce pen pot-holing because the bedding material acts as a sacrificial layer that protects the pen surface from direct contact with cattle hooves.
- reduce pen surface maintenance costs (as direct result of less pot-holes to fill / repair).
- provide a softer, more cushioning surface for pen riders and walkers. This improved the safety of staff and reduced the likelihood of slipping / falling when traversing over bedded areas.

6 Bedding use in Australian feedlots

This section provides details of observations for bedding use in Australian feedlots. Eighteen Australian feedlots that have used bedding materials in feedlot production or sick pens were contacted. Five of the eighteen feedlots operated either fully or partially covered feedlot pens.

6.1 Overview of bedding usage in Australian feedlots

Table 2 provides a description of the bedding related photographs collected from several Australian and northern United States feedlots (combination of uncovered and covered feedlot pens).

Table 2 – Photographs of bedding use and management at Australian feedlots

Photograph ID	Bedding and spent bedding photograph descriptions
Photograph 4	• Feedlot 1 located in northern Australia. • Pen surface was replaced with a compacted gravely-clay mix prior to placement of woodchip bedding. • Uncompacted bedded depth ≈0.2 m. • Whole pen surface bedded (except concrete feedbunk apron).
Photograph 5	• Feedlot 1 • Woodchip bedding showing a high percentage of small particles indicating an un-screeded batch / poorly graded.
Photograph 6	• Feedlot 1 • Condition of woodchip bedding ≈40 days after the bedding was added. The bedding is very clean and dry, indicating there hasn't been regular rainfall events since it was added to the pens.
Photograph 7 Photograph 8 Photograph 9	• Feedlot 1 • Condition of woodchip bedding ≈100 days after the bedding was added, and also after a recent rainfall event. The surface is wet and there is a fine film of slurry manure, but the cattle are clean and there are pools of rain and manure.
Photograph 10	• Feedlot 1 • Shovel used to dig beneath the surface of woodchip bedding to check the condition of the bedded profile ≈100 days after the bedding was added. • The bedding ≈4-5 cm underneath the surface is extremely clean and appears to be moist, but not saturated with manure.
Photograph 11	• Feedlot 2 located in the northern Australia. • Freshly placed woodchip over the entire pen surface and the cattle are very clean and several seen lying on the bedding.
Photograph 12	• Feedlot 2 • Cattle on woodchip bedding • Some cattle with a high percentage of dry dags and the beast in the foreground has skin lesions on its upper shoulder.
Photograph 13	• Feedlot 2 • Spent woodchip bedding prior to the pen being cleaned out. • High percentage of manure mixed in with the woodchip bedding, but the bedding surface is still relatively dry.
Photograph 15	• Feedlot 2 • Covered feedlot with concrete floors showing cattle standing on fresh

Photograph ID	Bedding and spent bedding photograph descriptions
	woodchip bedding.
Photograph 16	• Feedlot 2 • Covered feedlot with concrete floors showing spent woodchip bedding prior to clean out.
Photograph 14	• Feedlot 3 located in the northern Australia. • Cattle standing on a circular bedded mound of woodchip, parts of the pen surface exposed (no bedding).
Photograph 17	• Feedlot 4 located in southern Australia. • Covered feedlot with concrete floors showing a freshly bedded pen using a combination of sawdust (near the feedbunk) and composted sawdust bedding at the back of the pen. Average bedded depth 50-100 mm.
Photograph 18	• Feedlot 4 • Covered feedlot with concrete floors showing clean cattle sitting / standing in a sawdust bedded pen.
Photograph 19	• Feedlot 5 located in United States. • Covered feedlot showing fresh corn stubble bedding.
Photograph 20	• Feedlot 5 • Covered feedlot showing clean cattle standing on dry manure and much of corn stubble bedding is longer visible.
Photograph 21	• Stockpile of woodchip spent bedding at Feedlot 2.

Photograph 4 – Fresh woodchips being distributed to achieve 150-200 mm coverage

Photograph 5 – Close-up view of woodchip bedding

Photograph 6 – Woodchip bedding condition ≈40 days of age (Nov 2012)

Photograph 7 – Woodchip bedding condition ≈100 days of age (Jan 2012)

Photograph 8 – Woodchip bedding condition ≈100 days of age (Jan 2012)

Photograph 9 – Woodchip bedding condition ≈100 days of age (Jan 2012)

Photograph 10 – Woodchip bedding condition beneath the surface (Jan 2012)

Photograph 11 – Fresh woodchip bedding (Mar 2013)

Photograph 12 – Heavy cattle on woodchip bedding (Aug 2012)

Photograph 13 – Spent woodchip bedding prior to pen cleanout (Oct 2012)

Photograph 14 – Cattle standing on fresh mound of woodchip bedding

Photograph 15 – Covered feedlot showing fresh woodchip bedding

Photograph 16 – Covered feedlot showing spent woodchip bedding

Photograph 17 – Covered feedlot using sawdust and composted spent bedding

Photograph 18 – Covered feedlot showing cattle lying on sawdust bedding

Photograph 19 – Covered feedlot using corn stubble

Photograph 20 – Covered feedlot using corn stubble

Photograph 21 – Stockpiled spent woodchip bedding

6.2 Lot feeder survey results on bedding use and management

Eighteen Australian feedlots that have previously used bedding materials in either their production or sick pens were contacted or visited to obtain data on their experiences with pen surface covering. No feedlots were found that have trialled pen surface stabilisation in Australia. This section outlines the key experiences and data that were provided by all feedlots surveyed. A qualitative summary of the survey results is outlined below Table 3.

Eight feedlots were able to provide more comprehensive feedback from their experiences trialling bedding materials (identified as 'Feedlots A-H' in Table 3). Table 3 provides a summary of their location, licensed capacity, annual rainfall, dominant rainfall season and what bedding materials they have trialled.

Appendix 1 provides copies of the completed survey responses from 'Feedlots A-H'. Feedlot A operates a combination of fully covered and uncovered pens, and Feedlot F is a fully covered feedlot. Feedlots B, C, D, E, G and H operate uncovered pens.

Table 3 – Feedlot respondents to bedding survey

ID	Location	Licensed capacity (SCU)	Annual rainfall (mm/yr)	Dominant rainfall season	Bedding materials trialled
Feedlot A	Northern Australia	50 000	857	summer	woodchip (pine)
Feedlot B	Northern Australia	3100	774	summer	woodchip (pine)
Feedlot C	Southern Australia	6500	573	winter	woodchip (pine)
Feedlot D	Southern Australia	30 000	523	winter	woodchip (pine)
Feedlot E	Southern Australia	8870	372	winter	woodchip (pine), rice and almond hulls
Feedlot F	Southern Australia	4500	709	winter	woodchip (pine), sawdust, recycled manure, straw, sand, zeolite
Feedlot G	Southern Australia	2000	798	winter	woodchip (pine and blue gum), pine post peeling, straw
Feedlot H	Southern Australia	8000	468	winter	straw

The following sections are summarised responses from all eighteen feedlots. It should be noted that all of these responses are anecdotal. None of those surveyed using woodchip provided an accurate estimate of woodchip usage rate or changes in animal performance. As far as can be determined, there have been no systematic trials undertaken to quantify any of the responses noted below.

<u>What were their reasons for trialling bedding?</u>

All respondents provided similar answers and they can be summarised as:

- Perceived benefits for cattle comfort during wet winters and prolonged cold weather, and enhanced cattle recovery in sick pens.
- Perceived benefit of reduced odour intensity from wet pens.
- Wanted to prevent or minimise the formation dags and cattle washing.
- To minimise pot-holing.

Who recommended the use of bedding?

- nutritionist, veterinarian, had seen benefits of bedding use in the dairy industry.

What type of bedding has been trialled?

Woodchip (pine and blue gum)

- 14 feedlots have trialled pine woodchip, and one of these has also trialled blue gum woodchip.
    - the reported particle sizes were 3-6 cm, 5-8 cm and 5-30 cm long. One respondent said the woodchip had not been screened prior to use, and it would appear from the other reported particle size range of 5-30 cm a poorly sorted batch (not screened).
    - 2 feedlots preferred woodchip over woodchip containing fibrous bark.
- 4 feedlots have trialled straw.
- 2 feedlots have trialled sawdust.

Other bedding materials tried included rice and almond hulls, sawdust, sand, zeolite and composted manure (spent sawdust bedding).

Preferably, straw should not be chopped prior to baling (i.e. don't engage choppers on the baler), as longer straw particles create a stronger, structured pile that allows better drainage by providing greater void space within the bedded area.

Bedding source / cost / availability

- Woodchip was sourced from timber processors or commercial landscaping businesses located at Roma (QLD), Tamworth and Tumut (NSW) and Macarthur (VIC). Feedlots were able to source woodchip within 50-250 km radius of their sites. Prices landed at the feedlot ranged from \$20-30/m^3. One respondent indicated that VISY had driven up the price from \$10 to \$20/m^3 and they were buying up the majority of woodchip and general wood residues within a 300 km radius of their Tumut and Albury paperboard factories. All respondents that had used woodchip said the material was available all year round.
- Post peeling in western Victoria available from \$14/m^3 and available all year round.
- Blue gum plantation waste in Western Victoria available from \$1.50/m^3, but requires grinding / chipping to a suitable, uniform particle size.
- Cereal straw is available all year round throughout all the major grain growing regions of Australia. Feedlots were able to land wheat and barley straw for \$90-110/t (current season) or \$60-80/t (old season).
- Almond hull was sourced from north western Victoria and freighted within a 300 km radius for \$80/t. Almond production is based predominately in north western Victoria and the Riverina (NSW). Availability is assumed to be somewhat seasonal because the Australian almond industry only produces one crop per year and it is typically harvested in late summer and early autumn.
- Rice hull was sourced from SunRice in Deniliquin and freighted within 50 km radius for 6-8\$/m^3. Like almonds, Australia only produces one rice crop per year that is

processed in the NSW Riverina region and it is typically harvested in early autumn. Availability is impacted by water scarcity, as the majority of the crop is irrigated using surface water entitlements.

