final report

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Clean Cattle Manual

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Abstract

The purpose of project B.FLT.7010 is to prepare a manual outlining the different solutions available for mitigating and minimising dags at feedlots. The manual is to be used by feedlots of all sizes and is to include case studies showing how different dag management practices have been successfully implemented.

To deliver this project, data was collected via a comprehensive literature review, interviews with lot feeders who have implemented effective dag management practices at their feedlots and desktop research was conducted to gain clarity around cleanliness standards. This data, specifically the management techniques identified, was used to draft the Clean Cattle Manual. This MLA report presents the literature review, the summarised interviews with lot feeders, and the manual.

The Clean Cattle Manual been designed to assist operators identify which dag management options will best suit the specific needs of their operation.

Executive summary

Dags consist of faecal and soil particles that adhere to cattle hides. Dags usually develop in winter in climatic zones where high winter rainfall and low rates of evaporation combine to prevent rapid drying out of feedlot pens. This is usually between the months of April and September on the eastern coast of Australia.

During times when these conditions occur, known as the dag risk period, there are costs associated with dag removal, which include direct cleaning costs at the feedlot or abattoir, indirect costs caused by reduced productivity, reduced processing efficiency, reduced quality of carcase or hides, and increased carcase disposal and animal product waste to avoid food safety risks. Animal welfare impacts of dags are also a concern.

Despite the range of available practices to contribute to dag management at the feedlot, abattoirs are still required to wash cattle in accordance with the *AS4696:2007 Australian Standard for the hygienic production and transportation of meat and meat products for human consumption* (Commonwealth of Australia, 2007) and because animals must pass a veterinarian's pre-slaughter inspection before they can be cleared for slaughter. During the dag risk period, the labour, time, water-use, and effluent and water management requirements at abattoirs increase. This has environmental, economic, and social repercussions.

Retailers have identified that some of the costs incurred by processors during dag risk periods may be alleviated if increased effort was expended at feedlots to better prepare cattle for slaughter. B.FLT.7010 has been conducted to prepare a Clean Cattle Manual outlining the different solutions available for mitigating and minimising dags at feedlots. Case studies are to be included in the manual showing how different practices have been successfully implemented. The final manual is to be:

1. Educational for small, medium, and large feedlot operators (including management and operational staff) about advantages and disadvantages of available dag management options;
2. Allow feedlots to identify which options will best suit the specific needs of their operation;
3. Facilitate uptake of management techniques by describing the processes and resources required to implement and operate different solutions; and
4. Assist feedlot budget planning by providing capital and operational costs for dag management solutions.

To compile information for the manual, a comprehensive literature review investigating dags and dag management techniques was undertaken. Interviews with lot feeders who have implemented effective dag management practices at their feedlots that have led to cleaner cattle being dispatched to abattoirs and investigation of the roles of in plant Department of Agriculture and Water Resource (DAWR) veterinarians to gain clarity around cleanliness standards were also undertaken. This data, specifically the management techniques identified, was used to draft the manual and prepare the case studies for the manual.

The dag management techniques that have been included in the manual are:

1. Regular pen cleaning;
2. Design, construction and management of pen surfaces;

3. Pen surface bedding options;
4. Cattle washing;
5. Enzymatic and chemical treatments;
6. Manual and mechanical methods of dag removal; and
7. Covered pens.

The advantages and disadvantages of these techniques are included in the manual. The case studies demonstrate that it is the individual circumstances of each feedlot operation (i.e. size, water availability, labour force) that determine which technique/s are most appropriate to implement.

As a result of B.FLT.7010, it can be concluded that:

- Lot feeders need to view dag management as a year-round exercise, not just an extra activity to schedule for the rainy winter months. Maintenance during the dry season will help stay on top of dags in the dag risk period.
- Dag management isn't about implementing one specific method, but rather a year-round integrated management plan is required (which may include plans for increased pen maintenance, pen bedding, washing and combing).
- Extra labour is required in the dag risk period to provide additional pen maintenance, washing, laying of bedding etc.
- Pen bedding was consistently identified by the interviewed lot feeders as a good management option to minimise dags.
- Risks to worker safety and animal welfare implications (i.e. dark cutting) are recognised as a consequence of cattle washing.
- The identification of an effective chemical or enzymatic treatment is desired.
- The definition of dirty vs daggy, how cattle are defined as one and not the other and the implications for misclassification is a potential area for further investigation.

The key messages for lot feeders from B.FLT.7010 include:

Plan ahead

Have a year-round integrated dag management plan in place and budget appropriately to be prepared for additional labour costs in the dag risk period.

Worker safety is a priority

Maintain site training and safe working conditions for staff involved in cattle washing or manual dag removal.

Animal welfare

Pen bedding has benefits for the overall health and reduced dagginess of cattle. Ensure cattle recover fully after washing and/or manual dag removal.

As a result of the distribution of the manual, it is anticipated that there will be an increased uptake of cattle cleaning solutions by feedlots so that cattle are better prepared for pre-slaughter inspection when they arrive at abattoirs. This will result in cost savings for abattoirs and production of lower contamination risk meat and hide products for distribution.

Table of contents

1 Background

Dags consist of faecal and soil particles that adhere to cattle hides. They are formed when manure, dirt and hair are bound together with grain sugars. As dags dry and become hydrophobic, they become increasingly difficult to remove (Slattery, Davis and Carmody, 2005). Dags usually develop in winter in climatic zones where high winter rainfall and low rates of evaporation combine to prevent rapid drying out of feedlot pens, resulting in increased manure depths in feedlot pens. This time is known as the *dag risk period* and is usually between the months of April and September on the eastern coast of Australia. Dags have been known to occur outside of these climate zones and time periods, but the severity is substantially lower, and there is little, or no, management required.

During the dag risk period, carcase weight gain can decrease by 10 – 30%. In addition, there are costs associated with dag removal, which include direct cleaning costs at the feedlot or abattoir, indirect costs caused by reduced productivity, reduced processing efficiency, reduced quality of carcase or hides, and increased carcase disposal and animal product waste to avoid food safety risks. Animal welfare impacts of dags are also a concern.

At the feedlot, regular pen cleaning, management of pen surfaces (including the use of bedding), and/or partial or full pen covering is encouraged to prevent the build-up of mud and manure. Alternatively, dag removal can be carried out at the feedlot by:

- soaking live cattle with water to soften the dags and then washing with a high pressure jet or hose (Greenwood, House and Fell, 1998; Haines *et al.*, 2000);
- Enzymatic or chemical treatment to decompose dags (Slattery, Davis and Carmody, 2005) (Cassells and Haritos, 2009); and/or
- Manual or mechanical removal.

Despite the range of available practices to contribute to dag management at the feedlot, abattoirs are still required to wash cattle in accordance with the *AS4696:2007 Australian Standard for the hygienic production and transportation of meat and meat products for human consumption* (Commonwealth of Australia, 2007) and because animals must pass a veterinarian's pre-slaughter inspection before they can be cleared for slaughter.

A recent MLA report, B.FLT.0165, into the magnitude and extent of the dag problem in Australia showed that the cost of dag management to the Australian beef industry is between $4 and $10 million per annum. This is equivalent to between 0.02 and 0.05 % of the Australian beef and cattle industry's value of production. While there was high variability in the data used in B.FLT.0165, it was shown that, in the 2016 Australian winter, the cost of dags was approximately $10.56 per head (comprised of a $6.18 cost borne by processors and a $4.38 expense endured by feedlots). These costs are incurred mostly by the feedlot and the processing sectors and, to a lesser extent, other sectors in the industry. The higher cost borne by processors indicates that the charge back that processors are currently imposing on feedlots is, on average, insufficient. During the dag risk period, the labour, time, water-use, and effluent and water management requirements at abattoirs increase. This has environmental, economic, and social repercussions.

Retailers have identified that some of the costs incurred by processors during dag risk periods may be alleviated if increased effort was expended at the feedlot level to better prepare cattle for slaughter.

This study has been conducted to provide up-to-date information for small, medium, and large feedlots to enable them to make decisions about adopting dag management practices that are appropriate for their operation.

