



Best practice litter management manual for Australian meat chicken farms

by Eugene McGahan, Nic Gould and Mark Dunlop
April 2021



AgriFutures[®]
Chicken Meat

Best practice litter management manual for Australian meat chicken farms

**Covering fresh, in-shed, reuse and spent litter
management**

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and

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April 2021

AgriFutures Australia Publication No. 21-022
AgriFutures Australia Project No. PRJ-011589

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ISBN 978-1-76053-161-4
ISSN 1440-6845

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Electronically published by AgriFutures Australia at www.agrifutures.com.au in April 2021.

AgriFutures Australia is the new trading name for Rural Industries Research & Development Corporation (RIRDC), a statutory authority of the Federal Government established by the Primary Industries Research and Development Act 1989.

Foreword

Litter is a crucial resource and management requirement for the chicken meat industry in Australia and can be the most significant management practice influencing the performance of meat chicken farms. Good litter management is important because it optimises performance, reduces risks to meat chicken and human health, complies with biosecurity requirements and third-party accreditation schemes, and reduces the potential for environmental impacts.

While there is a large amount of information covering litter management, it is often in an inaccessible or hard-to-understand format to the average producer, or focusses on a single issue and doesn't describe the whole picture. This manual has been developed to make the relevant information regarding litter management available in one place.

This best practice manual covers: litter selection; management of litter in sheds including reuse; and options and utilisation of spent litter following removal from sheds. It has been structured in a manner that allows users to access concise information and guidance on the best management practice for each process involving litter. The summary at the end of each chapter provides details on why that section is important, desired outcomes, performance measures and suggested management actions based on the best available research. The document also contains links to industry partners who have produced instructional guides and video resources for the industry.

This report for the AgriFutures Chicken Meat Program adds to our diverse range of research publications. It forms part of our Growing Profitability Arena, which aims to enhance the profitability and sustainability of levied rural industries. For the Australian chicken meat industry, RD&E supports the industry to provide quality wholesome food to the nation.

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Mark Dunlop has led several poultry research projects completed by the Department of Agriculture and Fisheries, Queensland since 2005, including substantial work in litter management.

Acknowledgments

The authors gratefully acknowledge AgriFutures Australia for the provision of research funding and academic support. We would like to thank the chicken meat industry, and the industry stakeholders who provided information and individual perspectives that have been essential in developing these guidelines. We would also like to especially thank and acknowledge Brian Fairchild (University of Georgia), Byron Stein (NSW DPI), Michael Moore (Australian Chicken Growers Council) and Andrew Voigt (DAF QLD) who reviewed and contributed valuable input and insight into these guidelines.

Abbreviations and definitions

ACMF	Australian Chicken Meat Federation
ABS	Australian Bureau of Statistics
Acid	See below definition of pH
ACT	Australian Capital Territory
BSE	bovine spongiform encephalopathy
COPD	chronic obstructive pulmonary disease
DAF	Department of Agriculture and Fisheries
DDE	dichlorodiphenyldichloroethylene, a chemical compound formed by the loss of hydrogen chloride from DDT
DDT	dichlorodiphenyltrichloroethane
DEC WA	Department of Environment and Conservation Western Australia
DPIWE	Department of Primary Industries, Water and Environment, Tasmania
EPA SA	Environment Protection Authority South Australia
EPA VIC	Environment Protection Authority Victoria

FPD	foot pad dermatitis
GHG	greenhouse gas
HHV	higher heating value
LW	liveweight
MJ	megajoules
NH ₃	ammonia
NH ₄	ammonium
NMP	nutrient management plan
NRMMC	Natural Resource Management Ministerial Council
NSW	New South Wales
NSW DPI	New South Wales Department of Primary Industries
NSW EPA	New South Wales Environmental Protection Authority
ODTS	organic dust toxic syndrome
pH	A logarithmic scale from 0-14, where 7.0 is neutral, that measures the concentration of hydrogen to determine how acidic (below 7.0) or alkaline (above 7.0) a substance is
QLD	Queensland
RAM	restricted animal material
RIRDC	Rural Industries Research & Development Corporation (now trading as AgriFutures Australia)
SA	South Australia
STEL	short term exposure limit
TAS	Tasmania
TWA	time weighted average
USA	United States of America
UV	ultraviolet
VFS	vegetative filter strip
VIC	Victoria
VS	volatile solids
WA	Western Australia
WH&S	workplace health and safety
WPSA	World Poultry Science Association

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Glossary

Cake / caking	Dense and compacted excreta layer on the surface of the litter. This manure cake typically develops with a high moisture content (approx. >35%) but may become dry and hard under the right drying conditions.
Excreta	Excreta is a mixture of faeces and urine, excreted simultaneously by chickens. After being incorporated into the litter, it is generally referred to as manure.
Bedding/fresh litter	Material placed on the floor of meat chicken sheds at the start of a grow-out. Bedding materials in Australia are generally wood shavings, wood sawdust, rice hulls and cereal straw. Other bedding materials used include peanut shells, grass straw and shredded paper products. For the purposes of this guide, it refers to the material that does not contain excreta. Litter from previous grow-outs may also be used at the start of a grow-out cycle and this is defined as reused litter.
Friable	The ability to reduce a substance into smaller pieces. Friable litter is therefore free flowing and not caked or sticky and falls apart. Friable litter can be worked by the chickens as they scratch, dig and forage, which maintains aerobic conditions and accelerates moisture loss.
Litter	Mixture of bedding material and poultry manure. During the meat chicken grow-out, it serves several functions, including cushioning and insulation layer between the chickens and the floor; absorbing and releasing moisture; and providing environmental enrichment for meat chickens to display behaviour such as scratching and dust bathing.
Meat chicken	A chicken (<i>Gallus gallus domesticus</i>) grown for meat. Also referred to as a broiler in some Australian states.
Meat chicken sheds	Otherwise referred to as a broiler houses, poultry houses or barns, it is the buildings where meat chickens are reared from day-old to processing weight. The buildings provide a safe shelter for the chickens and are designed and managed to ensure the chickens grow quickly and efficiently.
Moisture content	Moisture content (wet basis) is the mass of water in a sample divided by the mass of the moist sample: $\text{Moisture content} = \text{mass of water (kg)} / (\text{mass of water} + \text{mass of oven dried solids (kg)})$ Dry basis moisture content is the mass of water in a sample divided by the mass of the dried sample: $\text{Dry basis moisture content} = \text{mass of water (kg)} / \text{mass of oven dried solids (kg)}$
Pickup	The process for removing birds from sheds for slaughter. It may otherwise be known as a thin-out, split, or catch-out.
Poultry	Chickens, turkeys, guinea fowl, ducks, geese, quails, pigeons, pheasants, partridges, ostriches and emus reared for meat and eggs used for human consumption.

Reused litter	Litter that was used in a previous grow-out and is being used again for a subsequent grow-out. Litter may be reused many times. Sometimes the litter is treated before being used again (dried, pasteurised, composted, chemically amended, de-caked or screened). Partial reuse is where new bedding is placed in the brood section of sheds, with reused litter on the remainder of the floor.
Sensitive receptor	A site (e.g. rural residence) at which potential amenity impacts may be experienced.
Sanitisation	The process of reducing the number of microbes in meat chicken sheds or chickens' drinking water to reduce the risk of illness, disease and food contamination.
Spent litter	Litter that has been removed from sheds and not reused in subsequent growth cycles.
Wet litter	Litter that has a moisture content high enough to have detrimental effects with regards to disease, food safety, chicken comfort, production efficiency and/or environmental outcomes (e.g. odour and ammonia).

Executive summary

What the report is about

Litter is most likely one of the largest operational investments on meat chicken farms. Litter management can affect meat chicken health, human health, odour and dust. Despite the issue being important for all industry participants, there hasn't been a single point where information has been brought together and maintained in an up-to-date format. While the industry has done a large amount of work in this area, the results are documented in a variety of reports, scientific papers and guides, without there being one document that synthesises this information and makes it applicable and relevant to the various industry participants.

This Best practice litter management manual for Australian meat chicken farms collects this knowledge in one place. The manual covers: litter selection; management of litter in sheds, including reuse; and options and use of spent litter following removal from sheds. It has been structured so that users can access concise information and guidance on the best management practice for each process involving litter.

Who is the report targeted at?

This guide has been written to assist meat chicken growers to maintain high productivity and minimise impacts to meat chicken health, human health and the environment by implementing best practice bedding and litter management measures. It also assists end users of spent litter to minimise potential environmental and biosecurity risks that may be associated with utilising spent litter.

Where are the relevant industries located in Australia?

Meat chicken growing farms are generally located within 200 km of a processing plant, near a feed mill, with guaranteed water, power and access to services. The region where chicken meat is produced dictates the availability, type and cost of litter used. The major chicken meat producing regions of Australia are outlined in Figure 14.



Figure 1. Major chicken meat producing regions of Australia (ACMF, 2020).

Meat chickens move freely within sheds and are not housed in cages, but on bedding material or litter typically composed of organic material such as wood shavings, sawdust or straw. The industry uses a variety of litter types, which may vary between regions due to accessibility. The most common types used in Australia are wood shavings, recycled wood chips, sawdust, cereal straw and rice hulls. The ability to source sufficient volumes of litter at a suitable price is a constant area of interest for the industry.

Spent litter from meat chicken farms is typically removed from sheds at the end of each growth cycle, but can be reused for several growth cycles in some systems. Because spent litter contains manure from the production cycle, it can be used for a variety of agricultural applications. Spent litter management options available to farm operators include off-site disposal, stockpiling, composting, incineration, anaerobic digestion and spreading on-farm.

Background

Litter is a crucial resource and management requirement for the chicken meat industry and can be the most significant management practice influencing the performance of farms. Good management of litter is important to optimise performance, reduce risks to meat chicken and human health, comply with biosecurity requirements and third-party accreditation schemes, and reduce the potential for environmental impacts.

While there is a large amount of information covering litter management, it is often either difficult to find or in a hard-to-understand format. This manual collates the relevant information regarding best practice litter management in one place.

Aims/objectives

The objectives of this project were to:

1. Review and consult industry regarding best management practice for litter in all regions of Australia, based on Australian and overseas research and experience.
2. Develop a best practice guide for litter management covering relevant topics.
3. Develop a troubleshooting guide detailing strategies to control major litter management issues.
4. Gain and review feedback from key industry stakeholders and industry experts and input that information into the guide.
5. Develop a prototype “next generation” solution for knowledge management around litter management using a web platform that allows users to access information relevant to their region and management constraints. We envisage this platform could allow users to contribute to the knowledge base and provide examples or user-initiated extension materials (i.e. videos) relevant to litter management.

Methods used

Current litter management best practices from around the world were reviewed for their applicability to Australian meat chicken production systems, and a best practice litter manual developed in consultation with key industry personnel and experts. An expert review and industry-wide consultation was undertaken to gain feedback on the applicability of the best practice methods, currency of the science and final format of the manual.

Results/key findings

This project produced a best practice management manual that covers: bedding and litter use in meat chicken production, including selecting and treating bedding materials, managing litter in sheds; reusing litter in sheds; and using spent litter. Key components of this manual include: information about how bedding type and management contribute to meat chicken and human health, and amenity; details on specific litter issues and best practice management; a summary of industry practices and the role of litter for those without a background in chicken meat production; management guidelines for different bedding materials; and a troubleshooting guide to define and address bedding and litter problems.

The bedding material and litter issues outlined in the manual contain a technical description of each issue and a summary of relevant research and literature. At the end of each section is a summary of best practice management actions.

A pilot web platform to demonstrate how the manual could be delivered to industry was also developed as part of this project.

Implications for relevant stakeholders

This best practice manual is specifically aimed at growers; however, the authors acknowledge that the guidance in this document may be useful for those auditing management practices on farms. The measures detailed in the best practice manual are not intended to be used in a prescriptive manner or regulatory context. They are written to assist meat chicken growers and spent litter end users with best practice litter management options for selecting bedding type, in-shed litter management, reusing litter in sheds and spent litter use.

Recommendations

With the latest litter management science and practices collated as a single resource, it is recommended that this guide be regularly reviewed (at least every five years) and updated with the latest research, technologies and knowledge. This will give growers access to the latest and best information on litter matters in one place.

It is also recommended that this litter guide be converted to a web platform in the future. This will allow growers and companies interested in a particular area to access more detailed information and reports specific to their requirements.

1 Introduction

1.1 Purpose and scope

This guide has been written to assist meat chicken growers to maintain high productivity and minimise impacts to meat chicken health, human health, and the environment by implementing best practice bedding and litter management measures. It also assists end users of spent litter to minimise potential environmental and biosecurity risks that may be associated with utilising spent litter.

The authors acknowledge that the guidance in this document may be useful for those auditing management practices on farms. However, these measures are not intended to be used in a prescriptive manner or regulatory context. They are written to assist meat chicken growers and spent litter end users.

This guide relates to bedding and litter use in meat chicken production, including selecting and treating bedding materials, managing litter in sheds, reusing litter in sheds, and utilising spent litter after removal from sheds. Key components of this guide include:

1. Information on how bedding type and management contribute to meat chicken performance and health, human health, and amenity (Section 1.2).
2. Details on specific litter issues, as well as best practice management measures (Section 2 to Section 11).
3. A summary of industry practices and the role of litter for those without a background in chicken meat production (Appendix A – The role of litter in the Australian chicken meat industry).
4. Management guides for different bedding materials (Appendix B – Management of common bedding materials).
5. A troubleshooting guide to define and address bedding and litter problems (Appendix C – Troubleshooting).

The specific bedding material and litter issues outlined in sections 2 to 11 contain a technical description of each issue and a summary of relevant research and literature available. At the end of each section is a summary of best practice management measures in the following format.

Format of management practices for each chapter

Why important: A description of the issue and why the management practices are important to achieve each of the desired outcomes.
Outcomes: Statements outlining what is to be achieved.
Performance measures: Indicators that are used to measure the actions implemented to meet the desired outcomes.
Best management actions:
A list of actions considered the best feasible management practices to achieve the performance measures.

1.2 Impacts of bedding type and litter management

Good litter management is important to optimise performance and welfare of the flock, reduce risks to meat chicken and human health, comply with biosecurity requirements and third-party accreditation schemes, and reduce the potential for environmental impacts.

Litter is one of the most significant management practices influencing the performance of meat chicken farms

1.2.1 Meat chicken health

Litter quality can affect meat chicken performance and welfare, and is also a major component of the environment within production sheds. Litter moisture contributes to chicken health and, according to Dunlop (2017) and Ritz et al. (2017), poor litter quality (due to excess moisture) can result in:

- increased ammonia production leading to:
 - respiratory conditions and increased infection
 - eye conditions and blindness
 - human health and environmental concerns
- proliferation of pathogens
- increased odour production
- breast blisters
- skin burns, including hock and footpad
- scabby areas
- bruising
- condemnations and downgrades.

Overly dry litter can also affect chicken health. Dry litter results in increased dust generation, which impacts meat chicken respiratory health, human health and the environment. As litter moisture is a major factor impacting chicken health, managing moisture in sheds is crucial for farm operators.

Other factors may also affect chicken health. For example, proliferation of pathogens in litter increases in environments with high temperature, humidity and pH (Ritz et al., 2017). Some litter viral and bacterial pathogens and diseases of concern (Ritz et al., 2017; Runge et al. 2007) include:

- Avian influenza
- Infectious laryngotracheitis
- Gangrenous dermatitis
- Gumboro
- Reovirus
- Bronchitis
- Pathogenic fungi (mycosis and mycotoxins)
- Parasites (e.g. coccidia, tapeworm and roundworm)
- *Campylobacter jejuni*
- *Clostridium botulinum*

- *Salmonella* spp.
- *Cryptosporidium* spp.
- *Listeria* spp.

1.2.2 Human health

Litter conditions can also impact the health of farm workers via the effects of ammonia and dust. Litter is a source of dust in meat chicken sheds. Inhalation of dust by workers (Jerez et al., 2014) may contribute to conditions such as chronic obstructive pulmonary disease (COPD) and organic dust toxic syndrome (ODTS) (Viegas et al., 2013). DEEDI (2010) suggested that poultry farm workers should wear appropriate dust masks (e.g. P2 Australian Standard or N95 USA Standard), as the air within poultry sheds can contain large numbers of fine particles (< 1 µm).

The presence of pathogenic microorganisms (such as mould, fungi, bacteria etc.) also poses a risk to the health of workers. Impacts to human health are typically less of a concern than impacts to meat chickens due to the reduced contact time of workers and lower susceptibility to pathogens at concentrations present in sheds. For example, two bacterial pathogens that are present in chickens and litter and pose a problem to human health are *Salmonella* and *Campylobacter jejuni*, which both cause gastrointestinal illnesses. However, both require ingestion rather than inhalation to cause infection. A study of litter and aerosols by Chinivasagam et al., (2009) determined that although both *Salmonella* and *Campylobacter jejuni* are commonly found in litter, they present a low risk to human health. The levels of these organisms transferring into internal and external environments as aerosols are of little significance in terms of human infections.

Ammonia is generated in the litter in poultry sheds and is a severe respiratory tract irritant in humans, known to cause severe damage and death, although only in doses well above typical workplace conditions within sheds. It is listed as an airborne contaminant under Australian workplace health and safety standards.

1.2.3 Amenity impacts

Litter moisture content is one of the most important factors in managing amenity impacts from litter. Odour is increased under conditions of high litter moisture, while low moisture levels can result in increased dust generation (although this is generally considered to be less of an amenity issue compared with odour). The moisture content of litter can be estimated from its physical properties, especially friability and appearance.

To reduce impacts from shed litter, it is important to achieve friable (easily crumbled) litter throughout the litter profile to prevent excessive moisture and subsequent caking at the surface of the litter

Litter moisture is regulated by the temperature, humidity and ventilation within sheds; however, meat chicken welfare requirements determine these factors. In other words, ventilation and temperature are controlled for the thermal comfort of the chickens and not to maximise evaporation of water from the litter. Thus, the control of litter moisture should focus on keeping litter dry and friable during the cycle to maximise the evaporation rate of water from the litter. However, climatic and weather conditions, such as a cold, wet winter or days of high humidity, may affect the operation of ventilation and cooling systems, hence the importance of ventilation to keep the litter dry and friable.

2 Bedding selection

2.1 Key factors in bedding material selection

2.1.1 Type of bedding

Different bedding materials can significantly affect carcass quality and growth performance in meat chickens, as well as shed litter quality and bacteria found in the litter (Lien et al., 1992; Malone et al., 1983). Poor litter quality can contribute to foot and leg problems, breast blisters and respiratory infections in meat chickens. This often leads to economic losses from lower weight gains, poor animal welfare, low feed-conversion ratios and downgrades at processing.

Globally, many bedding materials are used in the chicken meat industry including sawdust, wood shavings, cereal straw, rice hulls, bark, sugar cane stalks, peat, peanut hulls and inorganic materials such as sand (Table 1).

Different bedding materials have different properties and prices. Most meat chicken farms will select a bedding material based on regional availability and cost. A comparison of bedding types used in Australia and overseas is provided in Watson and Wiedemann (2018).