How was the bedding applied and managed in the pens?

- Prior to distribution of bedding all respondents completed a full pen clean and repaired pot-holes.
- Woodchip is usually transported in semi or b-double loads and dumped on the ground at the feedlot, then feedlot staff reload into heavy rigid tippers and deliver into the pen. Articulated loaders are used to distribute the woodchip around the pen.

Specific to uncovered feedlots

- Woodchip: respondents in the higher rainfall areas said that at least a 0.2 m thick layer is required, preferably 0.3 m.
- Two northern Australian feedlots reported that they cover the entire pen surface with 0.2-0.3 m of woodchip. Both these feedlots indicated that:
    - 0.3 m woodchip bedding was effective for at least six months without treatment, but longevity of the woodchip bedding could be extended out to 10 months with some minor ripping / cultivation after six months.
    - Pen stocking density of 10 m^2/SCU, approximate bedded area of 10 m^2/head.
    - The reason for bedding the whole pen was to prevent wet manure and mud from the exposed pen surface being tracked by the cattle onto the bedded areas. Complete covering also reduces damage to the underlying clay pen surface.
- One southern Australian feedlot in a high rainfall area reported that woodchip was formed into windrows (leaving an exposed pen surface in between the windrows). The woodchip bedding was effective for 10-12 weeks, then pens typical re-bedded in mid-winter. The windrows were approximately 5.0 m wide with an average height of 0.3 m. Bedded area of approximately 4-6 m^2/SCU.
- Straw: one southern Australian feedlot said they clean their pens in May prior to the usual wet period of the year, then in June when manure on the pad starts to turn ‘soupy’, straw is added to a depth of 300 mm across the top half of the pen only (fence-to-fence). Straw is removed after approximately four weeks. A fresh batch of straw is then added (as per the previously described method). Typically, pens are bedded twice during the winter period and approximately 60 kg of straw is provided per head per bedding (i.e. 120 kg of straw per head over the approximate 60 day winter bedding period).

Specific to a covered feedlot

- Woodchip: One southern Australian feedlot with fully covered pens typically adds 50-100 mm of woodchips to a clean pen surface and the bedding is effective for 1-3 months. Longevity of the bedding is increased in the summer months when some moisture can be evaporated from the manure / bedding mixture.

What happened to the bedding after removal from the pens?

- The majority of feedlots still using woodchip were very keen to be able to separate woodchip from the spent bedding. Only one feedlot had been able to successfully separate spent bedding into manure and woodchip. Two feedlots have decided to stockpile spent bedding until they can find a suitable use or effective method to separate the woodchip and manure (these stockpiles are segregated from the manure-only stockpiles).

- Five feedlots using woodchip said the spent bedding was composted and sold to off-site users and/or spread on their own broadacre land. One feedlot has successfully screened larger woodchip from old (18-24 months) stockpiles of spent woodchip bedding. It is possible using their 'Precision Screen', but it requires a relatively dry product, preferably <30% moisture. Their screen is not effective for screening post peelings, as they breakdown during their use in the pens and manure has a tendency to form a stronger bond to the peeling (possibly because they have a fibrous skin, compared to woodchips that have a relatively smooth surface).
- One feedlot still using straw said the spent bedding was composted, usually dried manure is blended with wet spent bedding straight after removal from the pens. It is then left in static piles for four months, then spread back onto their own broadacre land. The respondent said that the straw added bulk and porosity to the compost piles.

<u>Would they be interested in co-operating in any trials that may commence in the winter of 2013?</u>

- Eight feedlots indicated they would be interested in being involved, dependent on the level commitment and cost to their feedlot.

<u>Do they operate FY3000?</u>

- Five of the eight feedlots listed in Table 3 operate FY3000. Data availability and access from FY3000 feedlot management software allows for better on-site research trials.

<u>What were the outcomes of using the bedding?</u>

Advantages of using bedding:

- Cattle become stimulated when entering a freshly bedded pen.
- One uncovered feedlot in southern Australia reported an improved daily weight gain of 0.1-0.2 kg/day, cattle settled quicker, and greater percentage would lie down shortly after rainfall events, compared to cattle without bedding.
- Reduced number of leg abrasions on heavy cattle from standing or lying.
- Cattle heal quicker from lameness, cattle can heal from foot injuries without vaccination.
- Reduced washing time by up to 50% compared to cattle not provided with bedding.
- Sharp woodchip pieces assist in removing / wearing dags off cattle.
- Effective tool to keep cattle clean between washing and transport (up to a week if put on clean bedding after washing).
- Reduced dust released from the pen surface during dry conditions.
- Pleasant odour when woodchip is used.
- Pieces of post peeling are typically smaller than woodchip, so they breakdown in the pen and are hard to recognise after composting. This compost can be applied without

leaving visible timber residues on the soil surface that may otherwise contaminant future hay and silage production.

- Less potholes.
- Reduce slips experienced by pen riders and pen walkers in both wet and dry conditions.

Disadvantages of using bedding:

- Build-up of bedding and manure around fences can impede drainage, more frequent cleaning and maintenance to maintain effective pen drainage.
- If not enough material is applied, it can quickly turn into a messy bog. Two uncovered in southern Australia trialled 50 mm and 100 mm over entire pen surfaces (separate pens) and after 2-3 weeks the whole pen become a wet mess as the manure and residual moisture after rainfall was absorbed by the bedding. Moisture could not drain freely from the pens.
- Post peeling would be difficult (possibly impossible) to screen out of spent bedding. Post peeling pieces are typically long, fibrous particles that tend to form a strong bond with manure, stronger than the bond between woodchip and manure.
- Spent straw bedding was significantly more difficult to remove than spent woodchip bedding, as straw formed large dense clumps that were hard to pick up using loaders.
- Sawdust and recycled manure were not successful because they turned to ‘paste’ after rainfall and were no longer effective.
- Sand was trialled in covered feedlot pens, and the respondent said it was not suitable. It is expensive to transport due its weight and the sand surface blocks up with manure and quickly impedes drainage.
- Zeolite was too expensive and, like sand, it could not be recycled unless washed.

6.2.1 Australian feedlot industry specialists experiences

The following feedlot industry specialists were contacted to discuss their knowledge and experience with the use of bedding in feedlot pens and seek their ideas for the proposed observational trials:

Dr John Gaughan (pers. comm., 16 January and 20 February 2013)
University of Queensland – School of Agriculture and Food Sciences

- Dr Gaughan has recent experience in the last 12-18 months of working in South Dakota where bedding was trialled in feedlot pens to reduce the impact of heat and cold stress. Trials used straw placed on pen floor – usually round bales rolled out to form windrows that ran parallel with the pen slope. The results were:
    - summer: 25-30°Celsius reduction in temperature at the pen surface, the bedding absorbed heat and reduced the amount re-radiated. He also indicated that the US lot feeders had trialled corn husk / stubble.
    - coarser materials (with larger void spaces) tend to absorb more heat. Trials were conducted at feedlots without shade in pens. Some trials involved wetting the pen surface prior to laying straw.
- Winter results (ambient temp of -20°Celsius) showed improved cattle comfort and feed conversion when bedding was provided in addition to shelter around pens from prevailing winds (outdoor feedlots). The trial work concluded that less feed (energy)

was used to warm the body, thus improved feed conversion from the combination of bedding and shelter from prevailing winter winds.

For the observational trials, Dr Gaughan suggested the following:

- It is easier to observe changes in trials conducted in summer and winter, compared to autumn and spring trials.
- In-pen treatment using machinery should be minimized as this disrupts cattle and may affect the outcomes.
- Practical welfare assessment methods mainly include visual observations, e.g. panting score, percentage of cattle standing / lying throughout the day (in both normal and extreme weather conditions). He does not favour blood / saliva samples to analyse stress because handling cattle to collect samples impacts on the assessment.
- He recommended at least 2 m^2 of bedding per head and bedding thickness of at least 0.3 m.

Dr Simone Holt (pers. comm., 18 February 2013)
Nutrition Service Associates

- Straw can be expensive to use but is viable if placed correctly in the pen. The best method is to pile it in a corner and let cattle lie on it in turns. Straw is dragged around the pen and it can absorb moisture. Fresh straw needs to be continually added to the piles or mounds. This saves having to cover the whole pen and also assists in more efficient pen cleaning. Straw is more readily available than woodchip to the majority of Australian feedlots, as they are located in or near the main grain growing regions.
- Dr Holt believes that ALFA would be interested in quantifying the cost of bedding materials and generally the costs associated with its distribution and removal from pens. They are also likely to be interested in meat quality, thus bedded cattle should be traced through to processing.

For the observational trials, the following aspects should be considered:

- Weight gain is easily tracked via FY3000.
- Participating feedlots should be compensated for any monetary losses and this may deter lot feeders from deviating from the trial methodologies if they are completing the trial assessments / records keeping.
- Collaborating feedlots should use similar cattle (e.g. age, weight, breed) for the trials, heavy European cattle would be suitable, not Wagyu.
- Introducing new cattle to an already wet feedlot can cause bigger problems than those that affect existing cattle in the pens. Successfully getting cattle through the first 20 days is critical.
- Welfare assessment could include the number of cattle pulled for treatment in bedded and non-bedded pens.