2 Project objectives

The objective of this project is to prepare a manual outlining the different solutions available for mitigating and minimising dags at feedlots. The manual is to be able to be used by small, medium, and large feedlots and will include case studies showing how different practices have been successfully implemented.

2.1 Outcomes

Outcomes of the project will include:

1. Education of small, medium, and large feedlot operators (including management and operational staff) about advantages and disadvantages of available options;
2. Ability for feedlots to identify which options will best suit the specific needs of their operation;
3. Facilitation of uptake by describing the processes and resources required to implement and operate different solutions; and
4. Facilitation of feedlot budget planning by providing capital and operational costs for solutions.

2.2 Impacts

The impact of the project will be increased uptake of cattle cleaning solutions by feedlots so that cattle are better prepared for pre-slaughter inspection when they arrive at abattoirs. This may result in cost savings and production of lower contamination risk meat and hide products for distribution.

3 Methodology

The project objectives were achieved in three main stages:

1. Project initiation;
2. Data collection and collation, including interviews for case studies; and
3. Reporting.

3.1 Project initiation

An initiation meeting was conducted between Premise and MLA on the 30th of May 2018.
Discussions at this meeting focussed on the:

- identification of potential feedlots to participate in the development of case studies;
- identification of practices to include in the manual;
- development and agreement on a table of contents for the manual; and
- final expected outputs for reporting (Task 3).

3.2 Data collection and collation, including interviews for case studies

The data collection phase of the project included:

- a literature and information review, including:
    - previous MLA reports, including the final report for B.FLT.0165;
    - literature and internet searches to identify data gaps (gap analysis);
    - liaison with users and developers of different practices to gain a detailed understanding of:
        - how the solution achieves the goal of cleaner cattle;
        - implementation processes;
        - costs associated with implementation and operation; and
        - effectiveness at achieving the outcome of keeping cattle clean or preparing cattle for pre-slaughter inspection;
- interviews, for case studies, with feedlot operators who have adopted identified strategies that have led to cleaner cattle being dispatched to abattoirs; and
- investigation of the roles of in plant DAWR veterinarians to gain clarity around cleanliness standards.

3.3 Reporting

The reporting stage of this project included preparation of this final report and the associated documents, including the literature review, case studies and the primary objective of this project, a manual outlining the different solutions available for mitigating and minimising dags at feedlots.

4 Results

4.1 Initiation meeting

During the initiation meeting, potential feedlots to participate in the development of case studies were discussed. Participants identified during the initiation meeting included:

1. A large feedlot with sophisticated dag washing infrastructure and protocols in place; and
2. A small covered feedlot.

It was discussed that a medium sized feedlot was yet to be identified. It was also advised that visits to feedlots were beyond the scope of the project and that case studies would be prepared through phone and email liaison with feedlot managers and other relevant staff.

The table of contents for the draft manual was discussed and confirmed to include:

1 Introduction and background
1.1 Occurrence of dags
1.2 Impacts of dags
1.3 Pre-slaughter inspection cleanliness requirements
1.4 Objective of manual and how it is to be used

2 Solutions for keeping cattle clean at feedlots

2.1 Pen cleaning (such as GPS cleaning and other technologies to facilitate cleaning efficiency)
2.2 Pen surfaces (such as cement stabilisation, bedding solutions, best-practice design of slopes and drainage)
2.3 Cattle washing (infrastructure requirements, soaking times, high pressure washing times. This item will include consideration of water and energy requirements and animal welfare concerns.
2.3 Enzymatic treatments (such as enzymes that aim to decompose dags and their effectiveness and variability)
2.4 Manual removal (such as the Rockdale Robotic Dag Removal System (RRDRS), Rockdale Dedag Machine, Parke Rota Shear, and Jarvis de-dagging tool)
2.5 Covered pens (including partial and full covered A-frame and hoop design systems).

3 Case studies of at least three feedlots with successfully implemented solutions.
3.1 Cattle cleaning at a large feedlot
3.2 Cattle washing at a medium feedlot
3.3 Covered pens at a small feedlot
4 Matrix of solutions available for small, medium and large feedlots and/or matrix of advantages/disadvantages of each solution.

It was additionally confirmed that the reports will be provided in Word Format; a specific template for the manual was not provided. The draft manual was to be prepared based on information collected, collated and analysed during stages 2 and 3.

4.2 Data collection and collation, including interviews for case studies

4.2.1 Literature review

The main sources of written information used in the literature review for B.FLT.7010 are listed in Table 1 below. The full literature review is provided in Appendix A.

Table 1. Sources of information used in literature review

Reference	Publisher; Author	Year
B.FLT.0165 Cost of feedlot dags to the Australian Beef Industry – Final report	MLA; ACIL Allen Consulting, Premise	2018
B.FLT Beef cattle feedlots – design and construction	MLA; FSA Consulting	2016
B.FLT.0237 Feedlot bedding study	MLA; FSA Consulting	2015
B.FLT.0226 Assessment of an enzyme mixture for removal of dags from feedlot cattle - Abstract	MLA; CSIRO	2009
B.FLT.0379 Bedding material use in Cattle Feedlots	MLA; FSA Consulting	2013
FLOT.214 Use of enzymes for removing feedlot dags from the live animal	MLA; NRE – Rutherglen Research Institute	2005
Beef cattle welfare in US: Identification of key gaps in knowledge and priorities for further research	Cassandra Tucker et al	2013
FLOT.303 Welfare Assessment of Cattle Cleaning Techniques	MLA; NSW Agriculture Beef Industry Centre, University of New England, NSW Agriculture, Forbes	1998
FLOT.302 Assessment of cleaning systems for cattle	MLA; Agriculture Victoria	1999

AS4696:2007 Australian Standard for the hygienic production and transportation of meat and meat products for human consumption	CSIRO	2007
FLOT.213 A review of process interventions aimed at reducing contamination of cattle carcasses	MLA, Agriculture Victoria, Victorian Institute of Animal Science	2000
CO-003 De-dagging Factsheet	MLA	2001
PRTEC.008 – Automated DeDagger - Final report	MLA, AMPC	2004

4.2.2 Interviews for Case Studies

Premise have liaised with industry to collect relevant and current information for the Clean Cattle Manual. This included interviews with feedlot operators who have adopted identified strategies that have led to cleaner cattle being dispatched to abattoirs and investigations of the roles of in plant DAWR veterinarians to gain clarity around cleanliness standards.

4.2.2.1 Feedlot operators

Interviews were conducted with feedlot operators in dag affected areas that had implemented methods to prevent or remove dags. Premise have interviewed two small feedlots and one large feedlot that have implemented strategies that have reduced dag severity of cattle dispatched to processors. Numerous attempts to engage with a medium sized feedlot, in a dag-prone region, willing to participate in an interview, were made. Premise have spoken with the MLA Feedlot Project Manager, Dr Joe McMeniman, about this issue. Premise have proposed that the findings from interviews with the small and large feedlot can also be applied to medium sized feedlots.

Summaries of the feedlot interviews, which form the basis of the case studies included in the Clean Cattle Manual, are presented in Appendix B.

4.2.2.2 DAWR veterinarians

Department of Agriculture and Water Resource (DAWR) veterinarians perform ante-mortem inspection of animals, as well as verify post-mortem inspection procedures, oversee animal welfare, and compliance with plant Approved Arrangements (Department of Agriculture and Water Resources, 2017b). Under AS 4696:2007, the ante-mortem inspection must be carried out by the meat safety inspector or DAWR veterinarian in accordance with the approved arrangement, and the animals have to be passed for slaughter before being sent to the kill floor of the plant. Approved Arrangements have replaced Quarantine Approved Premises and Compliance Agreements and are voluntary agreements between the processor and DAWR (Department of Agriculture and Water Resources, 2017a). Approved Arrangements allow processors to use their own premises, facilities, equipment, and staff to manage biosecurity risks and prepare the appropriate documentation without constant supervision by DAWR. DAWR instead conduct regular compliance monitoring and auditing.