Bedding materials that have traditionally been used are usually organic (see Table 1 and Table 2), but inorganic materials, such as sand, are also used. With the cost of traditional bedding materials increasing and margins reducing, interest in alternative bedding has increased (Garcês et al., 2013; Grimes, Smithi, et al., 2002; Kheravii et al., 2017; Villagra et al., 2011), (reviewed by Cockerill et al., 2020). Alternative bedding materials derived from recycled wood and products, as well as crop residues, have been proposed and tested (Gerber et al., 2020). While some have been successful in experiments, they have not been used commercially by the chicken meat industry due to cost, availability, industry need or risks posed by potential contaminants. Gerber et al., (2020) reviewed bedding material contaminants and hazards, and recommended maximum levels of these in bedding used for meat chickens, with a focus on Australian production systems. From this, a risk assessment tool was developed to enable the industry to assess the likely hazards of proposed alternative bedding.

Before choosing an alternative bedding material, consider these factors:

- Will it keep chickens dry and clean?
- Will it maintain a healthy and productive environment?
- Are contaminant levels below the prescribed limits?
- Is it readily available?
- Is it of consistent quality?
- Is it cost-effective?
- Can it be easily stored?
- Can the resulting spent litter be utilised?
- What effect does spent litter have on the land and crop growth?

Table 1. Commonly used bedding materials by region (Watson & Wiedemann, 2018)

Region	Commonly used bedding materials	Reference
Australia	Pine shavings, sawdust, straw or rice hulls	Watson & Wiedemann (2018)
USA	Pine and softwood shavings or sawdust	Grimes et al. (2002)
South-east USA	Pine shavings	Carpenter (1992)
Northern Europe	Wood shavings, chopped wheat straw, peat, lignocellulose, canola straw or maize silage	de Jong and van Narn (2012)
Scandinavia	Peat or peat/wood shaving blend	de Jong and van Narn (2012)
Spain	Long rye straw, wheat straw, barley straw or pine shavings	Gençoğlan and Gençoğlan (2017)
Mediterranean	Rice stalks	Garcia et al. (2007)
Pakistan	Sawdust	Hafeez et al. (2009)
South-east Asia	Sawdust, rice husks or grain stalk	Lien et al. (1990)

2.1.2 Important considerations

Important considerations when selecting bedding material are cost, availability, ability to adsorb and release moisture, and impacts to meat chicken production and health. Another consideration is that the material has a useful purpose after its use as litter. This reduces costs and ensures that spent litter does not accumulate to unmanageable levels on-farm – see Figure 2. Litter must provide a warm and soft surface for the comfort of the chickens while also protecting and insulating them.

Properties of common bedding materials used in Australia are shown in Table 2 (Section 2.2).

Basic requirements of bedding material are good adsorption ability, fast drying time, competitive cost, availability and safety for chickens and workers.

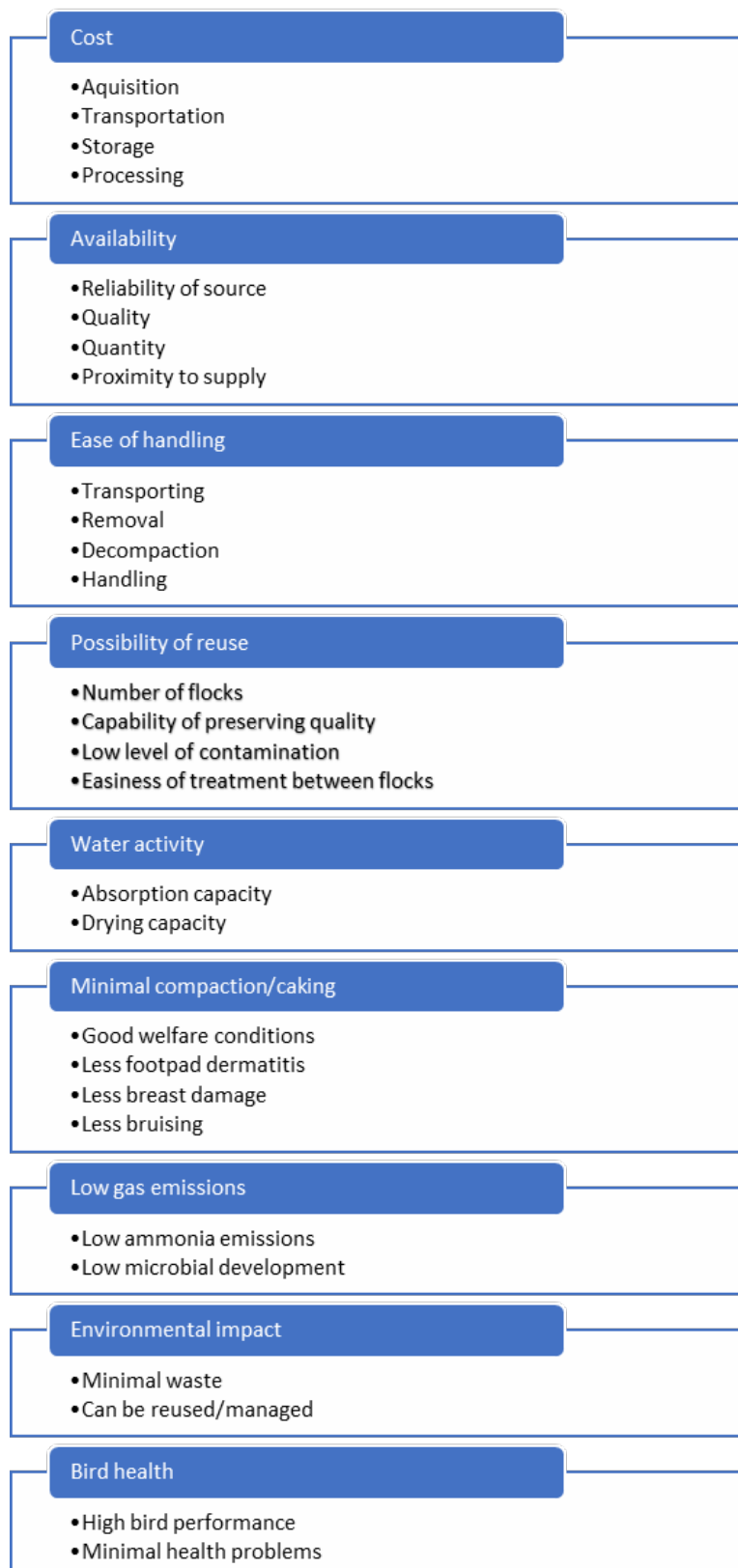


Figure 2. Desirable characteristics of bedding material (Garcia et al. 2012).

2.1.3 Contaminants

As litter can represent up to 6% of a chicken's diet (Malone & Chaloupka, 1983), contaminants (organic chemicals, elemental and biological, as well as physical and management hazards) need to be considered. Concentrations must be below the level that can impact chicken welfare and/or contaminate the meat chicken tissue, and ultimately the human food chain. This can occur through digestion or via adsorption.

2.1.4 Bedding cost and availability

Purchasing bedding materials is an appreciable cost in the production of meat chickens. A 2017 survey (Watson & Wiedemann, 2018) found that the cost of bedding ranged from \$10 to \$40 per cubic metre (Figure 3). In addition to the primary cost of bedding, the cost of transport can be a significant factor for meat chicken producers, which increases the cost in regions where there is a scarcity of supply. As supply of bedding tightens over time, the price will inevitably increase.

Higher prices have been common for wood and straw supplies in many regions in recent years, in response to declining volumes of wood products (smaller timber industry and more/severe bushfires), and an increase in high value alternative uses for straw. For example, straw prices exceeded \$500/t in some regions during severe droughts in 2019, and severe bushfires in 2019/20 limited supplies of wood-based bedding materials. These factors are driving the need for producers to consider alternative bedding sources, reduce bedding material volume requirements (e.g. litter reuse), or increase the price received for spent litter.

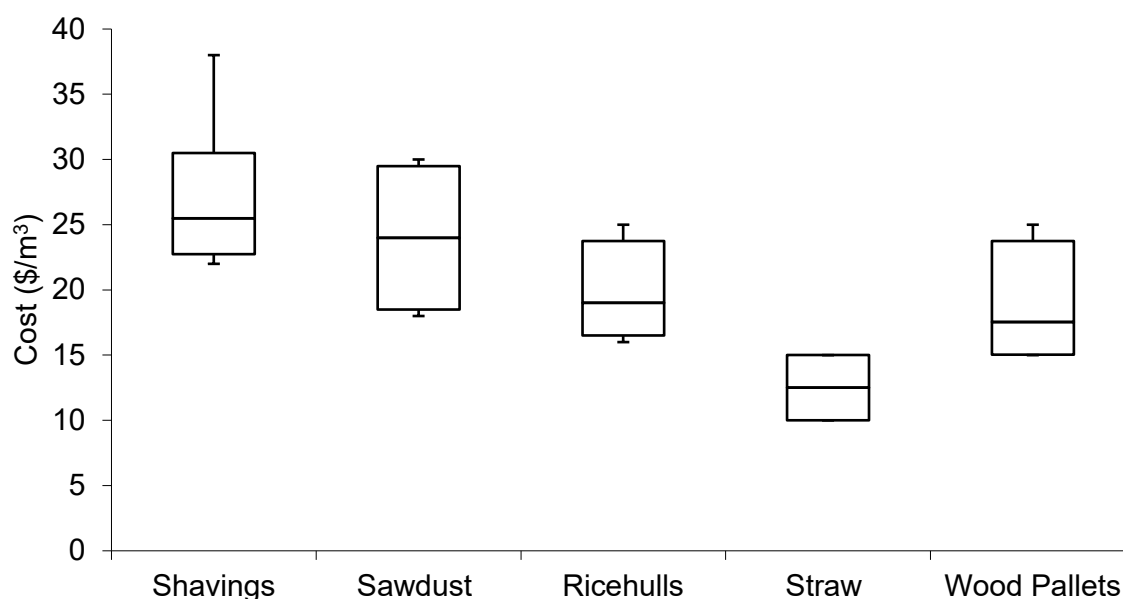


Figure 3. Costs of different bedding materials (landed on farm) (Watson & Wiedemann, 2018).

2.1.5 Litter reuse considerations

Litter reuse is a management practise that reduces the need for new bedding materials and therefore influences litter requirements. It involves growing multiple growth cycles of chickens on the same litter before removing that litter from the sheds for utilisation off site (e.g. as fertiliser), opposed to the

practise of changing the litter between every growth cycles of chickens. See Section 10 for more detail on litter reuse and management.

2.1.6 Spent litter utilisation considerations

Most spent litter produced in Australia is sold as a fertiliser to broad acre, horticulture, dairy farms or composters (Dorahy & Dorahy, 2008). The supply and price of bedding materials has increased substantially in recent years and future supply of wood products may be constrained, or only available at a higher price. There is a close relationship between the industry's capacity to pay for bedding materials and the market for buying spent litter. Ideally, sales would match or exceed costs, and maintaining the markets for spent litter must be considered when changing litter management or investigating alternative bedding materials (Watson & Wiedemann, 2018). Section 11 contains detailed information on spent litter utilisation and management.

Consider the markets for spent litter when changing litter management or investigating alternative bedding materials.

2.2 Properties of common bedding materials

The bedding materials most used in Australia are shavings (soft and hardwood), sawdust, cereal straw and rice hulls. The amount used by different chicken production regions varies with availability and cost. Watson and Wiedemann (2018) surveyed the industry and found that the use of sawdust, shaving and rice hulls has decreased, while the use of straw and other bedding types has increased since Runge et al. (2007) reported their levels. Pelletised straw is used as a bedding material in some areas (see Figure 4). A summary of commonly used materials and their properties is provided in Table 2.



Figure 4. Wheat straw pellets.

(Source: www.strawcomfort.lt/superior-straw-pellets, courtesy of Atenergy)

Table 2. Properties of the four most common bedding materials used in Australian meat chicken farms (from Watson and Wiedemann, 2018)

Bedding material	General properties and description	Moisture exchange	Chicken health and performance	Spent litter uses	Practical and economic considerations	Positives	Notes	References
Wood shaving	Lightweight Medium particle size Soft and compressible Low thermal conductivity	Highly adsorbent yet can dry rapidly	Excellent	Useful as a fertiliser in Australia	Regional availability Supply has been affected by wood industry mills	Considered by many as the best bedding material	Preferred bedding material but becoming limited in supply and expensive in some areas	Ritz et al. (2017), NSW Agriculture (2004), Atencio et al. (2010), Benabdeljelil and Ayachi (1996), Grimes et al. (2007), Villagra et al. (2011), Villagr�a et al. (2014).
Sawdust	Lightweight Small particle size Soft and compressible Low thermal conductivity	Highly adsorbent yet can dry rapidly	Excellent, but may be supplied wet and may be susceptible to Aspergillus if stored improperly prior to use	Useful as a fertiliser in Australia	Regional availability	A good bedding material when available	Often high in moisture and susceptible to dangerous mould growth if stored improperly prior to use	Singh and Sharma (2000) Ritz et al. (2017), NSW Agriculture (2004), Hafeez et al. (2009), Benabdeljelil and Ayachi (1996).
Rice hulls	Lightweight Medium particle size Low thermal conductivity	Lower water adsorbency, large surface area, dries rapidly	Excellent	Useful as a fertiliser in Australia	Regional availability Dependent on rice crop yields	A good bedding material when available	A good bedding material but availability is regional and variable.	Ritz et al. (2017), Singh and Sharma (2000), NSW Agriculture (2004), Swain and Sundaram (2000), Atencio et al. (2010), Benabdeljelil and Ayachi (1996), Villagr�a et al (2014).
Straw-chopped	Lightweight Medium particle size Soft and compressible Low thermal conductivity	Susceptible to caking, which limits moisture exchange when not diligently managed	Excellent, provided caking issues are sufficiently managed May be susceptible to Aspergillus if not appropriately dried and stored prior to use	Useful as a fertiliser in Australia	Regional availability	Large supply in most regions Good bedding material when managed properly	Caking problems Chicken contamination problems Susceptible to mould growth.	Ritz et al. (2017), Singh and Sharma (2000), NSW Agriculture (2004), Hafeez et al. (2009), Benabdeljelil and Ayachi (1996), Villagr�a et al. (2014), Avdalovic et al. (2017).

2.3 Bedding material selection guide

Why important: Each bedding material requires its own specific in-shed management and sometimes pre-treatment to avoid significant effects on meat chicken performance, welfare and carcass quality. Details of bedding materials used in Australian (pine shavings, recycled wood chips, sawdust, chopped straw and rice hulls) can be found in Appendix B – Management of common bedding materials.

Management techniques should depend on the material. For example, sawdust may require drying, and straw will require chopping and is likely to require greater in-shed management.

Outcomes: A bedding material is selected that: provides a comfortable safe bed for chickens; keeps the chickens dry and clean; maintains a healthy shed environment; is free of hazardous levels of contaminants; and the resulting spent litter can be used.

Performance measures: The selected bedding material is chosen based on the following parameters: cost; availability; quality; reliability; ability to adsorb and desorb moisture; ability to maintain performance over the period of use of the material; minimal impacts to meat chicken performance and health; and suitability for reuse or end use (land application/soil conditioner/energy generation).

Best management actions:

Where available and cost effective, give preference to bedding materials in this order:

1. Wood shavings – excellent product but availability issues in some regions.
2. Sawdust – very good product but can be high in moisture and susceptible to mould growth.
3. Rice hulls – particularly good product but is mainly only available in rice-growing regions.
4. Chopped straw – good product but is more susceptible to caking and thus requires greater management. Can also be susceptible to mould growth.
5. Recycled wood chips – good product where available. Has the potential to contain contaminants and users need to follow a strict process in its manufacture to avoid chemical and physical (splinters/sharp edges) contamination issues.
6. Alternatives – should only be considered after a risk assessment of their suitability. The AgriFutures Australia project PRJ-011935 '[Risk assessment of alternative litter types](#)' includes a risk assessment process that can be found at the AgriFutures Australia website.

Selection considerations

- Requires high adsorption characteristics and can dry rapidly.
- Has minimal impact on chicken health and aims to optimise performance.
- If litter is to be reused for multiple growth cycles, the bedding material needs to be easily treated (pasteurised and dried) between growth cycles.
- Has a beneficial use after removal from sheds to minimise potential environmental impacts and/or disposal costs.
- Chicken safety and welfare can be guaranteed. Avoid using alternative bedding material if safety and welfare cannot be guaranteed or if it may contain harmful or undesirable contaminants.

Records

- Record the bedding type, amount required and amount supplied to each shed in the farm records system.

3 Sourcing litter and quality control

3.1 Pathways to source litter

The four pathways for bedding material supply in Australia are:

1. **Integrators** – large buying power, consistent supply (via direct contracts with litter producers) and lower prices.
2. **Individual growers** (direct sourcing or via transport companies/specialist commodity suppliers) – smaller buying power because of competition with other industries, uncertain supply and quality (dependent on transport companies), increased costs and are subjected to increases in market prices.
3. **Grower collectives** – intermediate levels of buying power, price certainty and consistent supply (via direct contracts with litter producers).
4. **Self-supplied** – farms produce their own material and can therefore ensure quality and reduce costs. Farms commonly produce straw.

3.2 Supply

Surveys conducted by Watson and Wiedemann (2018) showed that various issues can affect the supply streams for litter in Australia. For example, droughts affect the supply of litter in states that are dependent on rice hulls or straw. Similarly, supply of wood-based products has been impacted by increasing costs, competing uses, bushfires and changes in primary product demand.

States such as QLD, NSW, VIC and TAS have large timber industry suppliers that have maintained a regular supply over the last 20 years. However, growers have noted the increasing price of wood-based products and the possibility of changes to government policies for the timber industry. This may force them to find alternative sources of litter. For example, the Runge et al. (2007) study identified that there has been a significant increase in the use of recycled wood pallets as litter in WA primarily due to the closure of several major wood mills in the state.

One alternative is recycled wood pallet litter sourced from the Eastern Metropolitan Regional Council recycling facility in Perth. It is made from timber pallets, packaging and timber off-cuts (see Figure 3). There were initial problems with contamination, but after consultation and communication with growers, policies were enacted to ensure the quality and safety of the litter supplied. This has been successful due to stringent operating procedures in the recycling plant, as well as the chemical testing of each batch of bedding material to ensure quality. This material offers good potential as a bedding material, provided hazards are identified and a satisfactory quality assurance program is implemented to ensure it is safe to use. In NSW, there is also information available from the NSW EPA on the specifications for the supply of recycled timber (Environment Protection Authority and Timber Development Association (NSW), 2012).



Figure 5. Australian recycled wood products used for litter.

(Source: www.emrc.org.au/waste-services/waste-and-recycling-services/recycling-services-and-products/emrc-recycled-products/wood-chip.aspx, courtesy of Eastern Metropolitan Regional Council).

3.3 Quality

Growers believe that the quality of litter has decreased over the past 20 years, with water content being the greatest concern. Rodent and wild bird contamination can also be an issue for all litter types and some litter suppliers use rodent-proof (inside) storage to minimise this problem. This, however, adds to the cost of the bedding. Straw bales can also have dead animal contamination due to the process of baling.