Dr John Doyle (pers. comm., 25 January 2013)
Integrated Animal Production Pty Ltd

- Dr Doyle consults to feedlots in Australia, South Africa, Indonesia, United States and Argentina. He is a strong advocate for bedding use and has Australian clients that use straw in the winter. The best way to convince lot feeders to use bedding is through the assessment of feed intake, ADG and FCR data captured in the winter months.

- He recommended at least 1.5 m^2 of bedding per head and bedding thickness of at least 0.3 m. He prefers bedding to be formed into mounds and leaving parts of the pen surface exposed.

6.3 Key findings to assist scoping the PSC observational trial

Bedding availability

- Woodchip and straw appear to be the most accessible and cost effective materials available in the main lot feeding regions of Australia.

Recommended bedded area and depth per head

- For dairy cows, Dexcel (2005) recommended 9-12 m^2 per cow if spending >12 hrs/day on a feedpad with access to a loafing area. The actual bedded area provided on the loafing area ranges from 5.5-9.5 m^2 per cow. The bedded depth ranged from 0.3-1.0 m.
- Anderson et al. (2007) approximated that 0.5 kg bedding should be added per head per day, for every 25 mm of mud depth in the pen (North Dakota winter climate). They investigated this with trials that operated over a four month period in winter and the average mass of fresh straw bedding added was 1.5 kg/head/day or 180 kg of straw/head over the 120 day winter period.
- At least 2.0 m^2/head, 0.3 m deep for feedlot cattle (Dr John Gaughan).
- At least 1.5 m^2/head, 0.3 m deep for feedlot cattle (Dr John Doyle).
- The surveyed lot feeders in this project (see Section 6.2.1) recommend a bedding depth of 0.2-0.3 m for uncovered feedlots.
    - Woodchip: Two northern Australian feedlots provide 10 m^2/head of bedding and a bedded depth of 0.3 m. This was effective for at least six months without treatment but longevity of the woodchip bedding could be extended out to 10 months with some minor ripping / cultivation after six months. Both of these feedlots covered the entire pen surfaces in woodchip bedding.
    - Straw: one southern Australian feedlot provided 120 kg/head over two beddings during a 60 day winter period (i.e. 2.0 kg/head/day).

Matching bedding to weather conditions – rainfall vs snowfall

FSA Consulting believe there may be merit in providing at least 5 m^2 of bedded area per animal in southern feedlots, as additional area may increase the serviceable life of the bedding (i.e. prevent it from fouling with excessive manure and moisture, which could result in its removal before the winter period has ended). The other reason to consider providing a greater bedded area is due to the potential for a persistent winter rainfall and low evaporation. The literature review provided results from bedding trials in the northern United States that typically experience freezing conditions (e.g. the pen surface freezes and rainfall lands as snow). Therefore, the bedding in the northern United States mainly deals with moisture from cattle manure only during the majority of the winter period. However, in Australia, winter rainfall will add a significant moisture load to the pens and the longevity of the bedding material may be reduced as a result of high rainfall and low evaporation, compared to the North American feedlots which do not have to deal with regular rainfall.

Some of the literature regarding bedding trials in northern United States feedlots showed that fresh bedding was being added to pens daily. It unlikely that will be achievable at some Australian sites because some pens may be too wet / slippery for heavy machinery to access or this daily task may be considered too onerous and/or costly.

Effect of bedding treatments and high stocking rates

Dairy NZ conducted a research trial using a dairy standoff pad stocked at 4.8 m^2/cow and a 1.0 m thick bedded pack to investigate environmental and welfare impacts of dairy cattle confined to wintering standoff pads. The results of the trial were:

- no noticeable difference in cow behaviour between the ripped and non-ripped quadrants
- the bedded pack compacted to an average thickness of 0.9 m
- the top 0.25 m was heavily fouled with wet manure, there were some drier mounds of bedding that formed through natural subsidence (and they remained drier than the rest of the standoff pad).

7 Proposed Observational Trials

It is proposed to conduct a trial in the winter of 2013 to observe and systematically assess (where possible) the impacts:

- that the type, amount and distribution of bedding within a pen have on general cattle health, welfare and performance.

The research could be tailored to look at the effect that bedding has on:

- the treatment / reuse options for wastes, including bedding reuse
- the integrity / structure of the pad; and whether these effect pen runoff and safety of staff (pen riders and cleaners).

7.1 Scope of the observational trial and potential add-on components

The following section outlines the aims, methods, equipment and materials required to set up and manage the *Trial – Bedding use in feedlot pens*. It also includes specific questions that can be considered by the MLA Feedlot R&D committee to select the most suitable qualitative and/or quantitative trial assessment methods. Two optional components to this Trial are described in Sections 7.3. These consider how spent woodchip could be treated / managed to separate woodchip and manure; and methods for assessing the impact of bedding on the pad surface and safety of staff working in bedded pens.

It was decided, in consultation with MLA, to focus on a systematic, comparative observational trial to firstly determine the effectiveness of different bedding materials, amount to supply per head, and how best to distribute bedding within a pen. MLA can use these outcomes to consider more rigorous R&D bedding projects in the winter of 2014.

A budget has been developed for Trial – Bedding use in feedlot pens (see Section 7.2). However, no detailed scope or budget is provided for the add-on components. The MLA workshop can be used to determine if more detail is warranted.

It is expected that the observational trials will require 4-6 feedlot pens at each of the collaborating sites. Conducting a statistically valid R&D experiment is likely to need say 30-40 pens at a single feedlot which is simply not practical. (Dr John Gaughan of University of Queensland indicted that a statistically valid experiment would need 3-4 replications per treatment (John Gaughan, pers. comm., 20 February 2013)).

7.1.1 Trial variables

Rather than setting up and managing replicated trials at the collaborating feedlots, it is proposed that treatments will be replicated at sites located in different climatic regions of Australia. There would be significant benefits if several collaborating feedlots could run systematic, side-by-side trials of woodchip and straw used in different ways to assess the effectiveness and suitability of the two materials under different climatic conditions.

The observational trial will include three main variables:

- type of bedding material (woodchip and straw)
- bedding distribution within the pen (e.g. top third or middle section of the pen; and mounds or windrows within the pen)
- area and/or depth of bedding.

The research will be conducted during the 2013 winter period and it is likely that one or two batches of bedding will be monitored for 4-12 weeks. Feedback from the eight surveyed lot feeders discussed in Section 6.2 indicates that a single batch of straw can last up to four weeks without any treatment and woodchip several months depending on stocking density and rainfall.

The trial pens will need to be ready before the autumn weather break to ensure the pen surface is clean, free of potholes and so all the pens are in an equivalent condition before the pen trials start.

Feedback from the surveyed lot feeders (see Section 6.2) and from Dr John Gaughan suggests that bedded pens should be passively managed (e.g. bedding should not be aerated) to align with current commercial feedlot pen management practices. There may also be practical or safety issues for heavy machinery trying to regularly access and manoeuvre in pens with slippery and wet surfaces.

7.1.2 Selection criteria for prospective feedlot trial sites

The following outlines the key selection criteria for feedlot trial collaborators. They must:

- use FY3000, or other suitable electronic database management system so that consistent data can be readily accessed
- have a weighbridge
- be able to commit enough staff to training and undertaking daily observations (potentially recording pen observations 2-3 times per day)
- have sufficient scale to supply:
  - a sufficient number of cattle of similar breed, age, entry weight
  - several identical pens (e.g. identical length, width, slope, pen surface material, pen surface condition, shade or no shade at the commencement of the trials).
- have an on-site automatic weather station (AWS).

Ideally, lot feeders will be able to obtain discrete carcase quality feedback for cattle kept on bedded and unbedded pens.

7.2 Trial – Amount and distribution pattern bedding used in feedlot pens

Aim: To observe and assess (where possible) whether the type, amount and distribution pattern of bedding in feedlot pens affects cattle performance and animal health and welfare outcomes during winter.

Potential trial outcomes: The following questions provide the MLA workshop attendees with the scope of potential outcomes.

Cattle performance outcomes:

1. Does the amount and distribution of bedding provided affect the Feed Conversion Ratio (FCR) of the cattle?
   a. Does the type of bedding provided affect FCR?
   b. Does the amount of bedding provided affect FCR?

c. Does bedding distribution within the pen impact FCR?

Animal health and welfare outcomes.

1. Does the type, amount and distribution of bedding affect the incidence of dags on cattle?
2. Does strategic distribution of bedding eliminate the need to wash cattle prior to slaughter? If not,
    a. Does strategic distribution of bedding reduce the time and volume of fluid required to wash individual cattle?
    b. Does strategic distribution of bedding reduce the number of cattle that need to be washed?
3. Does strategic distribution of bedding reduce the number of "pen pulls" due to sickness? (e.g. lame, leg abrasions, cast, respiratory disease)
    a. Does strategic distribution of bedding reduce the number of oral or needle health treatments to a pen of cattle?

Pre-slaughter and carcase quality outcomes:

1. Do cattle remain clean several days after washing if housed on clean bedding post-washing?
2. If bedding eliminates or reduces the need for cattle washing, does it have positive effect on carcase quality? (comparison of dark cutting on washed and unwashed cattle)

7.2.1 Trial organisation and setup

Train feedlot staff how to complete the trial observations / monitoring records

- Due to the large distances between research sites and the need for frequent observations, research costs can be minimised by engaging feedlot staff to monitor and record the trial observations. A toolkit will be developed to train the staff in observation / monitoring requirements and provide templates for recording these. Feedlot staff will be trained in trial observation / monitoring requirements using the toolkit.