Under AS4696:2007, the ante-mortem inspection needs to be carried out within 24 hours prior to slaughter and reasonable steps must be taken to ensure that clean cattle are presented for inspection.

4.3 Reporting

The reporting stage of this project included preparation of this draft report and the associated documents, including the literature review, case studies and the primary objective of this project, a manual outlining the different solutions available for mitigating and minimising dags at feedlots. The draft Clean Cattle Manual can be found in Appendix C.

The draft manual was prepared based on the agreed table of contents and the data collected and collated in Tasks 2 and 3.

5 Discussion

5.1 Literature review

Recently, major retailers have indicated that it is preferable for feedlots to implement management strategies to prevent the build-up of dags or to remove dags to a higher level prior to sending cattle to processors. This study has been conducted to provide up-to-date information for small, medium, and large feedlots to enable them to make decisions about adopting dag management practices that are appropriate for their operation. To assist with this aim, the literature review first discusses dags and the factors that lead to their formation, and then identifies the range of management techniques, which can be undertaken at the feedlot, to prevent and remove dags. The management techniques that have been identified, and discussed further in the literature review, include:

1. Regular pen cleaning;
2. Design, construction and management of pen surfaces;
3. Pen surface bedding options;
4. Cattle washing;
5. Enzymatic and chemical treatments;
6. Manual and mechanical methods of dag removal; and
7. Covered pens.

Based on the information collected and presented in the literature review, apart from enzymatic and chemical treatments to decompose dags, these remaining management options are all effective in managing dags. However, there are different 'costs' for each, as displayed in Table 2 below. These costs, or more specifically, the palatability of the costs, are dependent on the individual circumstances of each feedlot operation. For example, a feedlot which has plentiful water supply may consider washing more beneficial and less costly than constantly maintaining woodchip in their pens throughout their rainy winter, simply because woodchip is an expensive and unreliable commodity in their region. Therefore, a dag management plan that works for one feedlot will not necessarily work for another.

Table 2. Management techniques explored in literature review and associated cost of each technique.

Management Technique	Associated Cost
Regular pen cleaning	Labour and machinery costs.
Design, construction and management of pen surfaces	Design and construction expense, labour.

Pen surface bedding options	Labour, expense and availability depending on feedlot location.
Cattle washing	Labour, water and energy usage, wash facility infrastructure set-up costs, potential safety risk to workers and animal welfare issue.
Enzymatic and chemical treatments	Still undergoing trials and/or currently believed to have limited effectiveness.
Manual and mechanical methods of dag removal	Labour, potential safety risk to workers and animal welfare issue.
Covered pens	Infrastructure set-up costs.

5.2 Case study interviews

Three feedlot operators, who have successfully adopted management techniques that have led to cleaner cattle being dispatched to abattoirs, were interviewed by Premise. Their interviews were the basis for the case studies included in the Clean Cattle Manual. Table 3 provides an overview of the feedlots interviewed and the techniques employed.

Table 3. Feedlots interviewed for B.FLT.7010 and the management techniques employed.

Feedlot	Size	Management Plan
A	Small	Soaking, combing, sand bedding (only if dags persist after washing), increased pen cleaning during dag risk period.
B	Small	Completely covered feedlot, sawdust bedding replaced every six weeks.
C	Large	Cattle moved to pens bedded with woodchip before washing, washing (soak and high pressure), sawdust bedding after washing, regular pen maintenance and cleaning.

As shown in Table 3, Feedlot A, Feedlot B and Feedlot C each employ a different dag management plan to manage their cattle dags.

Feedlot A, B and C all undertake year-round pen cleaning (and maintenance if required), with Feedlots A and C undertaking additional pen maintenance and cleaning during the rainy winter.

Feedlots A and C both wash their cattle, with Feedlot A using a comb as their main technique to remove dags after a water soaking, and Feedlot C undertaking a more rigorous washing process. Feedlots A and C acknowledged the cattle stress associated with cattle washing and the associated dark cutting impact. Therefore, cattle at Feedlots A and C are washed and rested for at least 10 days before dispatch to the abattoir. The human safety factor associated with washing is also acknowledged.

Feedlots A and C also use bedding (specifically sawdust or sand) after washing. Feedlot A and C both mentioned that, besides the well-known health benefits associated with the use of bedding, there is the additional cleaning properties; Feedlot A put cattle that are still dirty after combing on sand bedding before dispatch to remove the remaining dags, and Feedlot C feel that when cattle are put in woodchip bedded pens prior to washing the sharp woodchip edges remove some dags.

Feedlot B does not undertake washing. It is a completely covered feedlot which does not undertake any further dag management practices. Feedlot B changes their sawdust bedding every six weeks.

The concept of 'daggy' vs 'dirty' was raised in discussion with Feedlots B and C. Based on the definition of dags from Slattery, Davis and Carmody (2005), that dags are formed when manure, **dirt** and hair are bound together with grain sugars, the cattle that are kept on sawdust bedding (not dirt) may be dirty (i.e., do not have actual "dags" built up on hides but still may require washing to remove excess manure and bedding dust) rather than daggy (i.e., have actual "dags" built up on hides). This is further evidenced by Feedlot B suggesting that their cattle dags "fall off" during transit prior to processing; a situation which is not likely to happen with severe dags.

5.3 Clean cattle manual

The Clean Cattle Manual was drafted using the content from the B.FLT.7010 literature review, feedlot operator interviews, and the agreed upon Table of Contents, keeping in mind that the manual is to be:

1. Educational for small, medium, and large feedlot operators (including management and operational staff) about advantages and disadvantages of available dag management options;
2. Allow feedlots to identify which options will best suit the specific needs of their operation;
3. Facilitate uptake of management techniques by describing the processes and resources required to implement and operate different solutions; and
4. Assist feedlot budget planning by providing capital and operational costs for dag management solutions.

During the course of the project, discussion with the MLA Feedlot Program Manager confirmed that the manual was to be a maximum 20 pages.

The manual includes the seven management techniques investigated in the literature review, three case studies based off the three feedlot interviews and solution matrices (covering solution appropriateness, costs and benefits) available for feedlots displaying the advantages/disadvantages of each solution.

The content included in the manual was adjusted from the literature review and interview summaries, included in Appendices A and B, to accommodate for the 20 page limit requested.

The solution matrices suggest that the most appropriate options for all feedlots, regardless of size, are regular pen cleaning, feedlot design, construction and management and pen bedding. However, the costs associated with feedlot design, construction and management and providing year-round pen bedding may be prohibitive for many feedlots (depending on their design and construction choices, feedlot location and availability of bedding). The matrices suggest that covered pens are a viable option for small feedlots, however, the initial infrastructure cost may be prohibitive.

5.4 Meeting B.FLT.7010 objectives

The project objective for the Clean Cattle Manual was:

B.FLT.7010 Objective	Was the Objective Met?
1. Prepare a manual outlining the different solutions available for mitigating and minimising dags at feedlots. The manual is to be able to be used by small, medium, and large feedlots and will include case studies showing how different practices have been successfully implemented.	Yes, as a result of data collected via a literature review and interviews, a Clean Cattle Manual has been prepared. The case studies highlight practices that have been successfully implemented in small and large feedlots. The management strategies investigated can be applied in small, medium and large feedlots.

6 Conclusions

The Clean Cattle Manual has been prepared to provide up-to-date information for small, medium, and large feedlots to enable them to make decisions about adopting dag management practices that are appropriate for their operation. Practices that have been successfully implemented in Australian feedlots have been highlighted for the reader, via the inclusion of case studies.

As a result of this manual distribution, it is anticipated that there will be an increased uptake of cattle cleaning solutions by feedlots so that cattle are better prepared for pre-slaughter inspection when they arrive at abattoirs resulting in cost savings and production of lower contamination risk meat and hide products for distribution.