Poor quality bedding and/or material with high initial water content can cause operational problems that require additional management practices. These include pre-treatment drying and turning to ensure meat chicken performance and health is not compromised. Growers indicated that it can be challenging to find other sources of bedding material if they have quality problems with their suppliers (Watson and Wiedemann, 2018). All growers surveyed had established management practices to address quality issues; however, these practices added significant cost to production. Many have found that they need to dry bedding if it is delivered wet by using gas heaters and ventilation after it is spread in sheds, which introduces further time and cost constraints.

3.4 Bedding material sourcing and quality control guide

Why important: Low-quality bedding and/or material with high initial water content can cause operational problems. Therefore, additional management practices to ensure optimum meat chicken performance and health, and low odour emissions, such as pre-treatment (drying) and turning are required.

Outcome: Bedding material is sourced from the best available supplier, which reduces cost and ongoing management requirements.

Performance measures: The sourced bedding material has been assessed to have the correct physical characteristics, desired moisture content and has been assessed as being safe to use before spreading in poultry sheds.

Best management actions:

- Ask suppliers to provide or describe their policies and procedures relating to the manufacture, storage and distribution of their bedding materials. This information could include quality management measures or checks that are undertaken prior to supply. Alternatively, ask for a statement of quality assurance which guarantees the condition of bedding on delivery (e.g. free from contaminants, specified moisture content and particle size). This may be in the form of a commodity declaration.
- Inspect each batch of bedding material delivered and notify the supplier of any issues, such as particle size, contaminants, dead animals, high moisture etc. It is recommended to keep a representative sample of bedding upon delivery which can be tested if issues associated with contamination are discovered during or after the growth cycle.
- If bedding is stored on-farm prior to placement, ensure it is kept dry and cannot be accessed by pests and vermin.
- If an alternative bedding material is proposed, conduct a risk assessment to help manage any increased risks to meat chicken performance and health, human health, or food safety. See AgriFutures Australia project PRJ-011935 [‘Risk assessment of alternative litter types’](#) for additional information. This risk assessment process could include testing for pathogens and heavy metals.

4 Litter pre-treatment and additives

4.1 Preparing litter

Storage of new bedding materials on-farm should be minimised to reduce the potential for contamination. In cases where material needs to be stored due to supply issues, it should be kept in a clean and dry place, preferably in a shed. For material that has high moisture content, it should be aerated to allow it to dry to avoid mould formation. This may need to be forced aeration.

Heating the floor and bedding in the brooding area before placement is as important as heating the air to the correct temperature for the health and comfort of young chicks. This will also avoid condensation in the litter. If the temperature of the floor is below the dew point, condensation will form in the litter. This will leave the litter compromised from day one of the growth cycle, and increase the risk of compaction, which then leads to the formation of cake and slower drying rates. The temperature of the bedding at chick placement should be around 30 °C (± 2 °C depending on processor requirements/strain of meat chicken). The Cobb Broiler Management Guide (Cobb, 2018) specifies litter temperatures should be 30-32 °C, while the Ross Broiler Management Handbook (Aviagen Inc., 2018) recommends a temperature range in the litter of 28-30 °C. The temperature of the floor also needs to be within about 3-4 °C of this to avoid condensation within the litter.

Refer to the [extensionAUS website to view a video](#) on pre-heating litter (AgriFutures Australia, 2020).



Figure 6. Ensure correct temperature in the litter at chick placement for the health and comfort of young chicks and to avoid condensation in the litter.

It is important that the minimum ventilation system is started prior to chick placement, particularly if litter reuse is practised. This will remove any excess moisture gases (e.g. ammonia) from sheds. Ritz et al. (2017) recommend heating and ventilating sheds 24-48 hours prior to chick placement. This will help to achieve the correct conditions at placement. Destratification fans, circulation fans or radiant/tube heaters will assist heating the floor and litter to the optimum temperature.

At chick placement, the bedding moisture content should be below 15% (wet basis). If the litter moisture content is too high at chick placement, it can be difficult to rectify once chicks are placed. A hand squeeze test is the simplest method to assess the moisture content. When the litter is dry, it should not form into a stable ball when squeezed and should not feel moist to touch. Conversely, the litter should not be overly dry and dusty. Becoming experienced at making this assessment takes practise. Alternative methods include oven drying and moisture probes. Moisture probes can, however, be inaccurate due to the inconsistent particle size of bedding materials compared with grain products, where moisture probes are commonly used.

At chick placement, perform a hand squeeze test to assess the litter moisture content. Too wet and it will form a stable ball that feels moist and is not easily crumbled.

Sawdust used for bedding can have variable particle sizes and, in some cases, may require sieving/screening to remove larger particles and produce a more consistent product. Large particles in the bedding material will make it more prone to caking, and sharp particles/slivers can cause micro-abrasions to the chickens. Wood shavings are generally a consistent product and do not require additional preparation prior to placement.

Straw and grass-based bedding materials require more pre-treatment prior to placement in sheds. In a survey of Australian growers, Watson and Wiedemann (2018) found several producers have optimised straw bedding by finely chopping and crushing it before use and then turning and mixing (conditioning) as required during the growth cycle. Reducing the particle size makes it more adsorbent and reduces caking problems during the growing cycle. Cobb-Vantress Inc. (2018) recommended wheat straw rather than barley straw for absorptive qualities. They recommend that coarse straw be chopped to lengths of 20 mm or less, as coarsely chopped straw tends to cake due to low absorptive qualities during the initial weeks of a growth cycle. Watson and Wiedemann (2018) also found several southern Australian producers add a layer of sawdust over straw to reduce moisture levels and caking during winter. They concluded that more producers across Australia could use straw, as the material is widely available at a competitive cost in most years. However, straw requires additional management (conditioning) to address problems with caking.

Straw requires chopping and/or crushing to lengths that are 20 mm or less when using it as a bedding material. Coarsely chopped straw will cake more readily, due to low absorptive qualities, during the first few weeks of a growth cycle. Some producers add a layer of sawdust over the chopped straw to control moisture levels and decrease caking during winter.

Pelletising is an additional pre-treatment option for straw products. This process usually requires straw to be crushed and potentially dried to approximately 13-15% moisture content and cut to 4-5 mm in size before pelletising (KMEC Engineering, 2018). Straw is then pressed into pellets under pressure of 115-300 MPa and a temperature of 100-130 °C in a straw pellet miller (Whittaker & Shield, 2017). The heat treatment reduces the microbial loads, and the temperature and pressure applied in the pelletising process influence the durability of pellets and physical characteristics. Watson and Wiedemann (2018) found that straw pellets have been used overseas as an alternative bedding material but they are not cost-effective for use in Australia. They gradually break down in sheds throughout the growing cycle, but they are more adsorbent, last longer and cake less than straw. They are also usually less dusty than other bedding materials, however this depends on the manufacturing process and the portion of fines used in the production of pellets, which will vary between pellet manufactures (Watson and Wiedemann, 2018).

4.2 Litter additives

Litter additives have traditionally been used to control ammonia production from litter (Ritz et al., 2017; Waziri & Kaltungo, 2017) in the USA, where litter reuse is a common practice. These litter additives are also used to limit odour production, reduce solubility of phosphorus in spent litter and improve composition of spent litter for utilisation. Ritz et al. (2017) concluded that additives that can achieve multiple goals or reduce pathogen loads in end products are likely to become more popular.

Most of the litter additives that are used in the USA are not widely used in Australia, and many of the additives are not readily available, nor have they been tested. There has been limited need for these litter additives in Australia due to ample supply of fresh bedding material, and almost all meat chickens in Australia are brooded on new bedding, which significantly reduces the need for litter additives.

If you are considering multi-batch reuse of litter, brooding on reused litter, or using litter amendments, this needs to be considered in consultation with your integrator company, and will require a risk assessment as would be necessary with any alternative bedding/litter material.

Litter additives can take multiple forms, and each has a distinct mode of action. The key litter amendments identified in Ritz et al. (2017), Waziri and Kaltungo (2017) and Cockerill et al. (2020) are:

1. acidifying agents –change the chemical properties of the litter (pH) and reduce ammonia generation.
2. clay-based absorbents –absorb odours and reduce ammonia release by absorbing moisture.
3. microbial and enzymatic inhibitors –inhibit enzymatic activity and microbial growth which contribute to ammonia generation.
4. alkalisers –inactivate pathogens in manure and sewage sludge before land application and promote the rapid volatilisation of ammonia.

Ritz et al. (2017) stated that litter accumulation, litter moisture, meat chicken breed, brooding temperature program and disease challenges are among variables that influence the selection, efficacy and return on investment, with the most effective products being those that react chemically to lower the pH of the litter (i.e. acids). Low pH creates an unfavourable environment for most bacteria, including those responsible for ammonia volatilisation. The authors also note that high litter moisture can reduce the effectiveness of chemical litter additives, with their effective life being less than three weeks, which may not significantly reduce ammonia generation over the production cycle.

The use of alkaline products in the litter is not recommended because they can increase ammonia emissions from the litter. It is recommended to use acidifiers instead. They control ammonia generation effectively by creating acidic conditions in the litter which reduce or prevent the conversion of NH_4 (ammonium) to NH_3 (ammonia). Commercially available acidifiers include alum, sodium bisulphate, ferric sulphate, sulfuric acid and phosphoric acid (Waziri & Kaltungo, 2017).

In a review of litter amendments, Dunlop et al. (2020) found that the most widely used litter amendment products in the USA are acids that reduce the pH of the litter and hence lower ammonia emissions. Their review found, however, that the timing of application is important. For example, if ferric sulphate is used, it should be applied 2-5 days before chick placement to allow activation, while sodium bisulphate activates quicker and should be applied 24 hours before placement. In their review of litter amendments, Cockerill et al. (2020) concluded that acidifiers are the most effective amendment types, sodium bisulphate and alum being among the most commonly tested.

4.3 Pre-treatment guide

Why important: The condition of bedding material supplied to farms can vary greatly depending on the supplier, climate and quality control measures, among other factors, and may not be suitable for use as a bedding material without pre-treatment. Pre-treatment requirements will vary depending on bedding type and supplier.

Outcomes: Treated bedding material minimises impacts on meat chicken performance and health, human health, and the environment.

Performance measures: Bedding materials selected are assessed to determine if pre-treatment is required to ensure they are suitable for use in sheds.

Any pre-treatment process applied produces a bedding material that has the desirable physical characteristics and moisture content. It also needs to be rendered safe to use before spreading in the poultry sheds and must be safe for land application when spent litter is removed.

Best management actions:

Storage of bedding

- The storage on-farm should be minimised to reduce the potential for contamination. If bedding requires on-farm storage before placement, it should be stored in a dry and aerated location, preferably in a vermin-proof shed, with storage time minimised.
- Bedding material which displays high moisture content (>15% wet basis, e.g. sawdust) is susceptible to potential mould growth and should be stored in a dry and aerated location prior to placement. Once placed, heating and ventilation should be used to remove excess moisture. Turning, mixing and/or forced aeration during this phase can release moisture.

Management and checks prior to chick placement

- Prior to chick placement, the floor and bedding should be heated to the optimum temperature for the breed of meat chicken and processor requirements, which is generally around 30 °C. If required, start minimum ventilation prior to placement to remove excess moisture from the bedding and sheds.
- Consider the use of destratification/circulation fans or radiant/tube heaters to ensure the floor and bedding are heated effectively.
- When litter is reused, heat the litter and ventilate sheds for at least 24 hours prior to chick placement, as it will release excess ammonia and reduce the release of ammonia during the brooding phase.
- Litter moisture at chick placement should be 10-15% (wet basis). A hand squeeze test can confirm this. If in doubt, the moisture content should be measured.

Pre-treatment quality control

- If bedding material contains large or sharp particles, use screening/sieving to remove these physical contaminants. Bedding material with small particle size (e.g. sawdust) is best suited.
- When straw or grass products are used as bedding, they require chopping/crushing to achieve a maximum length of 20 mm.

Use of pre-treatment additives

- Litter additives should not be a substitute for best management litter practices before and after placement. Their use is most effective in reducing ammonia levels where multi-batch litter reuse practices are undertaken.
- Avoid the use of alkaline drying agents such as lime.
- When using litter additives, apply them uniformly as per manufacturer specifications prior to the placement of chicks, and avoid applying them over feeder and drinker lines.
- The use of litter additives is not a substitute for other best management practices, so when using them, the following must be done to maximise the effectiveness of these products:
 - best practice shed preparation
 - correct application of the additive
 - active management of litter throughout the cycle
- Litter additives, such as clay-based absorbers, may help absorb moisture at times when the optimum shed environment cannot be maintained by ventilation and conditioning alone. They are not, however, a substitute for best management ventilation practices.

5 Shed heating and cooling to manage litter moisture

5.1 Shed ventilation systems

The internal environment in sheds (such as temperature, humidity and airflow) is controlled by the ventilation, design and management (Dunlop 2017). The primary purpose of ventilation is to provide the optimum thermal comfort for chickens, remove moisture and maintain air quality. Effective climate control is essential to manage shed litter moisture content and prevent wet litter. This improves meat chicken welfare and health, which in turn improves bird performance.

Effective climatic control with ventilation and heating systems plays a key role in removing excess water from sheds, and thus avoiding wet litter. Aviagen Inc. (2018) estimated that 10,000 meat chickens (up to 2.3 kg) consume about 50,000 litres of water that will be lost to the environment as expired moisture or excreted in droppings. This equate to 100 L/m² (or the equivalent of a 10 cm depth of water over the entire shed floor) over the course of a grow-out (Dunlop & Stuetz, 2015). Hence, the transfer of moisture out of the litter via evaporation, and an effective ventilation system that removes this excess moisture from sheds, is key to prevent wet litter problems.

[The transfer of moisture out of the litter via evaporation, and an effective ventilation system to remove excess moisture from sheds, is paramount to prevent wet litter and the problems caused by wet litter.](#)

Sheds can be naturally ventilated, mechanically ventilated or use hybrid ventilation systems depending on requirements. During natural ventilation, airflow from prevailing wind and natural circulation within sheds is generally sufficient to achieve the desired ventilation levels. However, in hot weather, mixing/stirring fans are sometimes required to maintain chicken thermal comfort. Full mechanical ventilation relies on fans to exhaust air from sheds, and replacement air is drawn from specially placed vents or through evaporative cooling pads. There are two general types of shed construction associated with mechanical ventilation systems:

1. **Tunnel ventilation (modern style):** These sheds have cooling pads at one end, large fans at the opposite end and mini-vents placed along the length of the shed. This design allows air to be drawn across the length of the shed to control air quality and for cooling during summer. Shed air quality is mostly automated by a computer-controlled process, optimising comfort for the chickens during the growth cycle.
2. **Naturally ventilated (older style):** These sheds have curtain walls or wall vents/flaps which can be opened or closed to control air movement and temperature within the shed.

A modern tunnel ventilated shed, as shown in Figure 7, can be operated in several modes depending on the level of ventilation required.

When minimal ventilation is required (e.g. to remove moisture, stale air or ammonia, but minimal/no cooling required), duty fans and mini-vents provide sufficient ventilation. Increased ventilation is achieved by increasing duty fan activity. Mini-vent ventilation ensures an even quantity of fresh air is introduced over the length of sheds, without creating drafts or airspeed (Dunlop & Duperouzel, 2014).

Aviagen Inc. (2018) suggested the use of stirring fans to assist the distribution of warm air throughout sheds when there is minimum ventilation, and when minimum ventilation fans are not in use. Stirring fans effectively bring warm air down to the chicks' level to help maintain litter and air quality.

When more ventilation is required to ensure chicken thermal comfort (particularly in warmer months), sheds can be operated in full or partial ‘tunnel mode’. This involves the closure of mini vents and opening of tunnel inlets. Tunnel fans draw air from the tunnel inlets through the length of sheds at windspeeds of 3-4.5 m/s. A wind chill effect is created by increased airspeed, and the greater quantity of air passing through sheds has a larger capacity to remove heat and humidity depending on the relative internal and external conditions. To ensure adequate air mixing in tunnel ventilated sheds in the roof apex before the air reaches the floor, at least 30 Pa of static pressure should be maintained, which causes an airflow through the mini-vents of 3-6 m/s.

Additional cooling is achieved by using evaporative cooling pads, which are located at the tunnel inlets, or foggers, which spray a fine water mist throughout sheds (Dunlop & Duperouzel, 2014).

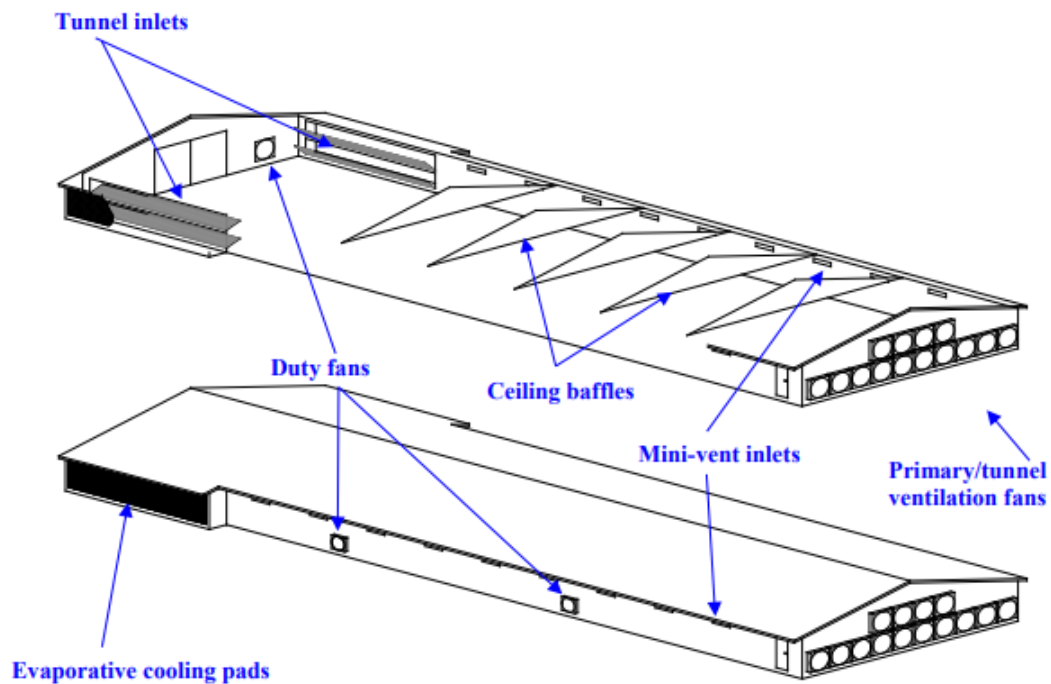


Figure 7. Components of the meat chicken shed ventilation system (top – inside shed with roof removed, bottom – outside shed) (Dunlop and Duperouzel 2014).