Organise trial cattle, set aside trial pens and a control pen, procure bedding:

In consultation with FSA Consulting, the feedlot manager would:

- Organise cattle for the trial and set aside a sufficient number of readily accessible pens. At least one control pen without bedding will be needed for comparison purposes and it will need to be monitored as per the bedded pens.
- Procure the bedding and collect representative samples of clean bedding for analysis. These will be tested for particle size distribution, bulk density, porosity and moisture content. This data will assist in building an Australian knowledge resource into bedding materials. It is recommended that similar tests be completed on the spent bedding (post removal from the pen and/or treatment). It would also be of interest to determine the buoyancy of clean woodchips, as it may be possible to wash spent woodchip bedding for reuse as bedding material.

Pen preparation

- Clean all trial pens before adding bedding and cattle so that all pens, including the control pen, are in comparable condition.

Amount and distribution of bedding within the pen:

The research outcomes from Anderson et al (2007) and feedback from the surveyed lot feeders (see Section 6.2) suggests that bedding should not cover the entire pen surface because it is not cost effective and restrict pen drainage. It is more effective to place bedding in the middle or top third of the pen (nearest the feed bunk); or in mounds or windrows within the pen.

The recommendations in Section 6.2.1 from the Australian feedlot industry specialists (Dr Doyle and Dr Gaughan) was to provide between 1.5-2.0 m^2 of bedding per head with a bedded depth of 0.3 m. Anderson et al. (2007) trial operated over a four-month period in winter and the average usage of fresh straw bedding was 1.5 kg/head/day. One of the lot feeders surveyed from southern Australia said that he provided 60 kg/head of straw bedding over each bedding period (i.e. 2 kg/head/day over the approximate 60 day winter bedding period). None of those surveyed using woodchip provided an accurate estimate of woodchip usage rate.

For the purpose of this report, the upper range of 2.0 m^2 of bedding per head and a bedded depth of 0.3 m has been chosen. Therefore, a pen of 150 head would require a bedded surface area of at least 300 m^2 or 90 m^3 of bedding.

The key outcome is to ensure that, whichever method of distribution is used (e.g. in the top half of the pen or several strategic mounds around the pen), the minimum bedded area requirement per head is met. The example bedded area calculated above for 150 head could be provided through:

- a single rectangular area of 300 m^2
- two windrows, each covering 150 m^2

The possible distribution methods and shape of the bedded area could include:

- *a rectangular section*: place bedding over the top half or third of the pen. Example dimensions could be 40 m x 7.5 m = 300 m^2 (bedded depth of 0.3 m).
- *windrows*: lay-out bedding in three to four windrows running parallel with the pad slope. Start the windrows approximately 10 m from the bottom of the pen and head towards the feed bunk apron. Leave a 5 m wide gap of exposed pad between the windrows. The windrows should have a slight triangular profile to encourage the cattle to lie with their head facing the apex of the windrow. Providing triangular windrows that shed water, and running the windrows parallel with the pen will promote efficient drainage. Figure 3 shows example dimensions for a 100 m^2 windrow with an average bedded depth of 0.3 m. Hence, three of these windrows would be required to provide a 300 m^2 bedded area for 150 head.

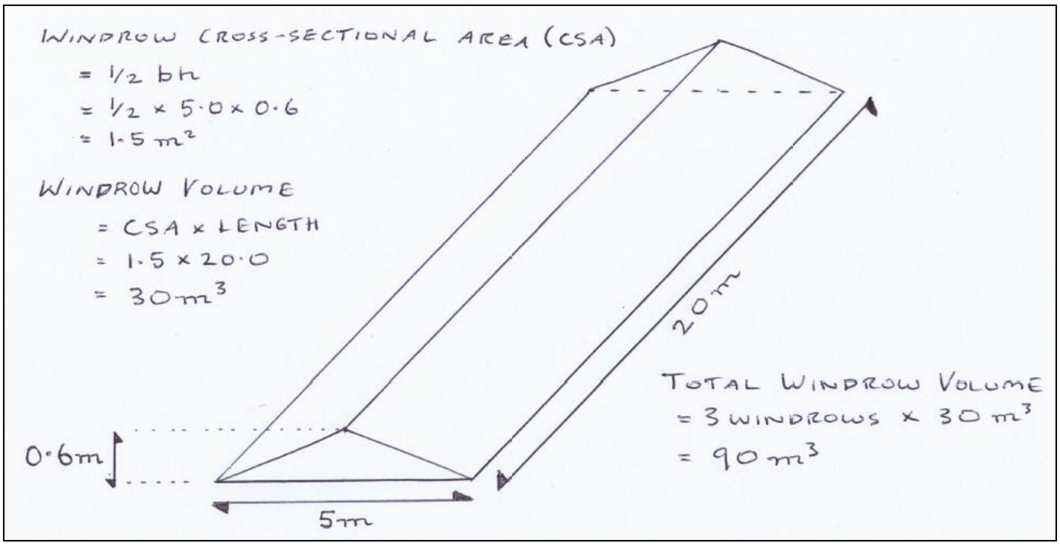


Figure 3 – Example dimensions for a 100 m^2 bedding windrow

- *mounds*: bedding is placed in circular mounds (as per Photograph 14), 6-10 m in diameter in the top half or third of the pen. Example dimensions could be 3 x 11.3 m diameter mounds = 300 m^2 (each mound with a bedded depth of 0.3 m). The design concept for a bedded mound is taken from Australian and American feedlots that create mounds of manure within pens to provide dry standing and lying areas for cattle.

Undertake trial:

- Competent personnel manage and monitor the trial (most likely trained feedlot staff).
- The research team would receive regular trial results (e.g. weekly or fortnightly) to monitor trial progress.

Removal of spent bedding:

- At the end of the trial period, all the research pens will be cleaned and the spent bedding removed to the on-site manure stockpile area. The material will be kept segregated from other manure stockpiles.

7.2.2 Trial monitoring and assessment methods

Qualitative assessment methods:

- Observations made by feedlot staff and nutritionists about the condition of the bedding with respect to manure content, moisture content, pen coverage; impact on pen drainage and build-up in / around fences will be recorded.
- Photographic records of the pens will be used to assess condition of the bedded area, the area and properties of the exposed pen surface, pen drainage, cattle dags (at least weekly, but also during and directly after heavy rainfall). Photo points could be setup (e.g. taking a photo from each corner of the pen facing into the centre, plus from the centre of the pen facing back to the corners)

Quantitative assessment methods

- FCR (data from FY3000)
- Percentage of cattle lying (2-3 times per day)
- Percentage of cattle lying on the bedded area (2-3 times per day)
- Percentage of cattle requiring washing (assuming they leave the feedlot at the end of the trial period)
- Time and volume of water needed to wash cattle
- Number of pen pulls and/or animal health treatments (data from FY3000)
- Feedback on standard of cattle presentation on arrival at the abattoirs, and incidence / impact of dark cutting
- Dag assessment: Two methods are suggested to determine the amount of mud and manure attached to the hide of cattle. The first is to measure the weight or volume of material removed during cleaning. The other is to visually assess the material on the hide using a mud and manure scoring system. Weighing or determining volume of scraped-off material may not be feasible as it would require capital investment, probably slow down throughput of cattle in the wash station and create a potentially time-consuming task for the feedlot. Hence, mud and manure scoring is preferred.
- Pen mud score: assessment of pen condition and percentage of the pen covered in more than 12 cm of mud / manure.
- Measurement of the quantity of spent bedding removed during the full pen clean-out at the end of the trial.
- Analysis of a representative sample of freshly-removed spent bedding for particle size distribution, bulk density (wet and dry), porosity, moisture content, and standard nutrient and salt parameters.

7.2.3 Trial budget

The trial budget provides a preliminary estimate of the costs for developing and undertaking the bedding trials. Data is presented as:

1. Costs directly related to an individual pen treatment using either woodchip or straw bedding – including bedding procurement, distribution and removal at the conclusion of the trial period.
2. Total trial costs:
    - the cost to develop the ‘bedding trial monitoring and assessment toolkit’ that feedlot staff will use to record the trial observations.
    - for six collaborating feedlots including time to train a feedlot team member in the bedding trial monitoring and assessment toolkit and the time for that feedlot team member to complete the daily trial monitoring and recording of observations.
    - for a project initiation site meeting and project management of the bedding trials at the six collaborating feedlots including two site visits to each site (first visit before trials commence; second visit two to three weeks into the trial).
    - laboratory analysis of samples.

7.2.3.1 Budget assumptions

Several assumptions were made so the budget scope could be clearly defined. These are:

- 150 head of cattle in pen; stocking density of 15 m^2/SCU
- 2 m^2 of bedding provided per head; uncompacted bedding depth of 0.3 m
- average bulk density of bedding materials:
    - straw bale: 140 kg/m^3 (typical range ≈100-180 kg/m^3)
    - woodchip: 425 kg/m3 (typical range ≈ 350-500 kg/ m^3)
- bedding material is available within 150 km radius of feedlot (freight estimate included in the costs shown in Table 8).

Table 4 shows a list of typical equipment used in Australian feedlots and commercial hourly rates for their use that were used in the budget. These rates were provided by a commercial feedlot located in southern Australia (11 March 2013).