As a result of B.FLT.7010, it can be concluded that:

- Lot feeders need to view dag management as a year-round exercise, not just an extra activity to schedule for the rainy winter months. Maintenance during the dry season will help lot feeders to stay on top of dags in the risk period.
- Dag management isn't about implementing one specific method, but rather a year-round integrated management plan is required (that may include but not be limited to increased pen maintenance, pen bedding, washing and combing).
- Extra labour is required in the dag risk period to provide additional pen maintenance, washing, laying of bedding etc.
- Pen bedding was consistently identified by the interviewed lot feeders as a good management option to minimise dags.
- Risks to worker safety and animal welfare implications (ie dark cutting) are recognised as consequences of cattle washing.

- The identification of an effective chemical or enzymatic treatment is desired.
- The definition of dirty vs daggy, how cattle are defined as one and not the other and the implications for misclassification is a potential area for further investigation.

7 Key messages

Plan ahead

Have a year-round integrated dag management plan in place and budget to be prepared for additional labour costs in the dag risk period.

Worker safety is a priority

Maintain site training and safe working conditions for staff involved in cattle washing or manual dag removal.

Animal welfare

Pen bedding has benefits for the overall health and reduced dagginess of cattle. Ensure cattle recover fully after washing and/or manual dag removal.

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9 Appendices

Appendix A – Literature Review

1 Introduction

Beef cattle processors in Australia require animals to meet certain standards of cleanliness before they can be passed for slaughter. In accordance with standards for cattle cleanliness, cattle wash facilities are required to be installed at processing facilities. However, at certain times of the year, such as during periods of cold and wet weather (known as dag risk periods in this report), cattle entering processing facilities can be impacted by much higher dag levels than at dryer times of the year. This means that additional washing is required to be carried out at processing facilities to ensure that cattle can be passed for slaughter. In general, the additional washing requirement involves increased duration of washing cycles for affected consignments of cattle or sending cattle that do not pass the pre-slaughter assessment back through the washing cycle. This can be costly to processing facilities due to additional water, energy, and labour requirements and costs are either passed back to suppliers or absorbed by the processor. The latter is more likely when suppliers and processors are vertically integrated.

Recently, major retailers have indicated that it is preferable for feedlots to implement management strategies to prevent the build-up of dags or to remove dags to a higher level prior to sending cattle to processors. This literature review first discusses dags and the factors that lead to their formation, and then identifies the range of management techniques to prevent and remove dags at the feedlot. The advantages and disadvantages of implementing these techniques at feedlots in Australia are also explored. The management techniques that have been identified include:

1 Regular pen cleaning;
2 Design, construction and management of pen surfaces;
3 Pen surface bedding options;
4 Cattle washing;
5 Enzymatic and chemical treatments;
6 Manual and mechanical methods of dag removal; and
7 Covered pens.

2 Dags and their formation

“Beef cattle feedlots: design and construction” (Watts *et al.*, 2016) was an outcome of an MLA project that aimed to assist lot feeders and consultants in site selection, feedlot and facility design, construction, and overall management of their feedlot operation. According to this report, “dags are accumulated balls of manure and soil that adhere to the coat or hair of cattle, and are most prevalent on the brisket, underbelly, tail and sides (ribs, flank)” and “the main factors affecting the accumulation of dags are weather, pen conditions, and the length of hair on the animal”.

This report also suggests that climate can lead to the formation of dags, with feedlots in areas where annual rainfall is greater than 750 mm and where winter rainfall dominates, identified as being more susceptible to dag formation.

British breeds (*Bos Taurus)* are the cattle most affected by dag formation because of the longer hair length and they are commonly found in areas with winter-dominant rainfall. In contrast, short-haired or smooth-coated cattle, such as *Bos indicus* breeds, are typically found in northern Australia and do not ordinarily require washing, especially during dry seasons.

3 Management Techniques

3.1 Regular pen cleaning

Regular pen cleaning is extremely important for maintaining a manageable level of manure in feedlot pens. More frequent pen cleaning and pen cleaning immediately prior to winter rainfall periods can help to reduce the mud volume susceptible to promoting dag forming conditions.

However, pen cleaning can be poorly executed as a result of poor equipment or operator error. Consequently, the pen surface may be over excavated, compromising the integrity of the interface layer. This layer is an essential component to managing nutrient leaching and damaging the interface layer can cause unnecessary ongoing operational costs.

Currently, pen cleaning is usually undertaken by feedlot machinery such as by box scrapers, front end loaders, or excavators as technology improves, there is the opportunity to improve pen cleaning efficiency. Laser levels and RTK-GPS (real-time kinematic Global Positioning System) are two technologies available that could be used to aid pen cleaning operations.

1) *Laser Levels*
   Laser levels are limited to operating on pens that have been constructed and (more importantly) maintained with specific pen grades. They have a limited range of operation. If there are humps and hollows in the pens that are to be cleaned, a laser controlled system cannot be utilised. Due to this operational constraint, the laser level approach can only be applied to new pens, which is not representative of most of the existing infrastructure in the Australian beef feedlot industry.

2) *RTK-GPS*
   RTK-GPS machine control is a technology used throughout the civil construction industry. The benefit of RTK-GPS for pen cleaning is that a design surface (digital terrain model or DTM) is developed and digitally uploaded. The DTM can have any number of design grades, which is important when considering the foundation of existing feedlot pens that have been cleaned and repaired for any extended period of time. Due to the ability to upload design surfaces that contain variable design grades, RTK-GPS machine control is ideally suited for both new and existing feedlot pen surfaces.

Improved pen cleaning, by using either laser levels or RTK-GPS, would reduce the incidence of cattle dags, but potentially:

- result in savings in pen maintenance costs (i.e. labour, clay and gravel materials, and machinery);
- improve manure quality by:
    - Reduced downgrading of manure, as a result of contaminants present in manure
    - Potentially achieving feasible biogas production in beef systems. While in its infancy, anaerobic digestion of beef feedlot manure is a growing opportunity for the feedlot

sector. Current pen cleaning practices inhibit the success of biogas production. Over-excavation and contamination of organic material with inorganic substances results in a larger proportion of non-degradable ash entering the digester, operationally, increasing sludge production which requires off-site disposal, and

- redefine feedlot 'best practice' pen management; as a result of better managing manure thickness, feedlots may be able to reduce odour impacts and, consequently, review their maximum capacity.

The use of RTK-GPS controlled equipment is well established in feedlot pen construction and provides greater operator control, with traditional vertical and horizontal precision of ± 15 mm from a predetermined design surface. Additionally, GPS technology has been used extensively to date in broadacre farming and earthworks. Earthworks operators find the technology aids them in safely providing a quality result in a reasonable time period, with increased accuracy. At the time of writing, there are no known studies that have explored machine-controlled pen cleaning, however several larger feedlots are taking the initial steps to investigate incorporating machine-controlled pen cleaning into their operation.

3.2 Design, construction, and management of pen surfaces

3.2.1 Design and construction

Various sources of information exist that provide details of measures that can be implemented in the design, construction, and operational phases of feedlots to ensure that drainage and runoff are optimised to reduce the likelihood that excessive muddy conditions will form in feedlot pens after rainfall events (Watts *et al.*, 2016). Examples of these measures include:

- Pen slopes in feedlots should be greater than 2.5% to promote effective drainage; and
- Pen surface stabilisation, with further technical information included below.

Pen surfaces can be stabilised with products such as lime and cement mixes. Soil testing needs to be undertaken initially to assess bearing capacity, particle size distribution, and Atterberg Limits. Based on the results of the soil stabilisation testing, soils will be treated with combination mix of lime and cement. Prior to the cement stabilisation process, general bulk earthworks need to be undertaken. This involves stripping the top 200 mm of soil to remove organic matter and conducting cut, fill, and compaction to reach the finished design levels. The soil stabilisation process involves adding quicklime using a spreader (Figure 1). After spreading, water is added (slaking process) to transform the quick lime into hydrated lime, which is blended into the top 200 mm of the pen surface (Figure 2). After blending, the surface is rolled out using a roller (Figure 3) and trimmed back to the finished design surface using a grader.

After the surface is rolled and graded, the pen needs to be allowed to cure for two days prior to the addition of cement. Cement is applied using a spreader and water again applied to the surface. This mix is then blended to a depth of 200 mm, rolled and trimmed using the same process used for the lime. Upon completion pen surfaces should be allowed to rest for 3 months before the addition of cattle.