Well-sealed sheds enable better control of litter moisture, reduce running costs and enable better temperature control. To measure air leakage in sheds, the Poultry Housing Tips website has a [fact sheet](#) (University of Georgia, 2014b) that directs readers to a [calculation sheet](#) (University of Georgia, 2014a).

Refer to the [extensionAUS website to view a video](#) on managing shed tightness (AgriFutures Australia, 2020).

Newer ventilation systems are emerging that are particularly suited to free-range production. These systems operate with inlet and outlet chimneys, and with negative, neutral and positive shed pressure depending on heating, cooling and ventilation requirements, and also with pop-holes. When pop-holes are open, the outlet chimneys are closed, ensuring air is drawn through the inlet chimneys via fans and exhausted out the pop-holes. This system is particularly beneficial for free-range operations in southern Australia that experience prolonged cold and wet periods during winter.

Well-sealed sheds enable better control of litter moisture. The target static pressure for well-sealed sheds is 30-38 Pa, and very well-sealed sheds may achieve 62 Pa.

5.2 Heating, relative humidity and ventilation

Heating and good ventilation play an important role in managing litter moisture. The ability of air to hold water increases as the temperature of ambient air increases. Dunlop and Stuetz (2015) provided a general rule that states the relative humidity of air halves if the air temperature increases by 10-14 °C, and the relative humidity doubles if the temperature drops by 10-14 °C. At a given temperature, air is saturated (when it reaches maximum water holding capacity). This is also known as the ‘dew point temperature.’

This heating of air can control litter moisture, particularly during winter in southern Australia, when prolonged wet weather occurs. Heating and good ventilation can remove considerable moisture from sheds (Ritz et al., 2017). Dunlop and Stuetz (2015) described the process of how the transfer of water is regulated by the water activity of the litter and the relative humidity of the air above it. If the water activity in the litter is lower than the relative humidity of the air, then the litter will absorb moisture from the air. However, if the situation is reversed, water will transfer from the litter to the air. Thus, one way to ensure that water evaporates from litter is to ensure that the relative humidity of the air at the litter surface is as low as possible.

To enable sufficient water evaporation from litter, ensure the relative humidity of the air at the surface of the litter is kept as low as possible (<60%). Heating can help remove litter moisture, as warmer air holds more moisture. The relative humidity of air roughly halves if the air temperature is increased by 10-14 °C, and the relative humidity doubles if the temperature drops by 10-14 °C.

For ventilation to be effective, Dunlop and Stuetz (2015) suggested that incoming air requires conditioning, so that it has low relative humidity (less than 60%) and can absorb moisture from the litter. They also stated that this can be difficult, as most water collects under feeders and drinkers (via excreta and water loss) where chickens congregate. They suggested strategies to regulate the relative humidity of air at the litter surface and keep the air moving, (e.g. using circulation fans and not excessively using evaporative cooling) that may prevent wet litter.

Effective ventilation, heating and humidity control can also compensate for factors that could cause wet litter (e.g. high moisture in bedding material, water added by excreta, drinker spillage or leaks, condensation). As Dunlop (2017) explained, adding additional dry litter (including repositioning of dry litter that may already be in sheds), or increasing ventilation or heating, can compensate for poor litter water holding capacity. Increasing ventilation, or making it more effective at chicken height, will reduce in-shed humidity and increase evaporation.

Temperature variation can cause chickens to congregate in cooler areas when they are hot or warmer areas when they are cold. This uneven stocking density can cause uneven manure distribution and lead to areas with wet litter. This will indicate that maintenance is required, or ventilation system changes are needed to prevent temperature variation.

5.3 Odour and dust emissions

The moisture content of shed litter is a primary contributor to odour and dust generation. Litter with a high moisture content generates substantially more odour than dry litter (McGahan and Tucker 2002). Odour emitted from meat chicken sheds is comprised of volatile organic compounds (VOCs) and non-VOCs, which include ammonia, hydrogen sulphide and reduced sulphur compounds (Dunlop 2017).

Water held in litter absorbs and retains odorous compounds, which are then transferred into the air in water vapour. This may be a major way odours move from litter to the air (Dunlop 2017).

Odour emission rates are influenced by shed ventilation and the ability to dry litter effectively. Key factors in the drying process are the flow pattern of the ventilation system and the temperature difference between inside and outside sheds.

The degradation of manure and the volatilisation of odorous compounds in litter are strongly impacted by the temperature in sheds. Regulation of temperature is largely achieved through roof insulation, which prevents the accumulation of heat from external radiation. According to McGahan and Tucker (2002), strategies that can assist regulating and controlling the temperature include:

- good roof and wall insulation
- building sheds along an east-west axis to reduce solar radiation
- having large overhangs (e.g. eaves) on buildings
- ensuring adequate ground cover, such as grass, is maintained on areas surrounding sheds to reduce ground radiation.

Excess heat, water vapour and odorous compounds in sheds are removed through ventilation systems. Effective ventilation allows maximum airflow through sheds. This helps remove excess moisture, keep litter friable, promote aerobic conditions and dilute odorous gases that are released into the outside air. Effective shed ventilation regulates the internal shed temperature, which aids in reducing and controlling odour emissions (McGahan & Tucker, 2002).

5.4 Ammonia control via ventilation

Ammonia concentration within the sheds is one of the most serious performance and environmental factors affecting meat chicken production (Miles et al., 2004; Ritz et al., 2017). When chickens consume protein, they produce uric acid, which is converted to ammonia gas under favourable conditions. Factors in litter that increase ammonia production include pH, temperature, moisture content, bedding type, chicken age, manure age, relative humidity and ventilation rate. While ammonia is an issue in meat chicken production, it is a symptom of other factors, particularly moisture levels.

At high concentrations, ammonia irritates the mucous membranes of chickens' respiratory tracts and the conjunctivae and corneas of the eyes. Damage to the mucous membranes of the respiratory system increases the susceptibility of meat chickens to bacterial respiratory infections, especially *E. coli* infection. The ammonia level, combined with the exposure period, can also negatively impact liveability, weight gain, feed conversion rate, condemnation rate at processing and their immune systems (Aziz & Barnes, 2010).

Ammonia is also a severe respiratory tract irritant in humans and has caused severe damage and death when found in doses well above typical workplace standards (EnviroMed Detection Services, 2020). It is listed as an airborne contaminant under Australian WH&S standards. The eight-hour time weighted average (TWA) exposure standard for ammonia under this framework is 25 ppm. The eight-hour TWA means the maximum average airborne concentration calculated over an eight-hour working day, for a five-day working week. Under this standard, the short-term exposure limit (STEL) must not exceed 35 ppm. The STEL is the maximum airborne concentration measured over 15 minutes (Safe Work Australia, 2013).

It is possible that ammonia concentrations within meat chicken sheds can cause health issues for chickens and workers where levels exceed 25 ppm. Australian animal welfare standards require ammonia levels to be below 20 ppm, with some farming schemes requiring the concentration to be

lower than this. Naseem and King (2018) suggested the ideal concentration in sheds should be below 10 ppm.

Australian research (Walkden-Brown et al. 2010) has shown that litter reuse causes higher ammonia concentrations, although in this research the concentrations were well below the threshold of 20 ppm where meat chicken performance and health may be compromised. The ammonia concentration in multi-batch litter is likely to be higher than in single-batch litter, and care should be taken to manage this risk to chicken health, particularly during brooding in winter. However, this is unlikely to pose a major risk in Australia, where only partial reuse systems (fresh bedding material for brooding) are used, as opposed to full reuse systems not practiced here.

In-shed ammonia concentrations in single and multi-batch use systems can be managed if they become a concern. Strategies include increasing ventilation and the use of litter additives (see Section 4.2 for a description of various litter additives and section 4.3 on best management of their use). At present, the use of litter additives in Australia, in either single or multi-batch systems, is minimal (Wiedemann, 2015b).

5.5 Shed heating and cooling to control litter moisture guide

Why important: Wet litter can have adverse effects on chicken performance, welfare and health, worker health, food safety, and the environment. Effective ventilation, heating and relative humidity control are necessary to reduce the incidence of wet litter.

Outcome: The internal environment in sheds is optimised by maintaining and managing the heating and ventilation systems. This will minimise odour and ammonia production from the litter.

Performance measure: Supply sufficient ventilation to remove excess moisture from sheds, optimise meat chicken thermal comfort, remove ammonia from sheds to minimise chicken welfare issues, and reduce WH&S risks.

Best management actions:

Shed and equipment maintenance

- Inspect ventilation and cooling systems daily to ensure they are working effectively, and complete maintenance when problems arise. This includes inspecting cooling pad collection trays, foggers and associated pipework.
- For mechanically ventilated sheds, ensure that they are airtight, and as much air as possible enters through ventilation openings. The most common leak points are around door seals, through broken mini vents and through unsealed fan shutters.
- When sidewall curtains are used, ensure they can be tightly closed.
- Repair any holes found in ceiling insulation.
- Between growth cycles, check fan efficiency rates, heating and ventilation system, extraction and inlet openings. This includes checking the rated fan capacity (i.e. revolution per minute) and that shutters work.
- Provide back-up generators that can fully ventilate sheds and associated equipment. These require operation at least weekly on full load to ensure they work effectively.

Ventilation operation

- Operate fans and the ventilation system in cold weather in a way that prevents moist incoming air from condensing on the floor next to the walls. Shed design will determine the best way to do this, but options include using stirring fans, deflectors, baffles and other devices to improve air mixing. Other options include adjusting mini-vent angles, ventilation opening widths and ventilation velocity.
- Increase ventilation rates if ammonia and wet litter become problems. This is done by systematically increasing ventilation time or fan speed (for variable-speed fans) until sufficient ammonia and moisture extraction is achieved. When increased ventilation is used to remove ammonia and moisture from sheds, temperature and humidity must be maintained (possibly requiring the use of heaters) to levels appropriate to the age of the chickens.
- In winter, provide heating to sheds to improve moisture removal, as warmer air holds more water. This may also require more ventilation to ensure meat chicken thermal comfort is maintained.
- Ensure incoming air has a low relative humidity (<60%) as much as possible to enable moisture to transfer from the litter surface to the ventilated air. Only rely on the evaporative cooling system when required to assist with this.
- Incoming air with higher relative humidity (>60%) should be managed via stirring fans, deflectors, baffles and other devices to improve air circulation, minimise hotspots and remove excess moisture.

- If in-shed ammonia concentrations are an issue and cannot be managed by ventilation alone, consider the use of litter additives such as acidifying agents and/or microbes that can bind nitrogen and reduce volatilisation rates. The benefits from these will be greater where multi-use litter practices are adopted.

Monitoring and recordkeeping

- Maintain shed ammonia concentrations below 20 ppm.
- To meet minimum standards under some farming schemes, lower shed ammonia concentrations may be required, and these will likely vary with bird age.
- To ensure adequate air mixing in tunnel ventilated sheds, static pressure should be at least 30 Pa to ensure airspeed entering through mini-vents is between 3-6 m/s.
- Take ammonia readings in every shed at least twice per week upon first entering, or at least twice per week within one hour after litter maintenance activities have ceased.
- Keep records of ammonia readings, including when and where taken and equipment used.

6 Wet litter management

6.1 Defining litter conditions

Collett (2012) described wet litter as when litter moisture exceeds 250 g/kg (25% moisture content on a wet basis). When this moisture level is exceeded, litter cushioning ability, insulating properties and water holding capacity begin to be compromised. Collett (2007) described the cause of wet litter as being when the rate of water addition (e.g. excreta, spillage, condensation, leaks) exceeded the rate of removal through evaporation.

Another important term commonly used to describe desirable litter condition is friable. The word friable means “to crumble”. An easy method to assess if a litter is in the ideal state of friable is to form a ball of litter in your hand. When you open your hand, it should easily crumble (fall apart). The litter is too wet if the ball stays intact (likely >30-35% moisture content). Conversely, the litter is too dry if it is dusty (<10% moisture content). Visit the [Australian Chicken Meat Federation website](#) to see videos of growers undertaking litter inspections (ACMF, 2020).

A method to assess if litter is in the ideal state (friable), is to form a ball of litter in your hand. When you open your hand, it should easily crumble (fall apart), but not be dusty.



Figure 8. Dry and friable litter (rice hulls on left, chopped straw on right).

(Source: Department of Agriculture and Fisheries, Queensland)

Dunlop et al., (2016) summarised the importance of litter condition, as it will influence how chickens interact with and work (scratch, dig and forage) litter and affects litter drying rate. DAF Queensland also have an assessment guide that contains detailed instructions and photographs on assessing litter conditions, as well as management strategies and corrective actions. The guide uses a 3 x 3 matrix that assesses the moisture in the litter (dry, moist or wet) against its friability (friable, clumping or caked). A scoring system of 1-5 is used to assess the litter, with a score above 2 requiring corrective action.

Table 3 shows the scoring system and some of the management strategies from the guide.

The aim should always be to maintain the litter in a friable state and not wet to avoid the formation of clumps and cake. This will aid in the transfer of moisture from the litter to then be ventilated from sheds.

Table 3. Litter condition assessment guide (adapted from AgriFutures Australia and Department of Agriculture and Fisheries, 2019)

Description	Score	Assessment and actions
Dry and friable	1	Flows freely through the fingers and will fall apart after being squeezed. No action required provided it is not causing dust problems. If dust issues, condition to homogenise with moister material.
Moist and friable	2	Can be darker and inconsistent in colour in the litter profile. May require litter conditioning to improve consistency.
Dry and clumping	2	Clods are seen when moving foot through the litter. Chicken activity may move clods around but will not break them up. May require litter conditioning to improve friability.
Wet and friable	3	Chicken activity will tend to compact the surface rather than work the litter. Will require ventilation to remove excess moisture as it will compact quickly.
Moist and clumping	3	Large clods or clumps of litter starting to form. Prone to caking, so will require corrective actions such as conditioning, additional ventilation and heating.
Dry and caked	3	Distinct capped or crusted surface. Can often see a distinct ridge line between the cake and dry friable litter. Will requiring mechanical conditioning to break the cake, as chicken excreta will remain on the surface. Will likely require additional ventilation to remove ammonia that is released.
Moist and caked	4	Litter lifts as large sheets of cake as foot moves through the litter. Caked litter will feel soft and spongy under foot. Will require mechanical conditioning to break the cake. Will also require additional ventilation to remove ammonia that is released.
Wet and clumping	4	Clumps or clods are visible in the litter and starting to form a thin layer of cake. Will require corrective action that includes adding dry friable litter to absorb moisture, as well as mechanical conditioning and ventilation to remove moisture and ammonia.
Wet and caked	5	Visibly wet and can look muddy. Will require immediate corrective action that includes adding dry friable litter to absorb moisture, as well as mechanical conditioning and ventilation. This litter may require removal and replacement with dry litter if the condition cannot be rectified.

6.2 Factors contributing to wet litter

There are a variety of factors that contribute to litter becoming wet and potentially caked. Dunlop (2017) summarised some notable causes, including:

- moisture entering the litter through shed floors
- shed leaks
- drinker spillage from chickens
- drinker leaks
- stocking density
- increased water excretion from nutrient imbalances or ingredients, disease, increased water consumption, water quality, feed supply interruption or gut microbiota
- increased in-shed relative humidity from exhaled moisture, high ambient humidity or poor in-shed temperature control
- season and/or climatic conditions
- condensation on walls, ceilings and in-shed equipment
- lighting equipment or program
- insufficient shed ventilation/air exchange
- farm biosecurity and cleaning practices
- litter bedding material type
- insufficient litter depth or excess litter depth
- cool litter and warm, humid in-shed air
- litter moisture content/water holding capacity
- shed floor material (concrete versus clay/stabilised soil)

Understanding the cause of wet litter may not be simple and the interaction/addition of any of the above factors, or other additional factors, that can cause the problem. Daily vigilance by the grower and processor company is critical to address any potential problems before the litter reaches a state where it is too wet and loses its desirable properties.

Watch [this video series](#) on the extensionAUS website for information on reducing wet litter and the issues caused by wet litter (AgriFutures Australia, 2019).

Moss & Selle, (2016) reviewed the literature on the causal factors that contribute to wet litter and found that they are mainly micro-environmental, with the main issues being proper management of drinking systems and provision of adequate shed ventilation. The height and water pressure of nipple drinkers are key factors that impact the moisture content of the litter and caking.

Drinker line height needs to be adjusted daily, but before this is done, the litter under the lines needs to be an even depth. This is to avoid some drinkers being too high or low, which causes localised wet spots. The Cobb Broiler Management Guide (Cobb, 2018) and Ross Broiler Management Handbook (Aviagen Inc., 2018) provide details on the correct height setting for drinker lines to ensure spillage from the chickens' beaks is minimised.

Adjust water drinker height and level litter under drinker lines daily to ensure optimal height at all drinkers. This will minimise spillage from the chickens' beaks.



Figure 9. Adjust drinker height to ensure spillage from the birds' beaks is minimised.

The build-up and blockages in water lines with scale and biofilm can cause a variety of problems that contribute to wet litter. Scale is the depositing of mineral solids on the inside of water lines and containers. Scale can lead to the formation of biofilm, which is a collection of organic and inorganic material amassed on a water system pipe surface.

Biofilms can cause loss of disinfectant residuals, increased microbial concentrations, reduction of dissolved oxygen, red or black water problems due to iron or sulphate-reducing bacteria, microbial-influenced corrosion, and reduced material life (Christensen et al., 1990). Biofilms can also affect the benefits of vitamins, electrolytes, organic acids, vaccines and stabilizers, antibiotics and probiotics. Microorganisms in biofilms can include bacteria, fungi, nematodes, larvae, and crustacea. Although viruses and *Cryptosporidium* do not grow in a biofilm, they can attach to biofilms after a contamination event (Watson & Wiedemann, 2018). Regular flushing between grow-outs and ongoing maintenance during grow-outs is required, because a build-up of scale and biofilm can lead to:

- restricted water flow and pressure fluctuation
- drinkers not sealing due to particles flaking off and getting stuck in the nipple
- health problems that may cause wet excreta and therefore wet litter

Regular inspection, cleaning/flushing and maintenance of the water delivery system is required to reduce problems caused by scale and biofilms

Sufficient pressure is required at the regulator in water lines to ensure it operates properly. Gravity-fed lines from tanks on stands may be insufficient to supply adequate pressure alone, and pumping may be required. Pressure in the water lines (after the regulator) also needs to be sufficient to provide

adequate water flow for birds to drink, meet water demand during peak periods and ensure the nipples on the drinkers seal.

Other issues and solutions identified by growers with drinking systems include:

- Too high pressure at drinkers causing excess water spillage when birds engage the nipples. This is exacerbated if there are leaks in the system.
- Pressure variation along the length of the drinker lines caused by sloped floors. This can be overcome by using multiple pressure regulators or water inlets along the length of the drinker lines.
- Using lower-flow nipples so pressure in the water line can be increased. This is being adopted by growers with sealed concrete floors who have found that drinker management is more important than it was with earth floors.

Correct and even water pressure before and after regulators is vital to ensure sufficient water is delivered to birds and spillages/leaks are minimised.

Correct design and operation of sheds' climate control systems has a major positive impact on litter moisture content throughout the growing cycle. See Section 5 for information and management practices regarding heating, cooling and ventilation.