Table 4 – Typical feedlot equipment costs

Equipment	Rate ($)	Unit (hrs or t)
Ski-steer loader	$ 80.00	per hr
Excavator	$ 110.00	per hr
Articulated loader	$ 110.00	per hr
Telehandler	$ 110.00	per hr
PTO composter	$ 100.00	per hr
HR tip-truck	$ 100.00	per hr
*Screen	$ 4.00	per t

Notes: all equipment rates include a feedlot operator rate of $35/hr.
* The heavy rigid (HR) truck can carry 12 t or 22 m^3.
**The screening rate includes one operator for both the screen and articulated loader.

7.2.3.2 Budget for an individual pen

Table 5 shows the estimated cost to clean a typical feedlot pen that has been used by 150 head for ten weeks. The cost to clean the pen and cart the manure to the stockpile area is $630 including labour and equipment costs.

Table 5 – Pen cleaning cost (manure only, 150 head, stocked for 10 weeks)

Task	Equipment	Time (hrs)	Rate ($/hr)	Cost
Push up and scrape pen	Articulated loader	1.5	$ 110.00	$165.00
Load into trucks	Articulated loader	1.5	$ 110.00	$165.00
4 loads carted to stockpile	2 x HR tip-truck	3	$ 100.00	$300.00
			Cost per pen	**$630.00**

Table 6 and Table 7 shows the labour and equipment costs to load bedding (from an on-site stockpile near the pens), transfer into a pen and distribute the bedding in a defined pattern. The calculations estimated a cost of $3.70/t for woodchips and $34/t for straw. This assumed woodchip was transferred in heavy rigid truck loads with each load carrying 22 m^3 or 8 t, and large rectangular straw bales being delivered using an articulated loader or telehandler (2-3 bales per load, 400 kg bale weight).

The data from Table 6 and Table 7 show that distributing straw in a pen costs $30/t more than woodchip. Mostly this is because straw is delivered into the pens as bales (not a bulk quantity like woodchip) and more time and effort is required to remove bale strings, breakup the bale and then spread it. Bedding distribution is only part of the overall cost of managing bedding in feedlot pens and the full cost is estimated in Table 8.

Table 6 – Woodchip bedding distribution cost for a single pen

Task	Equipment	Time (hrs)	Rate ($/hr)	Cost
Load truck	Articulated loader	0.086	$ 110.00	$ 9.46
Tranfer to pen	2 x HR tip-truck	0.166	$ 100.00	$ 16.60
Distribute in pen	Articulated loader	0.166	$ 110.00	$ 18.26
			Cost per pen	**$ 44.32**
			Cost per t	**$ 3.69**

Table 7 – Straw bedding distribution cost for a single pen

Task	Equipment	Time (hrs)	Rate ($/hr)	Cost
Deliver straw into pen	Articulated loader	1	$110.00	$110.00
Removing strings	Staff member	1	$35.00	$35.00
Spread straw in pen	Articulated loader	1	$110.00	$110.00
			Cost per pen	**$255.00**
			Cost per t	**$34.00**

Table 8 includes cost estimates for bedding procurement and freight, bedding distribution within the pen, and spent bedding removal from the pen to the on-site manure stockpile. Three bedding scenarios were considered and the results are summarised below:

Scenario 1 – Woodchip

- estimated useful (serviceable) life of the bedding 6-12 weeks
- provision of 2 m^2 of woodchip bedding per head with a bedded depth of 0.3 m
- ≈38 t of woodchip required; equivalent to ≈255 kg or 0.6 m^3 per head
- ≈$2710 to procure and place bedding, and remove spent bedding from a pen; or ≈$18 per head

Scenario 2 – Straw

- estimated useful (serviceable) life of the bedding 3-4 weeks
- provision of 2 m^2 of straw bedding per head with a bedded depth of 0.3 m
- ≈13 t of straw required; equivalent to ≈84 kg per head
- ≈$2750 to procure and place bedding, and remove spent bedding from a pen; or ≈$18 per head

Scenario 3 – Straw ***(pen bedded twice over 6-8 week winter period)***

- estimated useful (serviceable) life of the bedding 3-4 weeks, pen bedded and cleaned twice
- provision of 2 m^2 of straw bedding per head with a bedded depth of 0.3 m
- ≈25 t of straw required; equivalent to ≈168 kg per head

- ≈$6350 to procure and place bedding, and remove spent bedding from a pen; or ≈$42 per head

Table 8 – Total bedding cost estimate for a 150 head pen

Bedding material	Estimate of bedding's useful life (weeks)	Bedded area within the pen (m^2)	Volume of bedding required (m^3)	Mass of bedding required (t)	Mass of bedding per head (kg)	Bedding purchase & freight	Bedding placement cost	***Spent bedding removal cost	Total cost pen pen	Cost per head
Woodchip	**6-12	300	90	38	255	$ 1,800.00	$ 141.27	$ 771.27	$ 2,712.54	$ 18.08
Straw	**3-4	300	90	13	84	$ 1,260.00	$ 428.40	$ 1,058.40	$ 2,746.80	$ 18.31
***Straw**	**6-8	300	180	25	168	$ 2,520.00	$ 856.80	$ 2,973.60	$ 6,350.40	$ 42.34

Notes:
* This scenario requires the pen to be bedded twice i.e. spent bedding removed after 3-4 weeks, then fresh straw bedding added and removed after another 3-4 weeks. On both occasions the bedded depth would be 0.3 m.
** The estimate of the bedding's useful life before requiring removal due fouling with manure and compromising cattle comfort is based on feedback from the lot feeder survey conducted as part of this scoping report, and to a lesser extent the research outcomes from North American feedlot bedding trials.
*** The cost to remove spent bedding was determined by adding the 'manure only pen cleaning cost" shown in Table 5 and the relevant 'bedding material distribution cost' per tonne. For example for woodchip: [($650) + (38 t x $3.7) = $771]

7.2.3.3 Total trial budget

Table 9 shows the itemised project budget for conducting bedding trials at six feedlots assuming each feedlot provides four bedded trial pens and one control pen. The project cost estimate of $227,000 (excl. GST) includes the time, equipment and materials:

- to develop the 'bedding trial monitoring and assessment toolkit'
- for one staff member at six collaborating feedlots to be trained in the use of the bedding trial monitoring and assessment toolkit and to undertake the daily trial monitoring and recording of observations
- to undertake laboratory analysis of samples
- for a project initiation site meeting and project management of the bedding trials at each of the six collaborating feedlots including two site visits to each site (first visit before trials commence; second visit 2-3 weeks into the trial)
- for analysis, interpretation and reporting of results

Table 9 – Total bedding trial costs (6 feedlots; 5 trial pens per site)

Task	Person responsible / Item	Days	Cost	Cost for 6 feedlots
General project costs (6 feedlots conducting trials)				
Develop bedding trial monitoring and assessment toolkit	Consultant	4	$ 7,000	
Project initiation - 2 site visits to collaborating feedlots (incl. site visit time)	Consultant	18	$ 31,680	
Travel expenses	Mileage		$ 5,400	
Project management of the trials	Consultant	9	$ 15,840	
Analysis, interpretation and reporting of results	Consultant	7	$ 12,320	
				$ 72,240
Staff and laboratory analysis costs for a feedlot				
Feedlot staff familiarise themselves with bedding self-learning toolkit	**1 feedlot staff member	1.5	$ 420	
Laboratory analysis of clean and spent bedding	***4 samples		$ 1,000	
Collation of all observations at the end of the trial (4 bedded pens; 1 control pen)	1 feedlot staff member	2	$ 560	
Monitoring trial pens and recording observations for 60 days (≈0.5 hr/pen/day)	1 feedlot staff member	20	$ 5,600	
				$ 45,480
Bedding procurement, placement and removal costs for a feedlot (150 head, 2m^2/head, bedded depth 0.3 m)				
2 pens bedded with woodchip	refer to Table 6		$ 5,425	
2 pens bedded with straw (pens bedded twice)	refer to Table 6		$ 12,701	**$ 108,755.28**
			Total	**$ 226,475**

Notes:
* Assumes feedlots are located within 300 km radius of Toowoomba, Horsham and Wangaratta. Flights and accommodation would be charged at cost.
** Feedlot team member rate of $35/hr
*** Analysis cost: $250/sample including freight

7.2.4 Risks associated with Trial

- Earlier than anticipated break in the season (delayed or unable to undertake the trials).
- Bedding temporarily unavailable.
- Minimal rainfall during the trial period.
- Feedlot staff not undertaking or correctly recording the daily pen monitoring.

7.2.5 Issues to be addressed at the MLA workshop

- Determine the scope boundary: What is the available budget and what can be achieved with it and/or in-kind contribution from the collaborating feedlots given the short timeframe before winter starts?
- Open discussion to determine the most effective bedding trial configurations including:
  - the number of feedlots to be used
  - the number of pen trials to conduct at each feedlot
  - the area and depth of bedding to provide each animal (mass or volume per head)
  - the bedding distribution method within the pen
  - whether or not bedding should be removed and fresh bedding added. Australian lot feeder experience using straw shows it typically last 3-4 weeks before completely fouling with wet manure and then compromising cattle comfort.

7.3 Potential optional components to observational trials

Two additional components could potentially be included in the research:

- how spent woodchip could be treated / managed to separate the woodchip and manure to allow for reuse of the bedding; and
- observations of the impact of bedding on the pad and consequently on the safety of staff working in bedded pens.

This section of the report provides an overview of these optional components. MLA can use this information to determine whether to incorporate these into the research.

7.3.1 Effect bedding has on treatment / reuse options

The properties of spent bedding are different from those of harvested manure. This may have implications for management and reuse, including reuse as bedding.