Figure 1. Spreader applying lime to the pens surface. Source Premise Agriculture

Figure 2. Blending lime into the top 200 mm of the pen surface. Source Premise Agriculture

Figure 3. Roller compacting the blended lime and pen surface post mixing. Source Premise Agriculture

3.2.2 Management

Appropriate management of pen surfaces can prevent the conditions that lead to the formation of dags (Watts *et al.*, 2016), including:

- Imperfections, such as weak spots, wet spots, and holes, should be prevented from forming in pen surfaces;
- Manure should not be allowed to accumulate in pens;
- No areas in the pen should be allowed to remain wet for long periods (such as in winter, under shade, or around water troughs); and
- Maintenance of the "manure interface layer", which is an impermeable layer about 50 mm deep that consists of mixed compacted soil and manure; and/or
- Mounds of bedding or surface material can be used to provide dry-lying areas in pens (Tucker *et al.*, 2013).

3.3 Feedlot pen surface bedding

Feedlot pen surface bedding was the subject of the B.FLT.0237 feedlot bedding study project (Watts *et al.*, 2015). This study collated the type and cost of regionally available bedding materials in Australia and described the trials and use of bedding in feedlot pens during the 2013 winter period.

Feedlot bedding is a management option that can be used to prevent the build-up of dags or manage muddy, under-hoof conditions in feedlot pens. It may reduce the impacts and development of dags by absorbing moisture from cattle manure and mud and preventing it from sticking to animals and

initiating dag formation. Bedding materials can be applied before or after rainfall events and should be continually added to the pen over time, as required.

Bedding materials available, and brief summaries of their use and effectiveness, advantages and disadvantages, availability in Australia and costs are listed in **Error! Reference source not found.**. One of the major findings of the study was that feedlot bedding was unlikely to be viable for use across entire feedlots due mainly to costs of the bedding but was probably beneficial for use in post-washing pens, hospital pens, and in covered feedlots. Further R&D is required to examine the effect of bedding on feedlot cattle performance in randomised trials.

Table 3-1. Bedding materials available in Australia. Source: Watts et al., (2015). Costs have been converted to 2017 values where possible.

Bedding material	Use and effectiveness	Advantages and disadvantages	Availability	Costs ($AUD)
Sawdust	Widely used but quickly becomes part of the mud and manure layer, which reduces its effectiveness. Can be applied at thickness of 150-200 mm in open feedlot pens. Needs to be replaced approximately every 3 months. Can be used to cover whole or specific parts of pen.	**Advantages**: Highly absorbent, can reduce incidence of foot soreness, animal comfort improvements, associated with high daily liveweight gain, can be applied before or after rainfall events, reduced odour, good pen surface protection, dag reduction, easy handling (during removal/replacement), cost effective when close to sawmill/timber processing, good option for covered feedlots. **Disadvantages**: Can be moulded and shifted when force is exerted, can become part of the mud and manure layer, poor durability, poor porosity, no recyclability.	By-product of timber industry so available in timber producing/processing areas.	$4.50 - $11/m^3; $45 dry Transport can be expensive due to low bulk density (~160-300 kg/m^3)
Rice hull/husk	Widely used but quickly becomes part of the mud and manure layer, which reduces its effectiveness. Produced in first step of rice milling process. Can be used to cover whole or specific parts of pen.	**Advantages:** Water and fungus resistant, excellent thermal insulator, good porosity. **Disadvantages**: Low moisture retention capacity, quickly blend with manure and become embedded in the manure and dags, poor durability, absorbency and recyclability, difficult to handle, can blow out of pens when dry.	Available in close proximity to rice mills.	$67-89.59/m$^{3;}$ $627/t Transport can be expensive due to low bulk density (~70-145 kg/m^3)
Timber harvest residues	Residue from timber harvested in the forest such as bark, leaf, branch strippings and stripped tree tops. Can be used to cover whole or specific parts of pen.	**Advantages:** May aid composting, comfortable lying conditions in winter, good absorbency and porosity. **Disadvantages**: May cause splinters, can only be used once, poor durability and recyclability.	By-product of timber industry so available in timber producing/processing areas.	$11- $17/m^3 Transport can be expensive due to low bulk density
Timber off cuts	300 mm long and 150 mm wide off cuts of timber processing. Can be used to cover whole or specific parts of pen.	**Advantages**: Cattle prefer to lie on bedding than on wet manure, good durability, porosity, and recyclability.	Limited market, limited availability. Firewood can be used but this increases costs.	$56-90/m^3; $39.20 -44.79/t

Bedding material	Use and effectiveness	Advantages and disadvantages	Availability	Costs ($AUD)
		Disadvantages: Cattle can avoid walking and laying down on bedding in dry weather, off-cuts are uncomfortable to lie on, poor absorbency.		
Wood chips	Produced at timber mills and during disposal of trees removed in urban and infrastructure situations. Produced at various sizes, and bulk densities, and therefore, with varying water absorbing and porosity characteristics. Typically, they are about 25 mm in length. Used at depths ranging from 100-200 mm. Can be used to cover whole or specific parts of pen.	**Advantages:** Prevents cattle from walking on and churning up the pen floor, more durable than straw and sawdust, porosity within a wood chips bedded area typically lasts longer than a straw or sawdust bedded area, larger wood chip pieces can be recycled (i.e., screened from spent bedding), easier to handle, transport, distribute, and remove from feedlot pens than straw, cattle prefer to lie on woodchip than uncovered pen surfaces, may reduce incidence of lameness, may clean manure and mud from cattle without penetrating hide (through rubbing), absorb moisture, may reduce odour, may absorb volatile organic compounds allowing their removal from pens (preventing run off), can reduce dust (although can also create dust from fines), can delay run off, one of the preferred bedding materials for covered feedlots, reduces muddiness and slipperiness of pen surfaces, can be composted along with manure, good for maintaining cattle cleanliness in post wash pens, more acceptable to use in hospital pens from a welfare perspective, may reduce pen surface damage (although results are variable). **Disadvantages**: Needs to be recycled to make economically viable, high cost, poor availability, demand for products (for landscaping, paper production, and bioenergy) usually exceeds supply, needs to be replaced often, can increase dags by encouraging laying down behaviour, may cause increased dustiness and lead to cattle respiratory problems.	Generally available from timber mills, however, demand is high and usually exceeds supply.	$17-$48/m3; $56-90/t
Wood mulch	Produced when wood by-products are processed in a tub-grinder rather than a wood chipper. Consists of shattered and	**Advantages**: may reduce foot soreness, can improve lameness, may reduce dags (similar to wood chips).	Good availability from timber mills/landscape suppliers.	$17-56/m3; $118 – 560/t

Bedding material	Use and effectiveness	Advantages and disadvantages	Availability	Costs ($AUD)
	broken splinters rather than uniform short chips (like wood chips). Spread at depths of approximately 200 – 300 mm. Can be used to cover whole or specific parts of pen.	**Disadvantages**: No re-useable product can be recovered.		
Straw	Commonly wheat or barley straw but other sources available. Longer straw particles create a stronger, more durable bedded area that allows better drainage than chopped straw. Can be used to cover whole or specific parts of pen.	**Advantages**: Highly absorbent, can improve ADG and FCR, can improve marbling scores and dressing percentage, may improve hoof health, can be continually added to pen over time, may reduce odour, may absorb volatile organic compounds allowing their removal from pens (preventing run off), may reduce dust, can delay run-off, provides softer and more comfortable lying surface for cattle than wood chips. **Disadvantages**: Cattle may eat the bedding, unsuitable for recycling, only has average durability.	Good unless drought conditions are causing low supply.	$11-13.50/m3; $78-168/t.
Almond Hull	Separated from shell and nut during processing. Widely used as animal feed and bedding in the United States. Can be used to cover whole or specific parts of pen.	**Disadvantages**: Poor absorbency, durability, and recyclability, do not reduce dags, quickly blend with manure, may be considered palatable by cattle.	Availability and uptake limited by processing locations in north western Victoria and NSW Riverina.	NA
Composted manure	Composition varies. One covered feedlot uses this bedding in Australia. It is similar to sawdust as a soft flooring in concrete pens. Can be used to cover whole or specific parts of pen.	**Advantages**: Highly absorbent, Disadvantages: Turns into soft manure slurry that can be moulded and shifted when force exerted, cattle can become dirty.	Readily available within the feedlots.	Negligible (management only)
Sand	Used in free stall dairies and sale yards in Australia. Can be used to cover whole or specific parts of pen.	**Advantages**: Animal welfare benefits, has been successfully used in post washing pens **Disadvantages**: Surface can become heavily manured in short time frame, prevents drainage through bedded area, low porosity of fine screened sand, hard to recycle unless washed, can be abrasive on soft hooves.	Readily available when in proximity to sand quarry	Expensive to transport due to high bulk density
Recycled rubber chip	Can be used to cover whole or specific parts of pen. Can be sourced from car tyre recycling. Little research on use in feedlots but used	**Advantages**: Longevity, animal welfare benefits, **Disadvantages**: Could affect animal health and compromise food safety due to containing	NA	NA