6.3 Impacts of wet litter and remediation

Wet litter in meat chicken sheds can have adverse effects on animal welfare, flock health, food safety, the environment and productivity (Dunlop, 2017). Wet litter exhibits reduced friability and is susceptible to compression and cohesion. It has reduced thermal insulation properties when compared with dry litter and is prone to manure caking (see Section 7).

One of the primary health, welfare and productivity issues in meat chicken production is foot pad dermatitis (FPD) or 'foot-burn'. Although there are multiple causes that lead to this condition in meat chickens, the primary catalyst is wet litter (Shepherd & Fairchild, 2010) and high ammonia concentrations (Dunlop et al., 2016). This can lead to productivity losses through downgrades at processing plants and is becoming increasingly important from a welfare perspective (Shepherd & Fairchild, 2010). Food safety risks may also increase with wet litter, as it provides more favourable conditions for enteric pathogens such as *Salmonella* and *E coli* to multiple (De Rezende et al., 2001).

High moisture content in wet litter will generally contribute to more odour emissions compared with dry litter, as more moisture supports a higher level of odour-forming microbial activity. However, this is not always the case, as odour molecules also require a mechanism to move from the litter into the air and be emitted via the ventilation system. Thus, litter that has become very wet on the surface and has caked will inhibit this transport pathway (Dunlop, 2017). The issue with wet litter is that when it is combined with surface caking, it can lead to anaerobic conditions. These conditions are known to produce strong and unpleasant-smelling odorants when released and emitted. These odorants have a greater chance of causing off-site impacts and complaints.

Wet litter can affect meat chicken health, welfare and productivity, as well as human health. It can also generate excessive odour and ammonia emissions. Investment of time and resources in good litter management and addressing the issues that contribute to wet litter will enhance operations and productivity at a farm and industry level

Regular turning and mixing aerate the litter and help keep it in a friable state. This in turn allows the chickens to work the litter by scratching and digging, which further helps maintain friability and

remove moisture when combined with adequate ventilation. Maintaining friability is believed to maximise evaporation of water from litter. This is achieved by increasing the surface area for evaporation, opening pathways and pores in the litter for water to escape, and by continually bringing damp particles of litter to the surface, at which point they will dry quicker when combined with airspeed and low relative humidity. Evaporating water from litter may be challenging if there are unfavourable climatic conditions (e.g. prolonged cold and wet weather) that slow drying through ventilation. Once litter becomes wet and caked, it can be difficult to rectify without mechanical litter conditioning.

Keeping litter in a friable state allows chickens to turn the litter over via scratching and digging, which helps remove moisture when combined with adequate ventilation. Attempts to remediate overly wet and caked litter via conditioning and mixing alone are likely to be futile.



Figure 10. Keeping litter in a friable state allows chickens to work the litter, which helps maintain that friability and remove moisture when combined with via adequate ventilation.

6.4 In-shed litter management guide

Why important: Wet litter and caking may be caused by the interaction of a variety of factors. Maintaining litter in a friable state will enhance moisture removal from sheds when combined with effective ventilation.

Outcome: Wet litter in sheds is minimised and the litter remains friable.

Performance measures: Daily vigilance, including inspection, monitoring, record keeping and positive actions to reduce the incidence of wet litter.

Best practice actions:

Shed and infrastructure design and management

- For new sheds, ensure floors remain dry through correct design, where sheds are built above the outside ground level.
- Provide adequate drainage outside sheds to direct stormwater away from sheds as quickly as possible following rainfall.
- Adequately compact floors to prevent seepage from the ground. Do not assume that laying concrete floors will enhance litter management and reduce the incidence of wet litter. Concrete floors are less forgiving and may require additional management during the grow-out cycle.
- Ensure the roof and walls of sheds are sealed (other than the ventilation system) to prevent rain and surface water from entering.
- In areas of sheds prone to rising damp, consider laying concrete floors and installing guttering that directs water away from sheds.
- Flush drinker lines between growth cycles to remove slime and scale. This will help maintain correct pressure and reduce spillage.

Ventilation and cooling system

- Maintain and operate foggers to avoid the formation of coarse drops (those that fall to the floor of sheds). Mist produced by foggers should evaporate before reaching the floor.
- Where conditions allow, minimise the use of evaporative cooling and foggers to minimise relative humidity within the sheds. Attempt to achieve 40-60% RH to accelerate litter drying. When relative humidity is getting close to 60%, the ventilation rate should be increased.
- In cold and/or wet weather, operate the ventilation system in a manner that avoids moist incoming air condensing on the floor near inlets. Do this by combining air flow rate and heat (either from the birds or heaters) to reduce relative humidity in the sheds and accelerate drying.
- Ensure sheds are tight and have sufficient static pressure to get sufficient air mixing to maximise litter drying rates.

Bird health

- Inspect manure at least daily for incidence of watery droppings. Alltech have an example of a [chicken faecal chart](#). Identify the cause of the problem promptly and resolve the issue. This may require consultation with the processor.
- Monitor chicken health daily and ensure any digestion problems are promptly identified and reported to the processor if necessary.

Meat chicken stocking density

- Do not stock birds at rates which exceed the limits of any regulatory approval/licence, welfare codes, voluntary accreditation schemes (to which the farm subscribes) and processor/integrator requirements,.

- Check birds at least three to four times a day to ensure they are not congregating to particular areas (e.g. in front of cool pads). Monitoring will need to be increased during hot weather. Uneven bird distribution leads to uneven manure load, which can contribute to areas of wet litter.

Water supply

- Check drinker height daily to ensure it is the correct height for chickens.
- For nipple drinkers:
 - set height at chicks' eye level for the first few hours of age
 - In the early stages of brooding, adjust drinker height to just above head height. After this, maintain height above chicks' heads to ensure they are reaching (not straining) to reach the drinker and their feet are always flat while drinking. If they are turning their heads to the side while drinking, it will cause spillage.
 - adjust pressure so there is a droplet of water suspended from the nipple.
- Check of the flowrate and pressure of the drinker system at least daily to ensure it operates as per manufacturer specifications.
- Perform a high-pressure flush on water lines between each flock and after adding supplements through the medicator.
- Ensure water lines are made from material that is resistant to scale and biofilm build-up.
- If biofilms are detected or suspected in the water distribution system, sanitise the water line with approved chemicals.

Inspect drinker lines, drinkers, cooling pad collection trays, foggers and other plumbing at least daily to identify leaks and repair if found.

Water quality

Analyse drinking water annually to ensure it meets the health and optimised performance requirements of the chickens. Details of water quality requirements can be found in the AgriFutures Australia publication '[Industry best practice manual for water quality management and sterilisation on-farm](#)' (Watson et al., 2020).

Litter inspection

- Inspect litter conditions daily in each shed via sight and feel to ensure the litter is friable, with particular emphasis on likely high-moisture areas, such as around the air inlet, under drinkers and feeders, and near walls.
- Inspect litter depth daily and ensure it is even throughout the sheds. Minimum litter depth is generally at least 50 mm, but this may change based on the litter type, stocking density or accreditation requirements.

Litter maintenance

- Use mechanical conditioning to maintain friability, reduce caking and mix areas of wetter litter with drier litter. Mixing wet and dry litter may be useful to reduce the cohesiveness of the litter particles and prevent compaction and future caking. Breaking up wet and caked litter without adjusting ventilation and/or heating may not be effective or sufficient to prevent caking from rapidly re-occurring.
- Choose an appropriate time of the day and weather conditions to perform litter conditioning:
 - to avoid odour impacts if conditioning releases additional odour
 - to allow for higher ventilation following litter conditioning to remove ammonia
 - to allow for higher ventilation following litter conditioning to maximise the removal of water from the friable litter and reduce the likelihood of it becoming cohesive, compacting and allowing cake to reform.

Litter condition assessment

Conduct daily inspections of the condition of the litter in three different areas of the sheds (the fan or non-silo end, middle, and the cool pad or silo end). Record the condition of the litter based on the nine descriptors below. Detail any corrective actions undertaken.

Dry and friable	No action required unless dust issues, may require conditioning to improve consistency.
Moist and friable	May require conditioning to improve consistency.
Dry and flumping	May require conditioning to improve friability
Wet and friable	Will require ventilation to remove excess moisture as it will compact quickly
Moist and clumping	Prone to caking, so will require corrective actions such as conditioning, additional ventilation and heating.
Dry and caked	Will requiring mechanical conditioning to break the cake, as chicken excreta will remain on the surface. Additional ventilation likely required to extract ammonia that is released
Moist and caked	Will requiring corrective action in the form of mechanical conditioning to break the cake. Will require additional ventilation to remove ammonia that is released.
Wet and clumping	Will require corrective action that includes adding dry friable litter to absorb moisture, as well as mechanical conditioning and ventilation to remove moisture and ammonia.
Wet and caked	Will require immediate corrective action that includes adding dry friable litter to absorb moisture, as well as mechanical conditioning and ventilation. This wet and caked litter may require removal and replacement with dry litter if the condition cannot be rectified.

7 Caking and litter conditioning

7.1 What causes caking

When litter works effectively, droppings are broken down into smaller pieces and are coated with litter particles and dust. This effectively increases the surface area of the excreta, which accelerates moisture loss and drying and reduces the stickiness of the litter (Dunlop & Stuetz, 2015). By contrast, if the litter surface is caked, excreta are smeared on the litter surface. Because moisture is not readily transferred to the litter below, there is sole reliance on evaporative removal from the litter surface and the droppings will stay wet for longer. When conditions in sheds do not favour drying (e.g. low air velocity and high humidity, which frequently occur at night) the damp manure layer grows on the surface, and the chickens will be in contact with it. The surface of this caked litter may eventually dry, in which case the caked litter forms a hard, dry crust on the litter surface. The energy and force required to break the manure down into a friable mixture are more than the chickens can manage. Therefore, mechanical intervention with a litter conditioning machine is necessary to return the litter to a dry and friable state.



Figure 11. Cake forms when the energy and force required to break the manure down into a friable mixture are more than the chickens can manage.

Caking of litter is more likely to occur when the moisture content of the litter is 30-45% (Carroll, 2012). Litter maintained at a moisture content of 15-30% is less likely to cake and will generally remain friable, without being dusty (Carroll 2012; McGahan and Tucker 2002). Maintaining litter in a friable condition allows chickens to incorporate fresh excreta into the litter and aerate the litter as they move around, whereby they essentially act as the turning devices as they scratch and forage (Dunlop & Stuetz, 2015).

Another factor that drives the rate of caking is the particle size and shape of the bedding material. Particles 'bridge' or 'mat over' at an accelerated rate when bedding particles are more than 25 mm. The type of bedding material also contributes to the severity of caking. Using pine shavings as litter can reduce the severity of caking, whereas other materials such as straw, rice hulls, wood fibre, bagasse and pine needles cake more severely (Dunlop et al., 2016).

As previously discussed in Section 5, effective shed ventilation and management, as well as managing the factors that unnecessarily add water to the litter, are critical. (Section 5.5). These factors are also paramount to managing litter moisture and reducing caking.

7.2 Litter conditioning and de-caking

De-caking and litter conditioning are practices used to reduce litter caking by breaking it up or removing it from sheds, which improves friability at the litter surface. De-caking is a management practice that removes the caked layer from sheds and leaves the friable litter (especially when using a purpose-built litter de-caking machine). Litter turning and mixing (conditioning) is a mechanical process which chops the cake and combines it with friable litter. Both practices aerate the litter, which releases trapped moisture and gases (particularly ammonia). In cases where the moisture content of the litter is too high, caking may re-occur shortly after litter conditioning because the litter has lost the characteristics that allow it to be friable (Dunlop 2017).

Where the moisture content of the litter is too high, caking may re-occur shortly after litter conditioning because the litter has lost its friability.

De-caking is far more commonly used practice in the USA, where multi-use litter practices are widespread and where full litter clean-out may not occur for several years. This caked material will contain a greater manure component and less bedding material than spent litter removed during total cleanout. This material is potentially more valuable as an inorganic fertiliser due to it having higher nitrogen mineralisation rates following land application (Watts et al., 2012).

De-caking is conducted after each flock, with the cake separated from the litter by passing the cake and the dry litter materials over a grate. The grate allows fine materials to pass through and remain in the sheds, with larger aggregates of caked materials collected in a hopper for removal. Small quantities of fresh bedding material may be added to sheds prior to brooding to compensate for the amount removed with the cake (Sistani et al., 2003).

Ritz et al. (2017) recommend the removal of cake between flocks using de-caking, rather than litter conditioning. The removal of cake will get excessive moisture and manure out of sheds, rather than reincorporating it back into the litter. When wet caked material is not removed, it can contribute to more ammonia being released from the litter in the following flocks if the litter is reused.

The removal of caked material rather than conditioning and incorporation may be a better management practice, as it removes moisture from the shed, and may reduce ammonia release during subsequent flocks when litter is reused.

7.3 Managing caked litter guide

Why important: Caking of litter generally occurs when the moisture content of the litter increases to the point where the litter particles become sticky and cohesive and bind together. When this occurs, the surface of the litter compacts and the chickens are no longer able to incorporate their excreta into the litter.

Moist, sticky and compacted litter on the surface may occur rapidly and for short periods of time (a few hours during the night, or during short periods of rainy or humid weather). The full depth of the litter profile does not need to be wet for caking to commence.

Litter caking causes multiple problems, including increased ammonia and odour emissions. This increased ammonia can cause bird health and welfare issues and impact the health of workers. Increased odour emissions can cause off-site amenity impacts.

Litter conditioning and de-caking can be used to remediate caking.

Outcome: Litter is maintained in a friable state by remediating caking through effective litter conditioning and de-caking practices.

Performance measures: Litter surface is not sticky and compacted and chickens can actively work the litter.

Good housekeeping and effective ventilation, heating and humidity control manage litter moisture and reduce caking.

Best management actions:

- Ensure a suitable litter is selected and pre-treated (e.g. chopping/crushing) which exhibits the desired characteristics under operational conditions (Watson & Wiedemann, 2018).
- Follow the requirements listed in Section 6.4 to avoid unnecessary litter moisture. This may require regular conditioning to ensure excreta is blended into the litter when chickens fail to achieve this via their movement through the sheds and scratching and digging.
- If wet and caked litter cannot be incorporated and/or blended with dry bedding material to produce a dry and friable litter, the most suitable option may be to remove it from sheds and replace it with dry bedding material. Purpose-built machines are available to remove cake while leaving litter in sheds, but small areas of cake can be removed by hand or with manual tools, such as a shovel and wheelbarrow. Removed cake can be utilised in the same way as spent litter (see Section 11). Before utilisation, cake should be broken up/pulverised to ensure ease of spreading and to avoid non-uniform application rates on land.
- Small areas of wet or caked litter that can be successfully incorporated should be turned to aerate and dry the litter. This can be undertaken using manual tools, an automated rotary hoe, or a tractor fitted with attachments, such as a scarifier/harrow.

8 Litter pests and diseases

8.1 Darkling beetle

Alphitobius diaperinus is often referred to as the darkling beetle, with the larvae known as the lesser mealworm. The species is believed to have originated in the tropical east Africa region. It occurs naturally in bird and bat nests, where it feeds on droppings and animal parts such as feathers and carcasses (Lambkin, 2011). It is a common insect pest of meat chicken sheds, where it is mostly found in the litter. This is an ideal environment for this tropical species because the environment is warm and humid. Compacted earth floors provide a haven for the larvae after clean-out (Poultry Hub, 2020).

Compacted earth floors of meat chicken sheds provide an ideal haven for lesser mealworms between growth cycles.

The life cycle of the darkling beetle depends on a variety of environmental factors but is usually 40-100 days. Fifteen days after initial mating, females can lay 200-400 eggs every 1-5 days, with eggs taking less than one week to hatch as larvae. This means populations can increase rapidly without effective control (The Poultry Site, 2020).

All stages of the pest can act either as reservoirs or external carriers for serious avian/poultry diseases, including leucosis, Marek's disease, infectious bursal disease, reovirus, enterovirus, fowl pox, Newcastle disease and infectious laryngotracheitis. The pest can also act as an intermediate host for tapeworms and protozoans (Lambkin, 2011; Poultry Hub, 2020). It can cause serious economic losses in the chicken meat industry because it not only acts as a reservoir for the above avian diseases and parasites, it also destroys compacted earth floors and insulation materials within sheds. The pest is also known to transmit food-borne diseases and pathogens such as rotavirus, *Escherichia coli* and *Salmonella enterica* (serovar typhimurium), and has been implicated in the transmission of *Campylobacter* spp. (Lambkin, 2011).

Economic loss can occur through the pest consuming chicken feed, and when chickens feed on lesser mealworms in preference to provided feed. In this instance, the chickens' optimal nutritional requirements are compromised. In addition, if chickens feed on beetle larvae directly, it increases the likelihood of them ingesting disease organisms or parasites. (Poultry Hub, 2020). They will also reduce feed conversion rates by physically irritating chickens and generating skin lesions that could lead to downgrades at the processing plant.

Darkling beetles tunnel into the compacted earth floors of sheds, which reduces the effectiveness of cleanout (particularly if they tunnel under feed lines). They also tunnel into insulation, reducing its insulating value. This tunnelling behaviour causes the compacted earth floors to become perforated and hollowed. These hollows then retain spent litter at clean-out out time (Poultry Hub, 2020), reducing the effectiveness of clean-out and sanitisation.

The application of residual insecticides onto the floors and lower walls of sheds is the standard management method used in Australia. Three insecticides are mostly used: *Fenitrothion* (since the 1970s), *Cyfluthrin* (since about 1995), and *Spinosad* (registered for use in meat chicken sheds in early 2007) (Lambkin, 2001). Further work by this researcher revealed that the darkling beetle has become widespread and has developed high levels of resistance to fenitrothion and cyfluthrin in eastern Australia. He concluded that, because of the inadequacies of long-standing control practices and the prevalence of insecticide resistance, novel agents for their management are required. This has led to new and seemingly effective treatments that are formulated from Australian native essential oils.

Control of darkling beetle can be difficult as no acceptable field control strategies have been developed, and there has been little long-term success in controlling them. Research in Australia

has shown that the current standard industry insecticide is not effective when applied to meat chicken shed floors. This situation is exacerbated by strong and widespread insecticide resistance that occurs in meat chicken shed beetle populations (Poultry Hub, 2020). McGahan et al. (2014) reported that litter beetles are likely to cause increased problems when multi-use litter practices are used. Thus, good pasteurisation of multi-use litter is required to reduce populations between growth cycles. As with many pests, an integrated pest management approach is likely to be the most effective strategy. This would include effective insecticide application, pasteurisation of litter before reuse, total clean-out, or a combination of these.

Control of darkling beetles can be difficult, as no 'magic bullet' has been developed to fully control them.

Refer to the [extensionAUS website to view a video](#) on inspection and management of darkling beetles (AgriFutures Australia, 2020).