Most surveyed lot feeders were interested in the potential of recycling woodchip bedding for a second or third use (see Section 6.2). Only one feedlot reported they had successfully done this by screening spent woodchip bedding through a shaker-bed mechanical screen that allowed them to recover a large percentage of woodchip. The factors that result in the successful separation of woodchip and manure from spent bedding are discussed further in this section.

Aim: To observe the impact of bedding on conventional manure management practices within the pen and afterwards when the bedding is stockpiled, composted and/or screened; and to evaluate the potential for treating bedding to allow for its reuse within the pens.

Potential trial outcomes: the following questions provide the MLA workshop attendees with the scope of potential outcomes.

In-pen outcomes:

1. How long does it take to distribute and remove bedding from a pen? (compare against the estimates discussed in Section 7.2.3)
2. Does removal of bedding from the pens present any new problems?
3. Is conventional feedlot equipment effective in placing and removing bedding? (e.g. articulated loader, excavator)
4. Does bedding provide a fly breeding habitat?

Post-pen outcomes:

1. Can bedding and manure be effectively separated?
2. Can bedding be recycled and reused back in the pens?
3. Does spent bedding need to be managed differently from manure? Why?
4. What does the finished product (aged / composted bedding) look like?
5. Is a greater storage or drying area needed if bedding is used (at the manure handling area)?
6. How does the inclusion of spent bedding in manure (either stockpiled or composted) affect the potential end-uses of manure? (e.g. broadacre spreading, landscaping)

7.3.1.1 Factors that influence the effectiveness of separating manure and woodchip using mechanical screens

FSA Consulting has listed the following factors that that influence the efficiency of separating woodchip and manure using typical shaker-table screens that are used by several of the surveyed lot feeders (see Section 6.2). These factors are also applicable to the use and effectiveness of rotating cylindrical (trommel) screens that are used to remove rocks, wood, rubbish etc. from manure, compost and top soil.

- *Uniformity of woodchip particles:* larger, evenly-sized woodchips are more easily screened from spent bedding than small elongated woodchips. Screened batches of new woodchip are likely to contain a lesser percentage of fine wood residues. Fines may reduce the porosity within the bedded pack or mound.
    - Post peelings typically consist of long, fibrous particles that tend to form a strong bond with manure (stronger than the bond between manure and a large, smooth surfaced pieces of woodchip).
    - Pieces of post peeling are typically smaller than woodchip and they tend to start decomposing in the pen. Hence, they are very hard to screen after removal from the pen.
- *Moisture content:* the lot feeder who has successfully screened larger woodchip from old stockpiles of spent woodchip bedding said it was only possible with a relatively dry material, preferably <30% moisture. The feedlot uses a conventional shaker-table screen that was manufactured by Precision Screens Australia (see Photograph 22). The stockpiled spent bedding was firstly broken up using an articulated loader bucket, then screened.
- *Spent bedding storage methods:* storage methods that accelerate drying may be beneficial. Moisture loss will be optimised by spreading spent bedding out over a large surface area (rather than creating tall, dense stockpiles); or by reducing the cross-sectional area if storing spent bedding in windrows (increasing the surface area of bedding exposed to solar radiation will enhance moisture loss).
- *Extent of handling of spent bedding:* increased handling may help in separating manure from woodchips. For instance, the beaters on the horizontal augur shaft of a compost turner would smash against the woodchip and may assist in breaking the sticky bond between the woodchip and manure. Beaters can also be fitted to the shaker-bed screen in Photograph 22. They can be fitted at the top conveyor (just prior to material falling onto the shaker-bed) to provide further separation of woodchip and manure before screening.

Photograph 22 – 'Contractor 604' shaker-table screen

7.3.1.2 Separating manure and woodchip using water

Spent woodchip bedding could be washed to remove manure, but it is likely the material would need to be soaked first. The process of cattle washing at feedlots uses the same principle for removing dags by firstly hosing cattle to wet (and soak) their coats and the dags. Cattle are then kept in the washing area for a period of time to allow the dags to absorb the moisture, then washed a second time to remove the softened dags. It may be possible to apply a similar technique to woodchip bedding.

To successfully separate spent woodchip bedding via washing it would be important to firstly understand:

- If clean woodchip was placed in a vessel with water would they float on the surface after a period of time, or would they become saturated and sink?
- If heavily manured / soiled particles of woodchip could be cleaned via soaking only? (or would mechanical agitation be required to mix and macerate the spent bedding and soaking fluid)
- If heavy, saturated spent woodchip could be re-floated after heavy manure and soil is removed from the woodchip?

Floating woodchip would be easier to remove from the surface of the vessel, than if they sank to the bottom and re-mixed or settled on the slurry of manure and soil.

Spent woodchips could be washed in-vessel using a paddle mixer, mounted from either the top or base of the vessel and oscillated like the paddle shaft in a top-loading washing machine. The oscillating motion would create turbulent conditions to assist in separating manure / soil from the woodchip.

It would be important to measure the time and costs needed to clean the woodchips to determine if this is cost-effective.

7.3.2 Effect on pen floors and safety of staff

Aim: To observe if there are any workplace health and safety consideration regarding the use of bedding in feedlot pens.

Potential trial outcomes: the following questions provide the MLA workshop attendees with the scope of potential outcomes.

Pen floor outcomes:

1. Does bedding destroy the interface layer or integrity of the pen surface?
2. Does the depth of bedding influence the effectiveness of drainage through the bedding profile?
3. Does bedding impede pen drainage?
4. Does bedding reduce pen maintenance costs during and after use?

Staff safety outcomes:

1. Does bedding alter the stability for pen riders / pen walkers?
2. Does bedding reduce "near misses"? (e.g. horse or staff losing their footing when riding / walking through pens)

Example qualitative assessment methods:

- Record observations (written and photographic) on the condition of the exposed and bedded pen surface (after spent bedding is removed), compare the number of pot-holes that require maintenance between the bedded and control pens.
- Seek feedback from pen riders / pen walkers as to the stability of the bedded areas compared to bare pen surfaces, number of near misses / slips / trips / serious accidents relating to slippery surfaces.
- Photo records of the pens to assess condition of the bedded area, pen surface after spent bedding is removed, cross-sections showing the bedded profile in the middle of the bedded area (when the loaders are removing spent bedding).
- By involving the designated workplace health and safety officer at the feedlot, undertake a risk assessment of the use of bedding in pens.

7.4 Proposed Project on Pen Surface Stabilisation

This review has indicated that there are several methods of pen surface stabilisation of which fly ash is but one. The experiences from the US generally demonstrate improved animal welfare, health and performance when pen surface stabilisation is used in appropriate circumstances. Feedlot runoff is generally increase and harvested manure quality is improved. However, as far as is known, pen surface stabilisation has not been used in any feedlot in Australia.

It is proposed that a small research and extension project be undertaken that:

1. Documents the various options available for pen surface stabilisation.
2. Documents the chemical characteristics of any materials used and their implications for animal performance or meat quality.
3. Proposes a generic design and specification for each option to provide guidance for their use in existing feedlots.
4. Undertake an economic analysis of the cost of each option.
5. Develop appropriate extension material for dissemination to lot feeders.
6. Possibly include the design and specification material in the upcoming Feedlot Design Manual.

8 Conclusions

8.1 Key findings

Exposure to a layer of wet manure and mud, or a dry, hard and hot pen surface, can compromise the comfort of lot fed cattle and safety of staff working within feedlot pens. This project has identified the following problems that affect 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’).
- *Cold stress:* reduced body temperature as a result of being covered in moist dags 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 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, especially in conjunction with a pen surface. It can also lead to animals and staff slipping, resulting in injury.

This review has considered research outcomes from overseas animal production systems that use bedding materials and soil stabilisers. More specifically, it provides details of:

- The effect of stocking density on moisture content of the feedlot pad
- Pen surface stabilisation
- Pen surface covering with bedding
- Examples of the use of pen surface amendments for cattle
- Outcomes following the use of pen surface amendments.

Pen surface stabilisation aims to create a low-permeability, hard pen surface that optimises pen drainage and minimises the mixing of manure with pen foundations. Pen surface stabilisation has been achieved using fly ash, pond ash, cement-stabilised clay and chemical additions to the soil surface.

Pen surface covering, or bedding, is widely 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. The types of bedding used in various aspects of cattle production include:

- Woodchips
- Sawdust
- Straw
- Rice and almond hulls
- Composted manure
- Sand
- Recycled rubber chips

In general, American research indicates that the use of PSA improves animal welfare, health and performance to varying degrees. However, the effect on environmental issues such as odour generation and runoff quantity and quality is poorly understood. PSA alters the characteristics of the manure harvested from feedlot pens, again to varying degrees depending on the type of PSA used.

Observations on bedding use in Australian feedlots was obtained. Eighteen Australian feedlots that have previously used bedding materials in either their production or sick pens were contacted or visited to obtain data on their experiences with pen surface covering. No feedlots were found that have trialled pen surface stabilisation in Australia. The responses from all eighteen feedlots is summarised. All of these responses are anecdotal and none of those surveyed using woodchip provided an accurate estimate of woodchip usage rate or changes in animal performance. As far as can be determined, there have been no systematic trials undertaken to quantify any of the responses. In general, the use of bedding was regarded favourably but there remain uncertainties that prevent widespread adoption of the practice.

A series of initial observation trials are proposed to gain a systematic understanding of the use of bedding in Australian feedlots. These trials could be conducted in the winter of 2013 to provide baseline data for more rigorous technical trials in the following winter. These proposed trials are to be discussed at a workshop of feedlot managers, nutritionists and veterinarians.