Bedding material	Use and effectiveness	Advantages and disadvantages	Availability	Costs ($AUD)
	widely in dairy industry.	heavy metals such as Zinc and Lead.		

3.4 Washing

Cattle wash design is discussed in detail in Watts *et al.*, (2016). According to this report, an effective cattle wash should be designed and constructed to:

- Remove loose dirt and manure on cattle;
- Reduce the level of dags on cattle, particularly on the slaughter cutting lines;
- Allow safe and efficient movement of cattle;
- Provide for easy separation and removal of washed hair, manure and soil;
- Contain durable, non-clogging and non-rusting components;
- Minimise stress and injury to cattle;
- Provide a safe working environment for people;
- Maximise water use efficiency; and
- Safely contain contaminated water.

Feedlot cattle washing involves a soaking period to soften dags followed by a high pressure spraying period to remove softened dags (Greenwood, House and Fell, 1998; Haines *et al.*, 2000). The soaking period involves a low pressure, high volume spray and is carried out over an extended period, which can be up to 8-9 hours in extreme cases. Soaking aims to soften dags, mud and dirt and to wash loose manure and dirt out of the coat. The high pressure washing period is undertaken using high or medium pressure, low volume spray and is carried out over a shorter period (30 mins to 1 hour). The aims of the high pressure wash are to further soften dags and remove them from the coat.

Washing of cattle is the second highest user of water in feedlots in the months when it is undertaken (Watts *et al.*, 2016). The volume of water used for washing cattle at feedlots is variable depending on the size of the feedlot, the extent of dags, whether the washing is automated or manual, and the type of washing infrastructure available. Previous studies have shown that the water used in cattle washing at Australian Feedlots is about 3.5% of total water usage. While average water usage for washing at Australian feedlots has been found to range from 700 to 2,500 L per head per year, a monthly average water usage up to 3,500 L per head has been recorded. For feedlot planning and design considerations, 1.2/head/day is often used to approximate the water requirement by feedlots for cattle washing (Davis & Watts, 2011). Costs of water vary depending on flow rate, holding periods, proportion of stock requiring washing, and the ability to use recycled water.

Spray pipes for cattle washes usually need to be located on the floor, recessed into the floor, or installed on the sides or above washing facilities (Watts *et al.*, 2016). This is to ensure that the most dag susceptible areas of the animal, as well as processor cutting lines, can be accessed. Washing can be followed by waterless removal of dags, using mechanical means such as combing, shaving, or clipping (discussed further in Section **Error! Reference source not found.**). This is usually carried out manually and can be dangerous for operators if animals are not adequately restrained (such as in a crush).

Cattle wash water can be recycled (Watts *et al.*, 2016). However, due to risk of cross contamination, recycled water is only used for the initial soaking period, with clean water required for the high pressure wash. Water treatment can improve the quality of recycled water used for cattle washing. Furthermore, ozone treated water has increased oxygen levels, which increases the number of possible chemical reactions, and, therefore, can improve dag degradation and release from the hair.

To prevent dags from building up again prior to dispatch for slaughter, washed cattle are sometimes held in post-wash pens (van Moort *et al.*, 2018). For maximum effectiveness, these pens should be clean, roofed (Section **Error! Reference source not found.**), and the pen surfaces covered with a bedding material such as wood chip (Section **Error! Reference source not found.**). Resting in post-wash pens for 1-2 weeks prior to dispatch allows cattle to overcome any impacts of washing induced stress on meat quality.

In addition to the high volumes of water that are used for cattle washing, there are other disadvantages associated with this method. Soaking and high pressure spraying can lead to animal health and welfare issues due to stress, particularly during cold weather. Similarly, long periods of time between soaking and removal of dags can result in cattle losing significant heat (Watts *et al.*, 2015). If this occurs too soon before slaughter, carcase value can be reduced by dark cutting. This can be prevented if resting is allowed after washing to remove dags, but not if further dag formation occurs in the post washing holding pens. Furthermore, the high pressure washing process can take several hours and requires direct intensive inputs of labour, energy, and water that are costly to feedlot operators. Construction and implementation of washing infrastructure and other inputs such as bedding and coverings for post wash pens can also be associated with high capital and ongoing costs.

3.5 Enzymatic and chemical treatment to prevent and remove dags

Enzymatic prevention or removal of dags, if effective, is considered to pose considerable benefits to the feedlot industry. However, to date, no fully successful trials of the use of enzymes have been completed. An enzymatic treatment acts by breaking down the dag-hair bond. A treatment which could be applied via a hose system, onto live animals, would be most beneficial. MLA are currently working with enzyme manufacturers and testing organisations on some products that have been successfully trialled in New Zealand.

An investigation of the effectiveness of enzymes for removing feedlot dags was conducted in 2005 (Slattery, Davis and Carmody, 2005). The findings of this study were that cellulase, together with a dilute salt solution, increased the efficiency of dag decomposition more than laccase and xylanase. A follow up study was conducted in 2009 (Cassells and Haritos, 2009). The delivery mechanism for the enzyme solution investigated in this study consisted of mixing solutions of commercially available enzymes with a gel which would hydrate the dags, assist enzyme activity, and hold the enzyme close to the dags. The study found that, contrary to findings of the 2005 study, the addition of enzymes did not improve ability to remove dags from hair. Reasons put forward for this were that dags are variable and those that are dry, hard, and water repellent, will be very difficult to remove under any circumstances.

Chemicals have also been trialled in their effectiveness at preventing or removing dags. For example, using detergents while washing dags can help break down dags more effectively and is considered to be a low stress option (Rowland, Phillips and Coates, 1999). However, the limited observed

effectiveness of this method means that it is not widely used. Chemical products for dag removal can be used during washing or prior to slaughter. Chemical products that have been tested include sodium hydroxide, trisodium phosphate, acidified chlorine, and phosphoric acid (Meat Industry Services, 2006). Cargill Meat Solutions in the USA have adopted a post-slaughter 1.5% sodium hydroxide wash, followed by steam vacuuming in all of their plants. De-hairing chemicals can also be used prior to hide removal, though further investigation of these products is outside the focus of this review.

3.6 Manual and mechanical methods of dag removal

Removal of dags from live cattle using mechanical and manual methods is also possible. However, this form of dag removal can be associated with excessive workplace health and safety risks, due to the potential for human injury. In general, manual and mechanical systems can only be implemented where a crush is available to ensure cattle can be adequately restrained. A number of manual and mechanical systems that have been used in the past, or are currently being used, for dag removal at the feedlot are discussed below.

3.6.1 De-dagging machines

A number of machines have been developed for the removal of dags both pre- and post-slaughter (Greenwood, House and Fell, 1998;Meat and Livestock Australia, 2001). An example of a pre-slaughter de-dagging machine is the Rockdale De-dagging Machine (RDDM; (Greenwood, House and Fell, 1998). The RDDM was developed as an alternative to washing and can clean approximately 40 cattle per hour. It uses rotating cleaning drums and robotics to remove dags from dry cattle. While studies have shown that use of the RDDM does not result in undue stress in cattle, it is advisable that the levels of stress in animals cleaned with the RDDM be further investigated.