8.2 Flies

Flies are common in meat chicken sheds. While houseflies do not bite poultry, they can carry diseases. Effective manure management can reduce flies in and around poultry sheds. The moisture content of litter and spent litter needs to be dry to limit fly populations. Chemical control methods, such as residual sprays, baits and larvicides, can also be used to control flies. However, these should be considered a secondary option after good litter and spent litter management (Campbell, 2006).

The moisture content of litter and spent litter needs to be dry to limit fly populations. Chemicals can be used as a control method; however, they should be considered a secondary option after good litter and spent litter management.

In WA, stable fly breeding is a concern and local regulations need to be checked regarding spent litter storage and land application. The stable fly was declared a pest under the *Biosecurity and Agriculture Management Act 2007* in 2013. The Department of Primary Industries and Regional Development in Western Australia recommends that animal manure should be stockpiled for less than three days before covering with plastic, to protect it from getting wet. Alternatively, manure should be removed and used as a blend for compost or sprayed with insecticide to prevent fly development. For more guidance on reducing stable fly numbers, refer to Cook et al. (2018).

8.3 Pest management guide

Why important: Litter pests can have a significant economic impact on meat chicken production, including, but not limited to, infrastructure damage, spread of disease vectors, reduced FCR and the generation of skin lesions. Darkling beetles are a specific concern, particularly when multi-use litter practices are adopted. These pests can be difficult to control if an infestation occurs. An integrated pest management approach is needed to control them.

The use of certain insecticides can affect organic certification for the meat chicken farm and any end uses of litter.

Outcome: Pests are managed in sheds and spent litter via an integrated pest management strategy.

Performance measures: Prevalence of pests in meat chicken sheds and spent litter is minimised.

Manage pests through a program of inspection, good housekeeping and treatment.

In WA, stable fly is a declared pest under biosecurity legislation, and additional pest management measures may be required in some parts of the state.

Best management actions:

General

- Clean up feed spills immediately as these will supply a food source for darkling beetles and other pests.
- Litter pests can be controlled using suitable insecticides (taking chicken health and spent litter management requirements into consideration).
- If multi-batch litter practices are used, litter may need to be removed from sheds and replaced, to interrupt the pests' breeding cycles. Approved insecticides can be used to treat infested litter prior to spreading.
- Avoid stockpiling spent litter within 500 m of meat chicken production sheds, as it can offer a breeding site for manure beetles and other pests. It also poses biosecurity risks.

Darkling beetles

- Provide cement-based or cement-stabilised floors, as these reduce the potential for carryover of darkling beetle larvae between growth cycles.
- Repair floors damaged by beetles between growth cycles by re-compacting damaged areas.
- Keep litter dry and friable, as darkling beetles thrive in wetter litter. This includes repairing water leaks and removing wet litter from sheds. This also reduces the incidence of fly breeding.
- Use an integrated pest management approach to control litter beetles. This includes good housekeeping in the first instance, the use of chemicals and the regular inspection and resealing of shed floors.
- When using chemicals to control litter beetles, rotate the type based on active ingredients to avoid pesticide resistance.
- Only apply residual insecticides when sheds are empty and follow manufacturer specifications for withholding periods.
- Seal sheds following clean-out and treatment to minimise re-infestation between growth cycles.
- Where multi-use litter is practiced, ensure effective pasteurisation (see Section 10) between growth cycles. This may require the outside of the windrow/pile being incorporated and subjected to the pasteurisation process.

Stable fly

- Check and adhere to local regulations regarding spent litter storage and land application in WA, as it is a declared pest under the *Biosecurity and Agriculture Management Act 2007*.
- In WA, spent litter should be stockpiled for less than three days before covering with plastic to avoid it becoming wet. Alternatively, spent litter should be removed immediately from farm and used as a blend for compost, or sprayed with insecticide to prevent fly development.

Monitoring and recording

- Regularly monitor pest numbers and compare with previous checks. Act to minimise pest populations if they have increased.

9 Litter clean-out

9.1 Litter clean-out practices

The amount of litter and the interval between clean-outs will vary from farm to farm depending on the bedding material used and management practices adopted (e.g. multi-use). All meat chicken farms require a well-managed shed clean-out program to minimise the risk of disease transmission between growth cycles. During full clean-outs, any material that represents a risk to chicken health must be swept or vacuumed from sheds. Sheds (either part or whole) should then be washed with a biodegradable detergent.

In Australia, most spent litter is removed from the farm immediately after shed clean-out. The immediate removal is encouraged by processors to reduce the risk of disease transfer from one growth cycle to the next. This also reduces the risk of groundwater and surface water pollution on-farm, and the risk of dust and odour nuisance due to poor storage practices and use. Shed clean-out is mainly undertaken by contractors, who supply bobcats and front-end loaders. To reduce biosecurity risks, this equipment needs to be thoroughly cleaned and disinfected between each farm visit.

Most spent litter is removed from the farm immediately after clean-out,
which is encouraged by processors to reduce the risk of disease transfer
from one growth cycle to the next.

During clean-out, there is an increased risk of odour, dust and noise emissions from the farm, so shed clean-out needs to be carefully managed and timed to reduce these risks. Litter should not be excessively dry or wet at clean-out to reduce the potential for dust or odour to cause off-site impacts. If possible, schedule clean-outs when the impacts to close neighbours are minimal. Avoid early mornings, late afternoons and evenings when atmospheric dispersion is poor.

9.2 Litter cleanout guide

Why important: Litter clean-out practices in meat chicken sheds can depend on regulatory approvals, current industry welfare requirements or guidance, processor requirements, or third-party accreditation requirements.

The procedure for clean-out typically involves removal of spent litter (often by contractors who supply bobcats or loaders), sweeping or vacuuming remaining material, and washing sheds with detergents and sanitisers.

Odour and dust can be released while pushing up litter within sheds, while loading litter into vehicles or during transport. Disturbing litter during removal can release built-up gasses, which can be harmful to human health in high concentrations (inside the shed).

Outcome: Litter clean-out is managed to minimise odour and dust impacts on neighbours and to minimise the risk of disease transmission between growth cycles.

Performance measures: Spent litter is moist and friable at clean-out (20-30% moisture content on a wet basis) to aid in reducing off-site odour and dust impacts.

Best management actions:

Timing and communication

- Communicate the timing and duration of litter clean-out activities to relevant stakeholders (closest neighbours) to maintain good relationships and manage performance expectations.
- Conduct litter clean-out during favourable conditions (i.e. when the prevailing wind direction is away from sensitive receptors), and at favourable times of the day. The preferable time is between 9am and 3pm, as during late afternoons and early mornings:
 - atmospheric conditions are likely to be more stable, which causes odour to be trapped in the atmosphere and it will not disperse as readily
 - light wind conditions are more likely, which reduces the dispersion of odour
 - there is a higher likelihood of impacts at sensitive receptors.

Removal practices

- If litter is dusty at clean-out, use dust suppression equipment (e.g. water sprays), at loading.
- Minimise the height litter is released into the trucks to reduce dust emissions and blow-off.
- If washdown is conducted prior to litter removal, remove litter from the site before litter moisture causes odour problems. This will require having transport vehicles and handling equipment (loader/bobcat) onsite prior to completing the washdown.
- Ensure shed ventilation is sufficient to keep ammonia at safe levels during heaping and removal.

Loading and off-site removal

- Remove spent litter from the site following cleanout by loading it directly into transport vehicles parked adjacent to sheds without stockpiling litter near sheds.
- Immediately clean up any spillage of litter during loading and transport.
- Transport litter in appropriately covered vehicles, to minimise odour and dust emissions.

Monitoring and recording

- Record time and weather conditions during litter removal.
- Keep a record of the amount of litter removed and its destination.
- Consider providing a litter supply agreement form to 'warn and inform' contractors and end users of the restrictions and risks associated with spent litter. An example form is in Appendix D.

10 Litter reuse

10.1 Background

Litter can be reused for multiple grow-outs, as opposed to the most common practice in Australia of using new bedding for every growth cycle. As such, litter reuse reduces the requirement for new bedding materials. Litter reuse may be partial, where fresh bedding material is used for brooding, or full reuse, where brooding and grow out occur on reused litter.

Litter reuse is widespread in some countries (e.g. USA), but is not commonly practised in Australia. When it is, it is generally only partial reuse and only for 3-5 growth cycles. In the USA, litter is sometimes reused for several years, with full reuse for more than 15 growth cycles.

After a growth cycle, litter is generally heaped into piles or windrows (see Figure 12) before being re-spread in sheds. During this time, the litter should undergo a partial composting process called pasteurisation that generates heat via microbial activity. This in turn acts to kill pathogens and viruses that may be present in the litter. However, the effectiveness of this can be constrained by the time available between growth cycles. With partial reuse, new bedding is spread in the brooding area prior to placement of the next growth cycle. Reuse generally requires a longer break between growth cycles for the pasteurisation process to be effective. This can impose additional costs on the production system, including the need to vaccinate chickens for Marek's Disease. It may also result in fewer growth cycles due to the increased downtime between growth cycles.

Reuse will generally require a longer break between growth cycles than single use to allow sufficient time for the pasteurisation process to be effective



Figure 12. Australian meat chickens on reused litter; piling litter into a heap; and pasteurisation between batches (Wiedemann, 2015c).

In Australia, it is estimated that 86% of meat chickens are reared on single-batch litter, with the rest on partially reused litter (rather than full reuse, like the USA).

Growers tend to have contractual and/or planning approval conditions that dictate that their litter is managed as single use. Furthermore, a survey of growers identified that reusing litter may make it harder to comply with accreditation schemes and there is a perception that it will compromise meat chicken performance, welfare and health, as well as increase ammonia and odour emissions and impacts. This may also lead to increased management costs (Watson & Wiedemann, 2018). Although there is the potential for these problems to occur, the risk can be reduced with appropriate management.

10.2 Application in the Australian chicken meat industry

Reuse predominantly occurs in NSW and QLD with litter that started as sawdust or wood shavings bedding, or a mixture of both. Overseas, a wider variety of litter materials are reused, including shavings, sawdust, corn cobs, rice hulls and straw pellets.

Partial litter reuse has been successful in NSW and QLD for more than 30 years. It takes time to optimise systems and management practises but once established reduces costs without negatively impacting meat chicken health or productivity. Some consequences may require more management when reusing litter, such as in-shed ammonia concentration (see Sections 4.2 and 5.4). With appropriate monitoring and management, suitable levels of ammonia can be maintained for meat chicken production (Wiedemann, 2015c) and litter additives can also assist with reducing ammonia generation (see section 4.2). Pathogens associated with food safety and meat chicken performance and health can be managed via heaping or windrowing to partially pasteurise the litter between growth cycles (Wiedemann, 2015c). Detailed information on the principles, practices and procedures when under taking pasteurisation can be found in Laurenson et al. (2016), Walkden-Brown (2016a) and Walkden-Brown (2016b).

Partial litter reuse has been successful in NSW and QLD for more than 30 years, and although initially taking time to optimise systems and management practises, the practice reduces costs without negatively impacting meat chicken health or productivity

10.3 Practical and economic considerations

Watson and Wiedemann (2018) provided a summary of the practical consideration that need to be assessed before expanding the practice of litter reuse in the Australian chicken meat industry (Table 4). They demonstrated that litter reuse can be an economically attractive option if it is managed correctly, with large savings achieved when adopted over a several year cycle.

Table 4. Practical considerations of reuse litter application (Watson and Wiedemann, 2018)

Practical Considerations		Reuse
Supply	Commercially available in Australia?	Yes
Operation	Optimisation of product in an Australian context?	Would need to be optimised for each farm, and with each bedding type.
	Could it be available if demand was high?	Yes. With further research, reuse could be expanded to other regions and for different bedding types.
	What might it cost with high demand?	Very low cost
Management	Additional management practices needed?	Yes
Regulation	Regulatory/market barriers?	Some. Several growers identified that reusing litter may make it harder to comply with accreditation schemes and there is a perception that it will lead to meat chicken health, ammonia and odour issues, which may increase management costs. Although there is the potential for these problems to occur, they can be avoided with appropriate management practices. There may also be the need for vaccination against Marek's Disease.

10.4 Litter reuse guide

Why important: Litter can be reused for multiple growth cycles, as opposed to the common practice of changing the litter between each batch. As such, litter reuse reduces the need for new bedding. Litter reuse may involve partial reuse of litter between growth cycles, or full reuse of litter over multiple growth cycles.

Reused litter can lead to increased odour and ammonia emissions, and increased risks to meat chicken health, but this can be managed to reduce these potential risks.

Outcomes: Air emissions and meat chicken health and performance impacts associated with litter reuse practices are minimised.

Performance measures: Caked litter is not present in litter that is being reused.

If required by the integrator/processor, litter to be reused has been pre-treated via a pasteurisation process.

Reused litter meets the physical and contaminant standards of fresh bedding (e.g. moisture levels, ammonia levels, pathogen content).

Best management actions:

Treatment processes

- De-cake litter between growth cycles to improve quality.
- Remove heavily caked litter between growth cycles, with attention to areas under drinkers, feeders and air inlets.
- If pasteurisation of spent litter before reuse is required:
 - Push litter up into piles/windrows in the sheds to allow the material to partially pasteurise. Heat from the pasteurisation process will reduce pathogen load in the litter. Refer to Walkden-Brown (2016a) for details of practices and procedures to use in pasteurisation.
 - If the litter is too dry, add water to accelerate the pasteurisation process.
 - Leave until the litter temperature reaches 55 °C (typically three days).
 - Turn the outside of the piles or windrows into the centre to ensure this outer material also reaches 55 °C (typically a further three days).
- Consider the use of flame sanitisers on reused litter between growth cycles to reduce pathogens, insects and ammonia emissions.
- If acceptable shed ammonia levels (<20 ppm) cannot be achieved via ventilation, consider using litter amendments between cycles to release ammonia when the reused litter is spread.

Shed management and recording

- Spread the litter for reuse evenly following pasteurisation.
- If using partial litter reuse, provide new bedding in the brood end of sheds and a minimum of 5 m past the edge of the brooding curtain.
- Pre-heat and ventilate sheds before introducing chicks to reduce odour and ammonia emissions.
- Add additional new bedding if required to ensure the minimum depth requirements of approval conditions, farming schemes and processor requirements are achieved across the sheds. This will generally be a minimum of 50 mm.
- Replace or top-up reused litter if it fails to exhibit desired characteristics, such as appropriate porosity and the ability to adsorb/desorb water (refer to Section 6.1 for information on assessing these characteristics).
- Record the numbers of batches reused and any treatment processes used between batches

11 Spent litter utilisation

11.1 Introduction

A variety of uses for spent litter are available to growers. For detailed information on spent litter utilisation, refer to the report [Grower options for spent litter utilisation](#) (Wiedemann et al., 2015). Two extension publications have been developed from this publication relevant to spent litter utilisation:

- [Energy Recovery from Litter: A Guide for Users](#) (Wiedemann, 2015a)
- [Land application of Chicken Litter: A Guide for Users](#) (Wiedemann, 2015b).

Due to the varying environmental, biosecurity and economic impacts of different spent litter uses, it is important to choose the most beneficial outcome possible. Consult the National Farm Biosecurity Manual for Chicken Growers (ACMF, 2010) or later version to ensure that any solution meets biosecurity requirements.

Meat chicken sheds generate approximately 1.5 t (about 4-5 m³) of spent litter (litter containing manure) per 1000 chickens. It is a valuable and nutrient-rich organic fertiliser and soil ameliorant for crops and pastures. It must, however, be managed appropriately to reduce the risk of environmental and biosecurity impacts. Apart from nutrients, spent litter is a valuable source of carbon, but it can also contain metals (copper, zinc etc) and chemicals that were and remain present in the fresh bedding material. If present at unacceptable levels for the use proposed, the spent litter will require appropriate treatment and management.

Spent litter can generate odour and dust if not managed properly. Moisture content and litter handling practices contribute to odour and dust generation. If not managed properly, leaching of nutrients can impact soil and groundwater, and nutrient-rich surface runoff can impact waterways.

Meat chickens generate approximately 1.5 tonnes (about 4-5 m³) of spent litter per 1000 chickens. It is a valuable and nutrient-rich organic fertiliser and soil ameliorant for crops and pastures but must be managed appropriately to reduce the risk of environmental and biosecurity impacts

11.2 Land application of spent litter

11.2.1 Composition

The composition of poultry litter can vary greatly between chicken farms, and even within farms between growth cycles, in response to management decisions (stocking density and number of growth cycles), bedding material type and feed wastage. This makes predicting the average nutrient content of poultry litter difficult and the most accurate way is to analyse the batch supplied. Craddock and Hollitt (2010) provided the most comprehensive dataset on the characteristics of poultry litter in Australia. They collected and analysed 123 spent litter samples from a variety of bedding materials for their chemical properties (Table 5). Ranges in this data have a two-to-three-fold difference for some constituents, so end users are encouraged to understand the make-up of the product they use.

Table 5. Chemical properties (dry weight basis) of spent litter from different bedding materials (average and range) (adapted from Craddock & Hollitt, 2010)

Element	Straw (n = 28)	Sawdust (n = 28)	Wood shavings (n = 65)	Multi-batched (n=4)
Moisture (%)	20 (15-25)	25 (20-29)	26 (21-31)	21 (21-22)
Total N (% db)	4.0 (2.0-5.3)	3.8 (2.8-5.9)	3.9 (2.8-5.5)	4.0 (3.6-4.3)
Total P (% db)	1.1 (0.7-1.8)	1.2 (0.8-1.5)	1.3 (0.7-1.7)	1.7 (1.3-2.0)
Potassium (% db)	2.2 (1.6-2.8)	1.8 (1.3-2.5)	1.9 (1.1-2.8)	2.4 (1.9-2.7)
Sulphur (% db)	0.63 (0.5-1.1)	0.54 (0.4-0.7)	0.51 (0.3-0.7)	0.58 (0.5-0.8)
Zinc (% db)	0.04 (0.02-0.05)	0.04 (0.03-0.05)	0.04 (0.03-0.04)	0.05 (0.04-0.07)
Copper (% db)	0.02 (0.01-0.02)	0.02 (0.01-0.02)	0.01 (0.01-0.03)	0.01 (0.01-0.02)
Manganese (% db)	0.05 (0.04-0.08)	0.04 (0.03-0.06)	0.05 (0.04-0.08)	0.07 (0.06-0.07)

Nitrogen loss via ammonia volatilisation will also change the nitrogen levels of spent litter. The amount lost will depend on a variety of interactive factors, however the litter will lose nitrogen if it is stockpiled, composted or reused for multiple growth cycles. The storage conditions and management will influence the amount of nitrogen lost as ammonia. For example, wetter litter or litter that is turned will lose more ammonia via volatilisation. Barker (1990) reported total nitrogen losses of 17-30% from various litter treatments (stacking, covered and uncovered piles).

A survey of growers (Watson & Wiedemann, 2018) found that the nutrient concentration of spent litter has declined over time. This has been due to lower meat chicken density and minimum litter depth requirements in accreditation schemes, essentially a dilution effect. This has reduced the nutrient value and sale price of spent litter as a fertiliser. The price of synthetic fertiliser will also impact the price of spent litter.