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10 Appendix 1 – Feedlot Bedding Survey Responses

Site: Feedlot A
Date: 22 Jan 2013

1.	Why did they use it? (Discussion based on welfare, performance, dags, odour, dust or reduce pen maintenance)	• Comfort for heavy cattle and reduces impact on surface from heavy cattle
2.	Who recommended the use of bedding? (Personal interest, vet advised, read it in literature)	• Necessary for heavier cattle
3.	What type did they use? (Material type, size, shape, uniformity)	• Woodchip (pine) – good uniformity • Some pieces 3-6 cm long
4.	How was the bedding applied and managed in the pens? (pen coverage, depth, treatment during use, was maintenance bedding added, length between cleanout and/or maintenance)	• 300mm deep over the entire pen • Front end loader • Some indoor pens are bedded for certain animals • Typically cattle placed in bedded pens 30 days prior to processing
5.	What happened to the bedding after removal from the pens? (stockpiled and spread, long term stockpile due to chip contamination, recycled and used back in pens, sold off-site)	• Problems with recycling as it is difficult to separate manure from woodchip. A washing facility was discussed with FSA Consulting re: a small scale trial.
6.	Bedding source, contact details, cost (preferably cost ex depot – separate out freight), availability (seasonal, year round)	• Woodchips are supplied from a local prison farm in a cash + manure deal. Some chips have been brought in from as far as Tamworth (250km). • Costs the feedlot about $7000 a year in materials alone.
7.	What were the outcomes of using the bedding? (Pros and Cons)	• Less grazing of elbows, in-turn less illness and infection • Animals get up easier • Animals heal quicker on bedding • Halved the washing time to remove dags, in comparison to cattle from unbedded pens • Better pen rider safety • Less potholes • The sharp pine chips assist in removing/wearing down the dags
8.	Would they be interested in co-operating in any research projects that may commence in the winter of 2013?	• Yes – need to approach them again with details • Very interested in anything that helps them recycle bedding.
9.	Do they operate FY3000?	• Yes

Site: Feedlot B
Date: 10 Jan 2013

1. Why did they use it? (Discussion based on welfare, performance, dags, environmental issues)	• To protect newly commissioned pen surfaces and allow the gravel/clay surface to harden / bond together • To reduce dags • To reduce heat load on cattle, they believe that bedding absorbs heat and reduce the pen surface temperature • To reduce odour profile from the feedlot • To reduce pen cleaning frequency, especially during the wetter months of the year • To reduce "slipperiness" experienced by pen riders
2. Who recommended the use of bedding? (Personal interest, vet advised, read it in literature)	• Personal interest, also advised by vet and nutritionist
3. What type did they use? (Material type, size, shape, uniformity)	• Pine woodchip – preference for large chips, avoided product with high percentage of fine chips, typically 5 cm^2
4. How was the bedding applied to the pens? (pen coverage, depth, treatment during use, was maintenance bedding added, length between cleanout)	• 20 cm thick over the entire pen, used a rotary hoe after six months to aerate the surface, product lasted 10-12 months dependant on stocking density (usually 10-12m^2/SCU). Bedding quality good up to 6 months, then bedding deteriorates after this. • Preferred to cover whole pen otherwise cattle dragged mud and manure onto bedding from exposed pen surfaces
5. What happened to the bedding after removal from the pens? (Issues with spreading, still stockpiled)	• Remains in the stockpile
6. Bedding source, contact details, cost (preferably cost ex depot – separate out freight), availability (seasonal, year round)	• Cheapest option for us was from Roma around $20/$m^3$ delivered • Available at request
7. What were the outcomes of using the bedding? (Pros and Cons)	Pros • Protected pen base • Lame cattle were moved to these pens and large % recovered without any medical treatment. • Pine chips release a pleasant odour around for up to 4 weeks. • No dust from the pens during dry conditions. • Safe surface for pen riders no matter how wet or dry. • Cattle become more stimulated when they enter woodchip pens. • No regular pen cleaning required. Cons • Buildup of manure/woodchip at bottom of pens requires regular to maintain effective pen drainage.
8. Would they be interested in co-operating in any research projects that may commence in the winter of 2013?	• Yes
9. Do they operate FY3000?	• Yes

Site: Feedlot C
Date: Jan 2013

1.	Why did they use it? (Discussion based on welfare, performance, dags, odour, dust or reduce pen maintenance)	• Pen to pen drainage issue
2.	Who recommended the use of bedding? (Personal interest, vet advised, read it in literature)	• Matt George
3.	What type did they use? (Material type, size, shape, uniformity)	• Pine woodchip – variable in uniformity • Some pieces 5-30 cm long
4.	How was the bedding applied and managed in the pens? (pen coverage, depth, treatment during use, was maintenance bedding added, length between cleanout and/or maintenance)	• About 100 mm deep • Front end loader • Bogged sometimes but helps to keep the pens dry • Hospital pens and long fed cattle in winter
5.	What happened to the bedding after removal from the pens? (stockpiled and spread, long term stockpile due to chip contamination, recycled and used back in pens, sold off-site)	• Composted and screened as normal.
6.	Bedding source, contact details, cost (preferably cost ex depot – separate out freight), availability (seasonal, year round)	• No cost, swaps manure for pine bark
7.	What were the outcomes of using the bedding? (Pros and Cons)	• Effective. 300 day cattle washed a week before processing and placed in pen with clean bedding, this helps keep dags from reforming. • Bedding bogged into the pen surface towards the end of the trials. • Most cattle now on 100 day feeding, dags formation less and easier to manage.
8.	Would they be interested in co-operating in any research projects that may commence in the winter of 2013?	• Potentially – depends on the level of commitment and capital cost required.
9.	Do they operate FY3000?	• Yes
10.	Are they aware of any other feedlots that are using bedding that could be contacted as part of this project?	• Charlton hospital pens

Site: Feedlot D
Date: Jan 2013

1. Why did they use it? (Discussion based on welfare, performance, dags, odour, dust or reduce pen maintenance)	• Used in the sick pens mainly to recover from foot soreness / lameness • Welfare • Wanted cattle to leave feedlot clean for processing
2. Who recommended the use of bedding? (Personal interest, vet advised, read it in literature)	• Kev Sullivan, lots of discussion among lot feeders
3. What type did they use? (Material type, size, shape, uniformity)	• Pine bark, 5-8 cm long, uniform
4. How was the bedding applied and managed in the pens? (pen coverage, depth, treatment during use, was maintenance bedding added, length between cleanout and/or maintenance)	• 50 mm over whole pen using a front end loader and box scraper. • Packed down too quickly and too light, so another 50 mm was added after 1 month. • Some clean chip still existed after a month, realistically would need to add fresh chip every month
5. What happened to the bedding after removal from the pens? (stockpiled and spread, long term stockpile due to chip contamination, recycled and used back in pens, sold off-site)	• Composted as normal.
6. Bedding source, contact details, cost (preferably cost ex depot – separate out freight), availability (seasonal, year round)	• Nursery (Pike). $3000 per semi trailer load (freight incl.) • Brought in from the coast. • Available year round.
7. What were the outcomes of using the bedding? (Pros and Cons)	• Too light and expensive • Effective in keeping cattle drier • Cattle dispersed the woodchips over the entire pen quickly • Cattle can get up more easily • Lowered odour intensity, different character compared to rest of the feedlot
8. Would they be interested in co-operating in any research projects that may commence in the winter of 2013?	• Yes
9. Do they operate FY3000?	• Yes

Site: Feedlot E
Date: 11 Jan 2013

1. Why did they use it? (Discussion based on welfare, performance, dags, odour, dust or reduce pen maintenance)	• Performance and dags formed the basis for trialling bedding. • Initially finisher cattle were washed a week before processing, so after washing they were housed in pens with bedding to keep them clean. Cattle washing was extremely laborious and it is longer practiced – cattle are now only soaked prior to loadout. The cattle rub on each other during the 4 hr trip to the processing facility which softens the dags, then washed at facility. • Washing at the feedlot stopped because there was no monetary incentive from the processor. Cattle soaking shows the processor the feedlot is being proactive, without wasting $$ on full washing prior to transport.
2. Who recommended the use of bedding? (Personal interest, vet advised, read it in literature)	• Property also operates dairy with a feedpad, so dairy experience/ industry knowledge of using bedding to reduce mastitis and improve cow comfort.
3. What type did they use? (Material type, size, shape, uniformity)	• Wood chips are used in the cattle handling yards. • Rice hulls have been trialled mainly in the finisher pens but now some use in the production pens (since the switch to cattle soaking). • Almond hulls have been trialled on the loafing area of the dairy feedpad • All materials have a uniform shape, but the rice hulls are very light and tend to blow around the site.
4. How was the bedding applied and managed in the pens? (pen coverage, depth, treatment during use, was maintenance bedding added, length between cleanout and/or maintenance)	• Rice hulls – 2 trucks per pen (140 m^3) spread approximately 100 mm deep over pen floor, 200 mm near and on the feedbunk apron. Removed after 4 weeks and new bedding added, typically pens bedded for 2 months over the winter period of June and July. • No maintenance during the cleanouts.
5. What happened to the bedding after removal from the pens? (stockpiled and spread, long term stockpile due to chip contamination, recycled and used back in pens, sold off-site)	• Spent bedding treated same as clean manure – placed in windrow and composted using PTO turner. • No water added, wet manure blended to add moisture. Last five years all composted manure sold off-site to viticultural and horticulture industries. • No screening prior to sale.
6. Bedding source, contact details, cost (preferably cost ex depot – separate out freight), availability (seasonal, year round)	• Rice hulls: $6-8/m^3 • Almond hulls: $80/t
7. What were the outcomes of using the bedding? (Pros and Cons)	• Rice hulls great for bedding because of the their large surface area and make great compost. Fresh rice hulls are very light (act like polystyrene beans), thus in windy conditions they blow everywhere. They are also very hard to load, which creates difficulty if they cannot be added directly into the pens. Pen access for the 2nd batch is difficult due to the slippery and wet pen surface. • Almond hulls. No comment in relation to their effectiveness for feedlot cattle. They are also a great ingredient in the compost due to their high carbohydrate content.
8. Would they be interested in co-operating in any research projects that may commence in the winter of 2013?	• Yes – commented that other feedlots are often unwilling to participate and projects like this and the industry loses momentum. • Currently involved in the BRD project with Des R
9. Do they operate FY3000?	Yes