There are two other mechanical dag removal systems reported (Rowland, Phillips and Coates, 1999). The Rockdale Robotic Dag Removal System (RRDRS), is similar to the RDDM but the technology was found to be ineffective at removing all dags, and the associated capital cost was prohibitive. The other is the Jarvis de-dagging tool, which is used post-slaughter, and is not known to have ever been commercialised. Additionally, the MLA final report, PRTEC.008, outlined a manual (hand-held) de-dagging unit which is utilised commercially, post-slaughter. Both the Jarvis de-dagging tool and the manual de-dagging unit outlined in PRTEC.008 are used for post-slaughter, so will not be investigated further in this literature review.

3.6.2 Shearing

It is also possible to shear cattle to remove dags. An example of a shearing system is the Parke Rota Shear (Greenwood, House and Fell 1998). This is an air-driven handpiece which can be used pre- or post-slaughter to shear dag risk areas. It is reported to be an effective method, despite uneven hair combing, which can impact tanned hide quality. Greenwood, House, and Fell (1988) investigated the effectiveness of shearing using the Parke Rota Shear in relation to a range of other pre- and post-slaughter dag removal techniques (including the RDDM). Similar to the RDDM, this study found that shearing did not result in undue animal stress. Furthermore, the study concluded that shearing was the only technique that totally eliminated dag loads.

3.6.3 Combing

Some feedlots, such as one of the participants in this study, use a metal comb to remove dags after the soaking period. The case study participant noted that the comb is low cost and effective at removing dags, however, there are additional costs associated with labour required to carry out the washing, soaking and soaking, and a health and safety risk to the operator.

3.6.4 Clipping

In the United Kingdom, where intensively produced cattle are generally housed in covered yards, clipping is a recommended measure to prepare cattle for slaughter (Food Standards Agency and ADAS, no date). Clipping is carried out on finishing cattle and involves clipping approximate 5 cm each side of the spine to reduce sweating and the risk of wet dirty hides. It is necessary to also trim dirty hair on the belly and flanks prior to slaughter.

3.7 Partial or full pen covering.

Partial or full feedlot pen covering can overcome the development of dags by decreasing the volume of rainfall that enters the feedlot pens and results in build-up and retention of wet and muddy pen surfaces (Davis, Watts and Stafford, 2016).

Partially covered lot design provides a roofed area over the feed bunk and up to a third of the pen. The covered area, at the top of the pen, requires some form of bedding to prevent potential hoof problems. The bottom of the pen is then operated as an open lot. Partially covered pens can be designed to allow cattle to be enclosed under the roofed area during wet conditions and allowed into the open lot area during dry periods. Stocking density under the roofed area should be retained between 4 and 8 m^2/head and when the pens are open, an open feedlot stocking density (~12-15 m^2/head would ensure full use of the pen area. Water from the roofed area can be collected via a gutter and used to supplement drinking water supplies (Davis, Watts and Stafford, 2016).

While a sedimentation basin and effluent holding pond are still required for partially covered pens, the sizes of the ponds can be substantially reduced due to much reduced effluent runoff loads (Davis, Watts and Stafford, 2016).

One example of a partially covered system is provided in Figure 3-4. This is a skillion structure. Unlike fully covered sheds (discussed below), there is no impediment to airflow in partially covered structures (Davis, Watts and Stafford, 2016).

Figure 3-4. Partially covered single row housing system. Source: Davis, Watts and Stafford (2016)

Fully covered feedlots are operated in areas of particularly high rainfall (such as South-East Asia) or in areas of snow (such as the United States and Canada). Advantages associated with fully covered systems include:

- Reduced facility footprint through increased stocking densities;
- Eliminated rainfall onto pen surface and, consequently, the need for any effluent ponds;
- Provision of shade year-round;
- Increased airflow if located appropriately; and
- With the use of bedding, increased animal performance.

Capital costs of the fully covered system can be high (compared to open and partially covered feedlots). Furthermore, the requirement for the addition of bedding (straw, sawdust, sand, woodchip or similar) every 6-8 weeks, increases operational costs and labour requirements.

Two main designs exist for covered feedlots:

1. Hoop barn structures (Figure 3-5), which are constructed with hardstand bases of either stabilised soil or concrete, with timber or steel perimeter frames. The frame is covered with a long-lasting high-density poly ethylene (HDPE) liner.
2. Steel framed sheds, which are also constructed with hardstand bases. Depending on the design this can be a skillion roof or 'A frame' shed design Figure 3-6).

The shed system can be designed with either a central cattle lane or central feed road. For both design options, gutters are required to capture roof runoff, which can be used to supplement drinking water supplies. Regardless of which facility is developed, the cattle should be stocked at 4 – 8 m^2/head and bedding must be supplied.

Figure 3-5 – Covered feedlot using a hoop barn structure. Source: Iowa State University of Science and Technology (2018).

Figure 3-6 – Covered feedlot with 'A Frame' roof. Source: Davis, Watts and Stafford (2016)

Figure 3-7 – Inside a covered feedlot with 'A Frame' roof. Source: Davis, Watts and Stafford (2016)

4 Conclusion

This literature review has examined dag management techniques that can be utilised at the feedlot, pre-slaughter, to manage dag load on cattle before they arrive at abattoirs. All the management techniques investigated, with the exception of chemical and enzymatic treatments, are seen as effective in managing dags, however, the individual feedlot should consider their own unique situation before implementing any specific management strategy. Worker safety and animal welfare is also imperative and should be given the necessary consideration before a strategy is implemented.

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Appendix B – Summarised Interviews with Feedlots

Interviews were conducted with feedlot operators in dag affected areas that have implemented strategies that have reduced dag severity of cattle dispatched to processors.

Feedlot A - Dag combing and increased pen management at a small feedlot

Feedlot A is located in South East Queensland. It has a capacity of 1,000 head and is planning an expansion to 2,500 head in the near future. Currently Feedlot A has a throughput of approximately 6,000 cattle per year. The dag risk period for the feedlot is between April and September. During this time, approximately one third to one half of all cattle is impacted by dags, depending on how wet the winter is.

Feedlot A uses a comb to manually remove dags from impacted cattle. The combs were designed and manufactured by Feedlot A. They are a piece of steel approximately 200 mm long with 3 mm grooves, similar to a horse curry comb.

Feedlot A's dag management method involves soaking cattle for at least 20 minutes in a wash bay that holds 23-25 head of cattle. Soaking is followed by combing the cutting lines (underneath and sides of the cattle). During combing, cattle are held in a full hydraulic crush. The crush holds the head and has openings at the bottom and both sides to allow access to the dag impacted areas. Following combing, if dags still remain on the cattle, they go to a sand bedded pen. If the cattle have no dags after washing, they go back to their normal pen. The washing occurs about 10 days out from dispatch.

Feedlot A dispatch 56 cattle one week, and 159 the next; on average, around 106 cattle per week. If it is a wet winter, resulting in increased dags, it will take one person, one full day, to clean 106 cattle (this includes moving the cattle from their pens to the wash bay, washing, combing and returning the cattle to their pens).

In addition to the combing procedure to remove dags once they are formed, Feedlot A implements increased pen management during the dag risk period. A pen scraper piles the manure and a bucket removes it from the pen. Feedlot A also cleans the troughs and the backs of the bunks more frequently during winter.

The advantages and disadvantages of dag management at Feedlot A are listed in Table B-1.

Table B-1. Advantages and disadvantages of dag management at Feedlot A

Advantages	Disadvantages
The material costs associated with making the combs are minimal, approximately $10, plus a small amount of labour to manufacture.	Infrastructure: The feedlot already had the cement pad for the wash bay, and the crush and sand-bedded pens are all used for other tasks, not just for cattle washing, so the associated infrastructure costs are seen as minimal.