Further nitrogen losses will occur during land application of spent litter. How and when it is applied, and storage conditions prior to application, will affect the amount lost as ammonia. If spent litter is spread on the surface of a soil and not incorporated or washed into the soil, significant quantities of nitrogen will be lost via volatilisation (Griffiths, 2007). Losses are typically 15-50% of the ammonium fraction (5-20% of total nitrogen) when poultry litter is surface applied (Mitchell & Donald, 1995).

11.2.2 Uses and application

Most spent litter is used in the agricultural sector (e.g. pastures, turf farms, market gardens, broadacre cropping, horticulture and mushroom farms). Some poultry producers have diversified farms and use their litter for soil improvement and/or as fertiliser for crops and pastures. A component of spent litter also goes to compost and organic fertiliser manufacturers for additional processing and resale. Most growers are responsible for acquiring their bedding material and the subsequent spent litter sales/uses. In some instances, the chicken meat processing company will supply clean litter and handle spent litter sales.

As Griffiths (2007) noted, you need observation, a soil test and a nutrient budget to determine what rate of spent litter to apply and to check that you are getting the desired result. For additional guidance on preparing a nutrient management plan to ensure sustainable application rates, refer to the AgriFutures Australia project PRJ-011090 [‘Development of National Guidelines for the Meat Chicken Industry’](#).

A good rule of thumb when applying spent litter is to treat it as a phosphorus fertiliser, not a nitrogen fertiliser. If you apply spent litter to crops or pastures to meet their nitrogen requirements, you will likely over-apply phosphorus and risk losing phosphorus to the environment.

For pastures

The amount of litter to apply to pastures will depend on a variety of factors. As Griffiths (2007) stated, this will depend on the soil type, existing soil nutrient levels, crop requirements and the amount of nutrient being removed in animal products, silage or hay. This applies to crops, where the nutrient removal will be via grain and potentially straw. Using sawdust-based spent litter from Table 5 as an example, an application rate of 6 t/ha (wet weight) is equivalent to 15 m³/ha at a bulk density of 400 kg/m³. This would represent an application rate in kg/ha of 171 nitrogen, 54 phosphorus, 81 potassium and 24 sulphur.

Griffiths (2007) recommended for pasture production that soil testing be conducted to identify any phosphorus deficiency. Where extra phosphorus is needed, apply spent litter for two or three years if developing highly productive pastures, then soil test again to check that phosphorus has risen to the desired level. To maintain soil fertility, alternate one year of litter with one year of nitrogen or potassium fertiliser if required. On less-productive dry land or grazing paddocks, the same principle applies but less litter or fertiliser may be required to maintain target fertility levels. Similar principles to this can be used for cropping.

Warn (2013) conducted a study to investigate the value of spent litter as an alternative fertiliser source for pastures in Victoria. Some of the key findings were:

1. Broadcasting spent litter onto pastures can give similar pasture growth responses to conventional fertilisers.
2. In soils with adequate phosphorus levels, pasture responses were mainly due to nitrogen. In the short-term, it is more-cost effective to apply nitrogen (urea) alone rather than litter, based on the prices of spent litter and synthetic fertiliser at the time of the experiment.
3. Soil phosphorus levels and plant tissue levels of potassium increased with increasing rates of either product. Plant tissue levels of copper and molybdenum also increased with increased rates of litter. These elements/heavy metals were still at acceptable levels in soils and plant tissue where very high rates of litter were applied.
4. Soil organic carbon increased by 0.4-0.5% in the topsoil where high rates of litter were applied relative to the Control (nil fertiliser).
5. Spent litter had a positive effect on pasture composition, promoting clover and improved perennial grass content.

For crops

Assessing the value of spent litter as an inorganic fertiliser replacement was undertaken in broadacre, dryland wheat production in SA (Craddock & Hollitt, 2010). From their studies, they recommend rates of 2.5-3 t/ha (depending on nutrient content) to build soil reserves and rates of 1-2 t/ha for maintenance applications. They concluded that poultry litter is a useful source of nutrients for broadacre crop production, with the value to grain growers being dependent on the comparative cost of key nutrients in synthetic fertilisers. The authors recommend poultry farmers provide litter analyses and application advice to assist setting a competitive price for litter, depending on fertiliser values.

From dryland wheat production studies in South Australia, it is recommended that rates of 2.5-3 t/ha of spent litter be applied to build soil reserves and rates of 1-2 t/ha for maintenance applications. To gain the best value and ensure sustainable application, it is recommended that poultry growers provide litter analyses and application advice. This will assist setting a competitive price for litter depending on fertiliser values

The application of spent litter can enhance land productivity by not only improving a soil's nutrient status, but also its structure and organic carbon levels. However, it can also cause a range of soil degradation problems if poorly managed. Most of these concerns, such as elevated levels of environmentally relevant nutrients (e.g. nitrogen and phosphorus) and elevated heavy metals, are only applicable if too much litter is applied. Devereux (2012) conducted a study to determine nitrogen and phosphorus losses from farms applying spent litter to a variety of crops. The study concluded that the best strategies to minimise nutrient losses were to:

1. Use well-designed vegetative filter strips as close to the source as possible to reduce runoff loss once phosphorus has mobilised in runoff.
2. Apply spent litter to match but not exceed the crop phosphorus requirements, as opposed to nitrogen requirements. This reduced phosphorus runoff losses by 37-47% and prevented excess phosphorus accumulation in the top 10 cm of the soil.

11.2.3 Most suitable land for application

The best soils for the application of spent litter are deep, well-structured and well-drained clay loams (McGahan et al., 2015). These are more suitable than highly permeable sands and impermeable heavy clays. Shallow soils with significant amounts of rock and gravel or soils with a high salt content should also be avoided. Soils with higher clay content are better able to store nutrients, while sandy soils are more susceptible to nutrient leaching.

When selecting areas for spent litter application, consider the following:

1. Avoid land immediately adjacent to watercourses. Most separation/buffer guidelines will specify minimum separation distances, with the risk of nutrient loss being dependent on a variety of factors, including groundcover, erosion potential (rainfall erosivity), groundcover, slope, runoff convergence potential. The planting of appropriate vegetative filter strips is useful to intercept nutrients.
2. Avoid land subject to frequent flooding.
3. Avoid steep slopes with inadequate groundcover. Slopes greater than 10% should be avoided.
4. Avoid rocky, slaking or highly erodible land.
5. Avoid highly impermeable soils.

The best soils for the application of spent litter are deep, well-structured and well-drained clay loams. Shallow soils with significant amounts of rock and gravel or soils with a high salt content should be avoided. Soils with higher clay content are better able to store nutrients, while sandy soils are more susceptible to nutrient leaching

11.2.4 Contaminant hazards

11.2.4.1 Chemicals

Parkinson et al. (1999) determined the concentration of a large range of organochlorines and organophosphates in spent litter samples from nine meat chicken farms. From this work, only one sample had levels above detectable limits, which was for traces of DDE and p,p'-DDT. Pesticide and insecticide residues can be detected in materials used for bedding that have been grown on soils containing these residues. Therefore, growers and end users need to be aware of the restrictions that apply for spent litter that contains pesticide and insecticide residues (Wiedemann et al., 2015). To ensure material is not contaminated, growers should regularly communicate with suppliers about the origin of bedding. If the levels of contaminants in spent litter exceed jurisdictional requirements, it

may be useful to have the feed analysed to ensure pesticides and insecticides are not entering the litter through excreta.

Soils containing pesticide and insecticide residues can allow transfer of these residues to bedding material, so growers and end users need to be aware of the restrictions that apply for spent litter that contains residues. Growers should regularly communicate with suppliers about the origin of bedding material and ask for a commodity declaration when obtaining litter

11.2.4.2 Heavy metals

Spent litter and composted farm by-products can also contain other contaminants such as metals (copper, zinc, cadmium etc), which may limit the application rate. The contaminant levels in spent litter are generally well below the maximum acceptable limits set by various state guidelines (see Table 6), except for copper and zinc. But because many Australian agricultural soils are deficient in copper and zinc, this is unlikely to be a concern. Therefore, heavy metals will exist in the soil at safe levels at application rates that meet plant phosphorus requirements (Wiedemann et al., 2015). Soil testing is recommended if regular applications are made to the same paddocks to ensure there is no build-up of heavy metals.

The levels of heavy metals in spent litter are well below the maximum acceptable limits set by various state guidelines, except for copper and zinc. As many agricultural soils are deficient in copper and zinc, this is unlikely to be a concern. Therefore, heavy metals will exist in the soil at safe levels at application rates that meet plant phosphorus requirements.

The Fresh Produce Safety Centre (2019) highlighted cadmium as the heavy metal of most concern to fresh horticultural produce, particularly when used on root and tuber vegetables (e.g. carrots, beetroot, some potato varieties), as well as leafy vegetables and fresh herbs (e.g. spinach, silverbeet). Its uptake can also be increased in soils that are very sandy, saline or irrigated with salty water, acidic, low in zinc, or lacking organic matter. However, Craddock & Hollitt (2010) found levels of cadmium in a variety of spent litter samples well below the Class 1 (unrestricted use) category documented in various guidelines, so this is unlikely to pose a risk when utilising spent litter.

Cadmium levels are the most concern to fresh horticultural produce; however, the levels found in spent litter are well below the Class 1 (unrestricted use) category documented in state guidelines.

Table 6. National and state limits for heavy metals in compost and sewerage biosolids

Concentration (mg/kg db)	NRMCC (2004) ¹	AS 4454 (2012) ²	NSW EPA (1997) ³	EPA VIC (2004) ⁴	EPA SA (2017) ⁵	DPIWE (1999) ⁶	DEC WA (2012) ⁷	QLD (2019) ⁸	Craddock & Hollitt (2010) ⁹
Arsenic (As)	20 (60)	20	20	20 (60)	-	20 (20)	-	20	1.8 – 5.4
Boron (B)	-	100	-	-	-	-	-	-	
Cadmium (Cd)	1 (20)	1	3 (20)	1 (10)	1 (11)	3 (20)	1 (20)	3 (20)	0.02 – 0.06
Chromium Total (Cr)	100-400 (500-3000)	100	100 (500)	400 (3000)	-	100 (500)	-	100 (500)	1.7 – 3.5
Chromium VI (Cr VI)	-	-	-	-	1 (1)	-	1 (1)	-	
Copper (Cu)	100-200 (2500)	150	100 (2000)	100 (2000)	100 (750)	100 (1000)	100 (2500)	150 (2000)	124 - 147
Lead (Pb)	150-300 (420)	150	150 (420)	300 (500)	-	150 (420)		150 (420)	0.06 – 1.4
Mercury (Hg)	1 (15)	1	1 (15)	1 (5)	-	1 (15)		1 (15)	
Nickel (Ni)	60 (270)	60	60 (270)	60 (270)	-	60 (270)		60 (270)	2.1 – 7.7
Selenium (Se)	3 (50)	5	5 (50)	3 (50)	-	-		5 (50)	
Zinc (Zn)	200-250 (2500)	300	200 (2500)	200 (2500)	200 (1400)	-	200 (2500)	300 (2500)	360 - 538

Note: Limits presented are for Class 1 grade (unrestricted use) and, in brackets, Class 2 grade (agricultural use, forestry, land reuse). Check each state's guidelines for definitions.

1. NRMCC (2004) Guidelines for sewerage systems biosolids management

2. AS 4454 (2012) Composts, soil conditioners and mulches (draft for public comment) (AS 4454)

3. NSW EPA (1997) Environmental guidelines: Use and disposal of biosolids products

4. EPA Victoria (2004) Guidelines for environmental management – Biosolids land application

5. EPA SA (2017) Draft South Australian biosolids guideline for the safe handling and reuse of biosolids

6. DPIWE (1999) Tasmanian biosolids reuse guidelines

7. DEC WA (2012) Western Australian guidelines for biosolids management

8. State of Queensland (2019) End of State Code: Biosolids (ENEW07359617) – 2020

9. Craddock & Hollitt (2010) values are the range of average values found in four litter types – straw, wood shavings, sawdust and multi-batch.

11.2.4.3 Pathogens

Raw spent litter can contain pathogens that may limit its end use, particularly on horticultural crops for direct human consumption, such as leafy vegetables. The level of risk generally depends on the period between applying the spent litter and harvesting the crop. Nicholas et al. (2007) listed a variety of factors that affect the survival of pathogens in the environment outside their host after land application, including:

1. the presence, quantity and viability of the organism
2. method of application (surface or incorporation)
3. solids content of amendment (solid or liquid)
4. soil conditions, such as permeability, infiltration, soil moisture, texture, pH
5. climate exposure (especially temperature and UV light)
6. the presence of competitive organisms in the soil (Epstein et al., 2002, cited in Nicholas et al., 2007).

From the variety of pathogens that may be present in spent litter and relevant to animal/human health, Runge et al. (2007) categorised the following pathogens into high and medium-risk categories:

- *Campylobacter jejuni* (high)
- *Clostridium botulinum* (high)
- *Salmonella* spp. (high)
- *Cryptosporidium* spp. (medium)
- *Listeria* spp. (medium)

For most crops and pastures, Chinivasagam, (2008) found that simple precautions will reduce health or food safety risks associated with chicken litter application, with stockpiling found to achieve effective pathogen destruction.

The risk of pathogen transfers to grazing or foraging livestock on pasture/forage that has received spent litter depends on treatment processes and the livestock withholding period after application (Runge et al. 2007). They suggested that using spent litter for forage production poses negligible risk to livestock due to the time period between application and harvest.

Spent litter should be managed to minimise risks to personnel handling the material during spreading, with the main risk being via ingestion of material contaminated by litter. Risks can be minimised by ensuring high standards of personal hygiene when handling litter and avoiding very dusty and windy conditions.

Pathogen risk with horticultural crops

The risks associated with pathogens contained in spent litter primarily relate to contamination of food products with spent litter that are subsequently ingested by humans. Hence, the greatest risk relates to leafy vegetables that are consumed fresh. Refer to the Guidelines for Fresh Produce Food Safety 2019 (FPSC A-NZ, 2019) for information regarding the application of organic manures. Some recommendations include:

- The period between application of products containing manure and crop harvest should be as long as possible.

- Untreated manure must not be used on growing sites within an exclusion period of 45 days from harvest for most vegetables. This period should be 90 days for vegetables like rockmelon and lettuce, where the outer layer comes in contact with the ground.
- Manure may be used within the exclusion limits if subjected to a treatment verified to achieve *E. coli* <100 cfu/g and *Salmonella* Not Detected/25g.
- To prevent dust or runoff contaminating adjacent crops, ensure untreated manure is not applied in rainy or windy conditions and is incorporated into the soil after application.
- Manures are considered treated if they have been subjected to the times and temperatures proven to kill human pathogens. Evidence must be obtained when purchasing treated fertilisers and soil additives from a supplier, such as a certificate confirming that compost has been treated in accordance with Australian Standard AS 4454-2012 (Australian Standards, 2012). This standard specifies that:
 - The materials must be kept aerated and outer layers turned into the centre
 - Piles must be heated to $\geq 55^{\circ}\text{C}$ for three consecutive days
 - For windrows, the materials must then be turned, and the heating process repeated four more times to ensure all materials are thoroughly treated.

11.2.5 Restricted uses

State and industry biosecurity guidelines generally require withholding periods (generally 21 days) following the application of spent litter and composted litter prior to grazing and crop production. Spent litter containing dead chickens or parts of chickens should not be spread on pastures used for grazing. This is to ensure that dead chickens or feathers are not eaten by stock, due to the risk of botulism. Botulism occurs in animals that ingest the neurotoxin produced by the growth of the organism *Clostridium botulinum*, which can occur if chickens are left to decay anaerobically. *Clostridium botulinum* is a serious animal and food-borne pathogen, with affected stock becoming paralysed and usually dying.

State and industry biosecurity guidelines require withholding periods (generally 21 days) following the application of spent litter and composted litter prior to grazing and crop production. Spent litter containing dead chickens or parts of chickens should not be spread on pastures used for grazing to ensure that dead chickens or feathers are not eaten by stock, due to the risk of botulism.

Spent litter is also likely to contain waste poultry feed that often has restricted animal material (RAM), i.e. meat meal, as an ingredient. In Australia, it is illegal to feed animal-derived meal to ruminants or allow them access to it. This is to reduce the risk of spreading exotic animal diseases, such as *Bovine spongiform encephalopathy* (BSE). Thus, livestock must not be allowed access to spent litter. Spent litter may also contain dead chickens or feathers and must not be eaten by stock due to the risk of botulism.

Livestock must not be fed or have access to spent litter, whether raw or composted. Ruminants are not allowed access to restricted animal material (RAM), i.e. meat meal, that could be in the litter from spilt feed. Botulism toxins from poultry carcasses that may have decomposed anaerobically in the litter also pose a risk to livestock

Limitations also exist in WA regarding the use of raw spent litter, due to problems with stable fly breeding (see sections 8.2 and 8.3). Consequently, composting or transport to regions where

untreated spent litter can be used is required. This affects several shires and city councils on the Swan Coastal plain, from Gingin to Harvey.

11.2.6 Additional guidance

Additional guidance on land application of spent litter, including sustainable application rates, can be found in [Land Application of Chicken Litter: A Guide for Users](#) (Wiedemann, 2015b). It is important that end users of spent litter are aware of this information. An example form that contains information for end users can be found in Appendix D – Example agreement for the removal and utilisation of spent litter from a meat chicken farm.

11.3 Other options to utilise and treat spent litter

11.3.1 Energy recovery from spent litter

Spent litter is potentially a valuable source of energy, however recovery of this additional value has generally not been adopted by the Australian chicken meat industry. Energy recovery from biomass is not a new concept and public interest and research attention has grown in the past 20-30 years due to increasing energy costs and the GHG emissions generated from the combustion of fossil fuels. Spent litter has a relatively high energy value and low moisture content compared with many other organic by-products, making energy recovery a potentially viable option.

Energy recovery has the benefit of depleting the carbon content (energy value) of the spent litter, which results in a more concentrated fertiliser product. This reduction in carbon does, however, reduce the soil amelioration properties of spent litter.

Research has been conducted to investigate energy recovery options for poultry litter by McGahan et al. (2010) and Playsted et al. (2011). These reports included details on energy recovery technologies applicable to poultry litter, including pyrolysis (and biochar production), combustion, gasification, anaerobic digestion and others. Many of these technologies are in the development phase, particularly with regard to their use of poultry litter.

Carbon is the energy provider in poultry litter and usually comprises 28-40% (Playsted et al. 2011). Total carbon in poultry litter is comprised of carbon originating from the bedding portion and carbon from manure. Carbon from these two sources have quite different properties, particularly with respect to energy recovery. Carbon content is especially important for understanding different energy recovery systems, and substantial errors can be made when researchers and designers do not understand the differences between the manure and bedding components.

When discussing the energy content of a substance, the organic materials within the litter are described using the term volatile solids (VS) content. A simple theoretical mass balance by Playsted et al. (2011) for a single batch of poultry litter (10.5% ash) estimated that the proportion of VS derived from manure was 55%, while 45% came from the litter. This is important, for example, when investigating potential energy recovery using anaerobic digestion. In this process, most of the litter component will not be readily digested and hence little energy will be derived from it.