Site: Feedlot F
Date: 16 Jan 2013

1. Why did they use it? (Discussion based on welfare, performance, dags, odour, dust or reduce pen maintenance)	• Improve cattle welfare, unique covered feedlot with concrete floors. There is a need to provide bedding for long-feed cattle housed undercover, as the concrete is hard on their hooves and joints. The roof prevents solar radiation from drying the manure in the pens, so bedding is required to absorb moisture. • To reduce dags in high stocking rate system approx.4.5m^2/hd.
2. Who recommended the use of bedding? (Personal interest, vet advised, read it in literature)	• Industry experience
3. What type did they use? (Material type, size, shape, uniformity)	• Sawdust • Woodchip • Recycled dried manure • Straw • Zeolite
4. How was the bedding applied and managed in the pens? (pen coverage, depth, treatment during use, was maintenance bedding added, length between cleanout and/or maintenance)	• 50-100 mm over the entire pen floor using a front end loader. • No turning/aeration between cleanouts • Replace every 1- 3 months, more frequently in winter due low moisture loss from the pen floors • 10 m x 20 m pens, 6 buckets @ 3m^3 = 18m^3 added per pen.
5. What happened to the bedding after removal from the pens? (stockpiled and spread, long term stockpile due to chip contamination, recycled and used back in pens, sold off-site)	• Composted on-site, then sold to several commercial buyers (mainly landscaping companies and broadacre farms)
6. Bedding source, contact details, cost (preferably cost ex depot – separate out freight), availability (seasonal, year round)	• 'Tumut paper mill located 170km from the feedlot, now paying \$20/m^3 landed at the feedlot, originally paid \$10/m^3. The presence VISY paper manufacturing at Albury and Tumut has increased demand for woodchip, VISY sourcing majority available within 300 km radius.
7. What were the outcomes of using the bedding? (Pros and Cons)	• Sawdust and recycled dried manure – turns to paste too quickly • Woodchip – currently used and most practical and cost effective • Straw – poor absorptive properties • Zeolite – too expensive
8. Would they be interested in co-operating in any research projects that may commence in the winter of 2013?	• Yes, but unsure if a covered feedlot with concrete floors would provide beneficial outcomes for the wider industry.
9. Do they operate FY3000?	• Unknown

Site: Feedlot G
Date: 1 November 2012

1. Why did they use it? (Discussion based on welfare, performance, dags, odour, dust or reduce pen maintenance)	• Improve cattle welfare and performance during wet and cold winters – typically experienced in June, July and August. Winter dominant rainfall – annual avg. 800 mm. • Reduce dags, as they were getting feedback from abattoirs about dirty cattle on arrival.
2. Who recommended the use of bedding? (Personal interest, vet advised, read it in literature)	• Internal decision to trial, had also seen literature on bedding use. • Bedding used in winter 2011 and 2012.
3. What type did they use? (Material type, size, shape, uniformity)	• Trialled wood chips, post peelings and straw. • Prefer to use post peelings, as they are uniform size and they compliment the composting operation, and also softer (more cushioning) than large woodchip. They are elongated shred of pine – waste product from creating fencing posts.
4. How was the bedding applied and managed in the pens? (pen coverage, depth, treatment during use, was maintenance bedding added, length between cleanout and/or maintenance)	• Initial trials covered the entire pen floor with straw and/or wood chip. However, this impeded drainage during/after rainfall events (pens have minimal slope from top to bottom). • Preferred method is to distribute bedding in windrows, start 10 m from base of pen and bed up to self-feeders. Each windrow ≈5 m wide and 0.3 m high (cambered sides) with a 1-2 m spacing between windrows. • The windrows are parallel to the pen floor slope. The exposed pen floor and assist with pen drainage and the windrow footprint encourages cattle to lie on the windrows. • Entire feedlot clean prior to winter, then bedding added to pens. In previous years there has been no treatment during winter. In 2013 the aim is to partially re-bed in mid-winter (depending on access), remove top layer leaving residual contaminated bedding on the pen surface, then add new layer of bedding to reform the windrow. Pens will be bedded in mid-late May till Sept (or when its dry enough for machinery to access pens for cleanout)
5. What happened to the bedding after removal from the pens? (stockpiled and spread, long term stockpile due to chip contamination, recycled and used back in pens, sold off-site)	• Pens cleaned at the end of winter (approx. 10-12 weeks on bedding). Manure and bedding then processed through the on-site composting operation, which in addition adds fresh straw, lime, and clean water to meet AS 4454. • They have successfully screened larger woodchip from old (18-24 months) stockpiles of spent bedding. It is possible using their 'Precision Screen', but it requires a relatively dry product, preferably <30% moisture. Not effective for screening post peelings, as the breakdown during their use in the pens and manure has a tendency to form a stronger bond to the peeling (possibly because they have a fibrous skin, compared to woodchips that have a relatively smooth surface).

6.	Bedding source, contact details, cost (preferably cost ex depot – separate out freight), availability (seasonal, year round)	• Straw (wheat or barley) – available all year round, back loaded within 200 km of the feedlot. \$90/t for current season, \$60/t for old season. Previous years straw use calculated to be 3-5 m^3/head for winter period, equivalent cost of \$30/hd (incl. purchase and distribution within the pens). • Pine post peelings – high available all year round, \$14/m^3 within 50 km radius of the feedlot. • Blue gum plantation waste (trees chipped, remnant branches and stumps on the ground post-harvest) – \$1.50/m^3 within 50 km radius of the feedlot. This material needs to be ground down to produce a chipped product. They plan to tub-grind at the feedlot (\$700/hr) to produce a blue gum chips "finger size" and smaller.
7.	What were the outcomes of using the bedding? (Pros and Cons)	Pros • Improved winter feed intake, new cattle settled quicker within the pens and were willing to sit down on the bedding (compared to no bedding when they would stand for extended periods after rainfall) • Quantified through improved winter weight gain of 0.1-0.2 kg/day. The initial trials indicate that use of bedding was cost neutral, but now combined with the composting operation it produces a small positive margin. The composting operation was using fresh post peelings as a substrate, so in effect the volume of post peelings purchased has been reduced and replaced with the manure/peeling mix from the pens. Cons • Straw was hard to remove from the pens, as it formed large clumps and its high absorbency meant that it fouled up and became a sticky mess relatively quickly. • Post peelings are finer particle size compared to chip, so the surface of peelings tend to seal over with manure and foul-up quicker then woodchips
8.	Would they be interested in co-operating in any research projects that may commence in the winter of 2013?	• Yes
9.	Do they operate FY3000?	• No

Site: Feedlot H
Date: 10 Jan 2013

1. Why did they use it? (Discussion based on welfare, performance, dags, odour, dust or reduce pen maintenance)	• Improve cattle welfare and performance during wet and cold winters – typically experienced in June and July. Bedding added to 80% of pens. • The straw assist with manure composting during the winter months, as outside of winter manure is spread direct ex-pens. Reduced odour from the static compost piles during winter when straw is added / already mixed in with the manure.
2. Who recommended the use of bedding? (Personal interest, vet advised, read it in literature)	• Internal decision to trial.
3. What type did they use? (Material type, size, shape, uniformity)	• Straw – it was selected primarily because of availability and it is relatively cheap in comparison to the material types. • Straw baled with long fibre long (not pre chopped)
4. How was the bedding applied and managed in the pens? (pen coverage, depth, treatment during use, was maintenance bedding added, length between cleanout and/or maintenance)	• Aim to pen clean in May, then after rains in June and manure starts to pool in pens straw is added to a depth of 300 mm across top half of pen only – stop bedding at feedbunk apron. • Front-end loader used to distribute straw over pen surface and removed after approximately 4 weeks and new batch added, then removed after 4-6 weeks.
5. What happened to the bedding after removal from the pens? (stockpiled and spread, long term stockpile due to chip contamination, recycled and used back in pens, sold off-site)	• Static compost pile formed, an old mixer wagon used to combine wet and dry manure; and spent bedding that has been freshly removed (wet or dry manure used to manage moisture content); plus microbes. Pile left static for at least 4 months, then spread on farm using tractor towed purpose built manure spreaders (2 x $16m^3$).
6. Bedding source, contact details, cost (preferably cost ex depot – separate out freight), availability (seasonal, year round)	• Local grain farms - $100/t delivered.
7. What were the outcomes of using the bedding? (Pros and Cons)	• Provided soft area for cattle to sit, slightly warmer surface. • Dags still an issue and possibly increases dags because cattle are willing to lay on the bedding, so greater part of the cost exposed to the manure / slurry surface.
8. Would they be interested in co-operating in any research projects that may commence in the winter of 2013?	• Yes
9. Do they operate FY3000?	• No – Possum Gully