Power costs associated with the wash bay are minimal; the pump used is not very big and it does not pump for long periods of time.	Washing-related costs (labour and water): • Based on being able to soak, wash and comb 53 cattle in four hours, at an hourly rate of $35, labour costs are $2.64/head. • Additional maintenance that takes place during the dag risk period can be costly. Whilst overall, the same volume of manure is probably removed annually, in winter it needs to be removed more regularly. In the non-dag risk period, pen cleaning is carried out every 8 weeks, but in winter it is up to once a month, depending on the volume of rain. • There are costs associated with water use. Water use increases with the severity of the wet winter period.
	Animal welfare: Cattle do not seem to become stressed by the soaking and combing, however, a decreased intake following the procedure has been observed. If intake reduces to a point above the base metabolic rate, weight will still be gained, although reduced. If intake reduces to a point below the base metabolic rate, animals may even lose weight. Either of these outcomes are costly to the feedlot. Feedlot A have always wanted to install pen shade, however, if shade was installed the pens would be even wetter and dags worse (due to winter rainfall, cool overnight temps and morning fogs keeping the ground wet).
	Health and safety risks: There are health and safety risks to the operator by carrying out the combing procedure as it is seen as a high risk activity. However, Feedlot A rarely have any dag washing related injury, as staff are cautioned to be very careful.

Overall Effectiveness

The combing system, combined with increased pen management, is considered by Feedlot A to be very effective. Feedlot A is penalised $3 – 5 per head by the processor for dirty cattle that require additional washing to meet compliance with AS4696:2007. If no washing or combing is carried out, up to half of the cattle (depending on the severity of the wet winter and the type of cattle) will incur the additional $3 - 5 per head charge for additional washing requirements. However, if washing and combing is carried out, the feedlot usually receives no penalty from the processor, indicating that cattle do not require extra washing.

Feedlot B - Covered pens at a small feedlot

Feedlot B is a completely covered feedlot located in South East South Australia. It has a current capacity of 400 head and is currently seeking approval for an expansion to 4,500 head. Currently Feedlot B has a throughput of approximately 750 cattle per year. The dag risk period for the feedlot is between May and September.

The covered feedlot design includes two sheds, each 30 m wide x 50 m long, with four 20 x 10 m pens in each shed. Each shed holds 200 cattle.

Due to the very high rainfall of the region, the feedlot was designed and constructed as a covered feedlot, not directly to control dags, but primarily to ensure good cattle foot health. However, because of the reduced rain impact, the feedlot is not susceptible to the levels of built-up mud that open feedlots are susceptible to in high rain periods. This has substantially reduced the impacts of dags, which would be expected to affect 100 % of cattle in an uncovered feedlot in the same area. Feedlot B do not undertake any additional dag management practices.

Sawdust bedding is used in each shed which is sourced from a local timber mill. The feedlot is in an area where timber is the primary industry outside agriculture. The composted sawdust waste is spread, using Feedlot B's compost spreader, onto their own property and also sold off site. They also lease the spreader to people who purchase the compost.

The advantages and disadvantages of dag management at Feedlot B are listed in Table B-1.

Table B-2. Advantages and disadvantages of dag management at Feedlot B

Advantages	Disadvantages
Feedlot B is not burdened with any additional labour or costs for dags management. As part of their existing bedding routine, Feedlot B replaces the bedding every 6 weeks, and this involves an additional truck driver.	Infrastructure: To date, costs have been approximately $1,000 per SCU.
Waste management is a profitable part of the business, rather than a cost. Feedlot B currently sell their sawdust waste product for the same cost as what they pay for the original sawdust. There are interest payments and lease payments on the spreader, but these are offset	

by the income they receive from people purchasing the sawdust compost and leasing their spreader.	
There is very little maintenance of the sheds themselves. The feedlot uses solar power and generators, so there are no additional power costs for the sheds.	

Overall Effectiveness

Whilst not the original intention, the sheds substantially reduce the incidence of dags at Feedlot B. The operator believes that it is the bedding which causes the dags or dirtiness at Feedlot B. The dag residue is only on the back legs and the underbelly, not up to the spine. Specific dag management practices have never been in place at Feedlot B, and the feedlot has not been penalised, until just recently, for having dag impacted cattle (Feedlot B was charged a single cleaning fee of $200 across a load of cattle). This may have been due to cattle being "dirty" rather than "daggy". The operator of Feedlot B advised that any dags that are present, dry and break off in the period between yarding, transport, and pre-slaughter inspection.

Feedlot C - Dag management plan at a large feedlot

Feedlot C is located in northern New South Wales and has a capacity of 32,000 SCU and a throughput of approximately 45,000 cattle per year. The dag risk period for Feedlot C is between April and September. All cattle are impacted by dags during this period.

The dag management plan employed at Feedlot C is multi-faceted and involves a maintenance and cleaning regime as well as defined cattle washing process.

Prior to washing, cattle are put in pens bedded with 150 mm woodchip. The period of time spent on woodchip depends on the cattle, as follows:

- Long fed - at least 100 days;
- Short-fed - one to two weeks; and
- Wagyu - one month.

The primary purpose of the woodchip is to increase the health of the cattle. It is found that there are less morbidity and mortality problems due to casting and foot hygiene problems on the woodchip and that there is an equal or better feed intake in wet weather. The sharp edges on new woodchip can help to manually remove dags, however, the sharp edges are smoothed out relatively quickly and the woodchip needs to be replaced every month.

The cattle washing process is conducted in a covered wash facility and is carried out only during the dag risk period. Washing is carried out 2 weeks prior to slaughter. First, the cattle undergo a soaking cycle, with the period of time depending on the dryness of the dags. Dryer dags require a longer period of time to allow the water to penetrate and soften the dags prior to removal. In general, it is a 30 minute soak, 30 minute rest, 30 minute soak cycle.

Following the soaking period, cattle are washed with high pressure sprays (600 psi) that are directed to the dag prone areas (belly and legs) and cutting line areas of the cattle. The high pressure wash lasts for 5 minutes and is usually carried out twice. A high pressure hose is used to rinse and remove remaining dags following the high pressure wash cycles.

Following the washing cycle, cattle are kept on sawdust in covered sheds to allow them to recover from the washing in an environment that will prevent the re-occurrence of dags.

The advantages and disadvantages of dag management at Feedlot C are listed in Table B-1.

Table B-3. Advantages and disadvantages of dag management at Feedlot C

Advantages	Disadvantages
There is no lost opportunity as a result of having the covered post washing sheds, because these are used year-round to feed cattle.	Infrastructure: • A generator was purchased for $200,000 to power the cattle wash facility; • The washing facility itself cost approximately $800,000 - $1,000,000 to construct. • The post wash pens would also be a capital expense, but these existed prior to the development of the cattle wash. • Woodchip is replaced every 4-6 weeks for a cost of approximately $10,000.00. • The cost of sawdust is $55/tonne and there are 2.5 m^3 to a tonne. Approximately 55 tonnes of sawdust is used every 6 weeks. (240 cattle, 42 days, 10080 beast days). This equates to 30 c per head per day not including labour.
	Washing-related costs (labour and water): • The operator reports that washing costs approximately $50,000.00 per year. • In a bad season, 2 people would be required for 5 days a week (8 hours @ $30/hour) to conduct cattle washing. • In the worst case scenario, the water requirement is 1 ML per day x 5 days per week for 6 months. No recycled water is used due to the age of the infrastructure in the washing facility. It is estimated that improvements to this infrastructure, to allow recycled water

	to be used in the wash, would cost approximately $5 million. The cost of water is approximately $100/ML.
	Health and Safety risks: The safety risks associated with the washing are not thought to be high at Feedlot C which mean that staff have to take care while working.
	Animal Welfare: A decreased intake following the washing procedure has been observed.

Effectiveness

Feedlot C reports that approximately 20 – 25 % of dags are removed by using their dag management plan. However, this operator draws a distinction between cleanliness and dagginess; Feedlot C believes that cattle can be 100 % clean, but still have dags.

No stock from Feedlot C has ever been sent back from the processor and no penalty has been incurred by Feedlot C due to dagginess. However, on occasion, the feedlot has had to send staff to the processor to wash cattle that are assessed as being daggy.

Appendix C – Clean Cattle Manual