The heating value or energy value of a substance is the amount of heat released during the combustion of a specific amount of that substance. The energy content of spent litter is reported in terms of megajoules (MJ) per kilogram of material on a *dry basis*. The higher heating value (HHV) is usually reported. The energy content of single batch poultry litter in Australia is estimated to be 17.5 MJ/kg (HHV) (Playsted et al. 2011).

11.3.2 Composting spent litter

Composting is a treatment option that can reduce the volume of spent litter, change the nutrient composition, pasteurise weed seeds and pathogens, and reduce odour generation compared with raw litter and anaerobic stockpiles. Composting is the managed breakdown of an organic material using aerobic bacteria. The aerobic bacteria used in composting require a constant source of oxygen and produce heat throughout the decomposition process, and therefore regular conditioning of the compost is required. Along with oxygen, the nutrient composition (particularly the carbon:nitrogen ratio) and moisture content of the compost also affect the performance of the composting process and must be carefully managed.

The Australian Standard AS 4454-2012: Composts, soil conditioners and mulches (Australian Standards, 2012) details the physical, chemical, biological and labelling requirements for materials that are specified as a “compost”. One of the primary objectives of the standard is to facilitate the beneficial recycling and use of compostable organic materials with minimal adverse impact on environmental and public health. It details best practice guidelines on composting materials, including desired temperature, turning and testing requirements.

11.4 Spent litter utilisation guide

Why important: Spent litter can be used in a variety of ways, although most spent litter produced in Australia is used as a fertiliser in broadacre cropping, horticulture and dairy farms production. Some product also goes to commercial composters and organic fertiliser manufacturers for further processing.

When deciding on spent litter use strategies, consider options that extract the most value from the product and ensure any risks posed due to odour, dust, nutrients, chemicals, pesticides, pathogens, biosecurity and restricted uses are minimised.

Outcomes: The nutrient and carbon value of spent litter is optimised in a manner that minimises any potential environmental impacts.

Performance measures: The beneficial properties (i.e. carbon, nutrients) of spent litter have been considered prior to sale or use. This might mean using it on soils that benefit most from its carbon value, or converting the carbon to energy in waste-to-energy systems.

The by-products produced from further processing of spent litter (e.g. digestate, incinerator ash, and compost) are managed in a way that does not impact the environment (amenity, soils, water resources etc).

Best management actions:

Composition

- To ensure spent litter is not contaminated, growers should regularly communicate with suppliers about the origin of clean bedding and request a commodity declaration.
- If levels of contaminants are found in spent litter that exceed jurisdictional requirements that are applicable to its end use, it may be useful to have the feed analysed to ensure pesticides and insecticides are not entering the litter via this pathway.
- Supply information to end users on the constituents of spent litter and risks and restrictions associated with its use. This can be in the form of a chemical analysis or fact sheet on typical industry values. [Land Application of Chicken Litter: A Guide for Users](#) (Wiedemann, 2015b) contains useful information that can be supplied to end users on the safe and sustainable use of spent litter.

Storage and Composting

- Where spent litter is stored or composted, it should be done on an impermeable base that is concrete or a 300 mm layer of compacted clay (comprised of two 150 mm compacted layers) that has a design permeability of at least 1×10^{-9} m/s. Detailed information on achieving this are available from DAF Queensland. Ensure state or local government requirements regarding storage and composting are met.
- If treating spent litter and producing a product that is claimed to be “composted”, ensure it meets the minimum requirements of the Australian Standard AS4454-2012 (Australian Standards, 2012).
- When spent litter is composted, it should be maintained in an aerobic condition to avoid excessive odour generation. This will mean maintaining optimum moisture levels and turning regularly (or using aerators to provide oxygen).

Environmental hazard mitigation

- Avoid application of litter close to open waterways and maintain a vegetative filter strip (VFS) between cropping areas and waterways. A well-designed and maintained VFS located as close to the application site as possible will reduce phosphorus losses once phosphorus has been

mobilised in runoff. Note that a VFS may become ineffective with high application rates and excessive stormwater runoff. Details on designing and maintaining VFSs can be found in the AgriFutures Australia project PRJ-011090 '[Development of National Guidelines for the Meat Chicken Industry](#)'.

- Avoid application on steep slopes (>10%) and drainage features in the landscape where the material may be carried with runoff, particularly when these areas are near open waterways, as most runoff is via drainage features/depressions.
- Carefully manage applications on permeable soils, particularly in groundwater recharge areas.
- Ensure spent litter or composts used for spreading are in a moist and friable condition to minimise odour and dust generation and subsequent impacts.

Nutrient management plans

- When raw spent litter or compost product is used on crops and pastures, ensure it is applied at sustainable rates to avoid negatively impacting water resources (ground and surface) and soils. This is best achieved via a well-designed nutrient management plan (NMP) or fertiliser management plan to reduce the risks of nutrient runoff and leaching. Detailed information on how to develop an NMP can be found in material developed for AgriFutures Australia project PRJ-011090 '[Development of National Guidelines for the Meat Chicken Industry](#)'.
- Use litter to supply pasture or crop phosphorus requirements, rather than as a nitrogen fertiliser/source. Because litter is not a balanced fertiliser, applying it as a nitrogen source will likely result in the over-application of phosphorus. Applying spent litter to match crop phosphorus removal, as opposed to nitrogen removal, can substantially reduce phosphorus runoff and prevent excess phosphorus accumulation in the surface soil. This does not mean that application each year should meet the amount removed. Different soils have different capacities to store/bind phosphorus, and this affects the amount of phosphorus available to plants. Building phosphorus-deficient soils up to sustainable agronomic levels and/or applying three years of phosphorus requirements in three-year rotations are acceptable practices provided excess available phosphorus does not accumulate in the soil surface and is lost in runoff.
- Additional inorganic nitrogen fertiliser, e.g. urea and potash, may need to be applied to meet crop nitrogen requirements in intermediate years.
- In soils with adequate phosphorus levels, it may be more-cost effective to apply inorganic nitrogen fertilisers rather than spent litter. This will also reduce the risk of potential nutrient loss to the environment.

Horticultural crop management

- The period between application of spent litter and crop harvest should be as long as possible.
- Untreated spent litter must not be used on growing sites within an exclusion period of 45 days from harvest for most vegetables. This period should be 90 days for vegetables like rockmelon and lettuce, where the outer layer comes into contact with the ground.
- Alternatively, spent litter may be used within the exclusion limits if subjected to a treatment verified to achieve *E. coli* <100 cfu/g and *Salmonella* Not Detected/25g.
- Ensure untreated spent litter is not applied in rainy or windy conditions and is incorporated into the soil after application to prevent dust or runoff if applied adjacent to high-risk crops.
- Spent litter is considered treated if it has been subjected to the times and temperatures proven to kill human pathogens. Before using, obtain evidence from supplier to substantiate treatment process, such as a certificate confirming that compost has been treated in accordance with Australian Standard AS4454-2012 (Australian Standards, 2012).
- Refer to the Guidelines for Fresh Produce Food Safety 2019 (FPSC A-NZ, 2019) for detailed information on applying raw and composted spent litter to horticultural crops.

Restricted uses of spent litter

- Livestock must not be fed or have access to spent litter, whether raw or composted. Ruminants are not allowed access to RAM (i.e. meat meal, that could be in the litter from spilt feed). Botulism toxins from poultry carcasses that may have decomposed anaerobically in the litter also pose a risk to livestock.
- Be aware of state and chicken meat industry biosecurity and manure use guidelines, as the application of spent litter and compost may be limited or require withholding periods in areas used for grazing or crop production.
- Check and adhere to local regulations regarding spent litter storage and land application in WA, as stable fly is a declared pest under the *Biosecurity and Agriculture Management Act 2007*.
- In WA, spent litter should only be stockpiled for less than three days before covering with plastic to avoid it becoming wet. Alternatively, spent litter should be removed immediately from farm and used as a blend for compost, or sprayed with insecticide to prevent fly development.
- Livestock should be kept off pasture following spent litter application for long enough to ensure that ruminants can no longer access it via grazing.

Testing, recordkeeping and ‘warning and informing’

- Keep records of any spent litter sales, including dates, recipient details and destinations.
- Inform contractors and end users of the risks and restrictions associated with the use of litter. An example form can be found in Appendix D – Example agreement for the removal and utilisation of spent litter from a meat chicken farm.
- When spent litter is to be used in crop production with higher risks (e.g. horticulture industry), have spent litter tested annually for nutrients, pathogens and heavy metals and check levels of metals against state and industry guidance. More frequent testing is required if changes are made to the production system or litter material.
- Limitations exist in WA regarding the storage and use of raw spent litter, due to problems with stable fly breeding. Refer to regulations in that state for information about restrictions.

Alternative uses and additional best practice information

- Operate anaerobic digester in accordance with the parameters specified by the manufacturer to ensure efficient operation and adhere to relevant workplace health and safety requirements.
- Additional guidance on land application of spent litter, including sustainable application rates, and typical nutrient and heavy metal contents of spent litter, can be found in the [Land Application of Chicken Litter: A Guide for Users](#) (Wiedemann, 2015b).

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Appendix A – The role of litter in the Australian chicken meat industry

Industry growth and location

Australia’s production of chicken meat has increased by more than 160% over the past 20 years. Chicken meat is now Australia’s most significant source of meat protein, with 90% of the population consuming chicken meat at least once a week (ACMF, 2014). As there is minimal import or exports of chicken meat in Australia, effectively all chicken consumed in Australia is locally produced. The Australian Chicken Meat Federation (ACMF) forecasts a continual, steady growth in domestic production and consumption of Australian chicken meat (ACMF, 2011), which is supported by ABS statistics as shown in Figure 13.

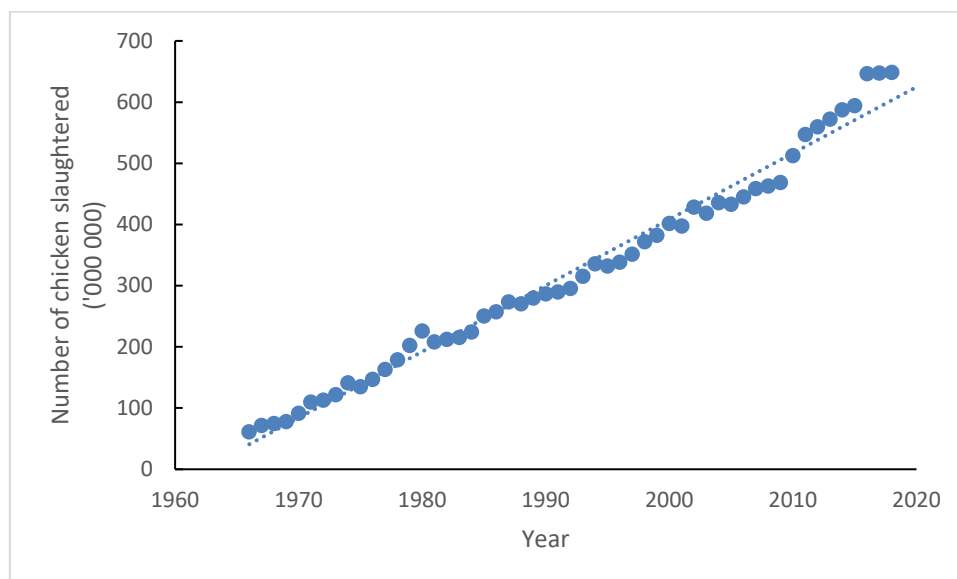


Figure 13. Australian chicken production (ABS, 2016 – 7121.0 Agricultural Commodities) with dotted trend line.

The Australian chicken meat industry is largely integrated, and companies own or control most aspects of their supply and production chain. Large chicken meat companies may have breeder farms, hatcheries, chicken meat farms, processing plants, feed mills and laboratories. Smaller companies will have some of these facilities and use third parties for others. The larger Australian chicken companies sub-contract the growing stage of production. Chicken meat growing farms are generally located within 200 km of a processing plant, near a feed mill, with guaranteed water, power and access to services. The region where chicken meat is produced dictates the availability, type and cost of litter that is used. The major chicken meat producing regions of Australia are outlined in Figure 14.



Figure 14. Major chicken meat producing regions of Australia (ACMF, 2020).

Production cycle

Meat chickens are typically delivered to the farm as day-old chicks, and are grown in enclosed sheds for 5-8 weeks, when they are harvested and transported off-farm for slaughter. Meat chickens may be harvested at several points throughout the growth cycle, called a ‘pick-up’, once they meet the desired weight. A period of 1-2 weeks is typical between growth cycles, with sheds cleaned and disinfected between production cycles.

The typical inputs and outputs for a production cycle are shown in Figure 15.

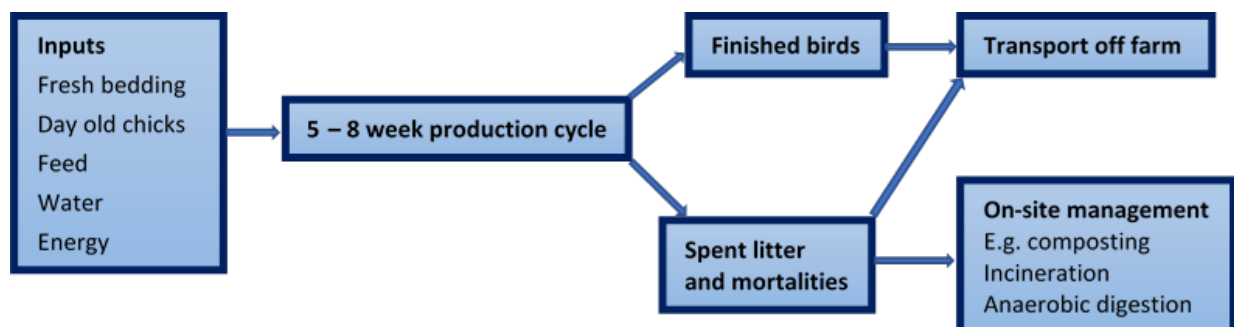


Figure 15. Typical inputs and outputs of the meat chicken farms.

Role of litter

Meat chickens move freely within sheds and are not housed in cages but on bedding material or litter typically composed of organic material such as wood shavings, sawdust or straw. The industry uses a variety of litter types, which may vary between regions due to accessibility. The most common types of litter used in Australia are wood shavings, recycled wood chips, sawdust, cereal straw and rice hulls. The ability to source sufficient volumes of litter at a suitable price is a constant area of interest for the industry. See [Review of Fresh Litter Supply, Management and Spent Litter Utilisation](#) (Watson & Wiedemann, 2018) for more information on litter types.

Spent litter from meat chicken farms is typically removed from sheds at the end of each growth cycle, but can be reused for several growth cycles in some systems – refer to Litter Reuse: An Evidence-based Guide to Reusing Litter (Wiedemann, 2015c) for more information. Because spent litter contains manure from the production cycle, it can be used in a variety of agricultural applications. Spent litter management options available to farm operators include off-site disposal, stockpiling, composting, incineration, anaerobic digestion and spreading on-farm.

Appendix B – Management of common bedding materials

Wood shavings

<p>Introduction</p> <p>Wood shavings generally come from pine plantations. They are usually kiln dried and have dust removed via extraction. They are the most used and preferred bedding material in Australia.</p>
<p>Characteristics</p> <p>Low bulk density; Medium particle size; Soft and compressible; Low thermal conductivity; High adsorbency; Reasonable drying rates; High friability.</p>
<p>Contaminants and pests</p> <p>Generally free from pests, weed seeds and diseases if stored correctly before use. There is no evidence that they are more or less susceptible to litter beetle infestations than other bedding materials.</p>
<p>Sourcing and pre-treatment</p> <p>The supply of wood shavings has traditionally been consistent in QLD, NSW, VIC, and TAS that have substantial plantation timber industries. In recent years it has, however, become more limited in supply and expensive in some areas. In 2017, the price per cubic metre (m³) on-farm was \$22-40.</p> <p>Wood shavings are generally a consistent product that do not require additional preparation or pre-treatment, such as drying, prior to placement.</p>
<p>Ventilation and moisture management</p> <p>They do not require any increased management, as they are highly adsorbent yet can dry rapidly with correct ventilation.</p>
<p>Caking and litter conditioning</p> <p>As with all bedding materials, wood shavings may require mechanical conditioning to address caking if it is not managed correctly and/or becomes too wet from chicken excreta, outside moisture or extraneous water from broken/poorly maintained infrastructure. Due to its high friability and consistency, it is generally less susceptible to caking than other bedding materials.</p>
<p>Litter reuse</p> <p>The most common material used in litter reuse practices in Australia. It has proven to be very successful, provided that adequate pasteurisation and moisture removal are practiced between grow-out cycles. Sometimes blended with sawdust material as part of the reuse practice.</p>
<p>Spent litter management</p> <p>Useful as a fertiliser in Australian conditions due to its consistency and being a wood-based product, which makes it generally free of weed seeds and other pests.</p> <p>It is less desirable for use in energy generation using anaerobic digestion, as the timber component will not readily digest. However, the manure and wood components will generate energy in combustion processes, provided the moisture content is low.</p>

Recycled wood chips

Introduction

Recycled wood chips generally come from recycled wood pallets. There have been mixed outcomes with the use of recycled wood material as chicken litter in Australia. The major issue is chemical contamination, although physical contamination can also be a problem.

Characteristics

Low bulk density; Medium particle size; Soft with good insulating properties; Low thermal conductivity; High adsorbency; Good drying rates; High friability.

Contaminants and pests

Generally free from pests, weed seeds and diseases if stored correctly before use. There is no evidence that they are more or less susceptible to litter beetle infestations than other bedding material.

The major concern with using recycled wood pallets is the risk of chemical and physical contamination. Pallets that are used for transport of goods internationally are made of treated timber (copper chrome arsenate – CCA). Pallets may also have been used to transport toxic materials, leading to contamination with paint, fuel, pesticides, solvents and other flammable materials, and nails can be a source of physical contamination.

Sourcing and pre-treatment

Recycled wood pallets were unsuccessfully trailed in VIC, where there were problems with contamination in certain recycling facilities. However, recycled wood materials are successfully used in WA for a large portion of its chicken meat industry. The recycling plant that produces this material has stringent operating procedures and chemical testing of products to ensure it meets industry requirements. A small proportion of chicken meat producers in NSW also use recycled wood materials for litter, supplied by a private pallet company. In 2017, the price per cubic metre (m³) ex-plant was \$15.10 in WA.

Strict processing and quality controls are required to ensure that chicken meat industry specifications are met and contamination is minimised. Specific screening equipment is required, and plant operators need to be educated to ensure incoming timber is not contaminated. Processed materials should be stored away from incoming timber to avoid cross-contamination. A typical process to ensure a safe product is:

- Visually screen pallets coming into plant to ensure only untreated and unpainted end-of-life Australian timber pallets, packaging and off-cuts are used
- Test all pallets for chromated copper arsenate (CCA) before processing
- Process pallets into wood chip and fines
- Analyse each batch for organic and inorganic contaminants
- Regular testing by an independent third party for organic and inorganic contaminants

Ventilation and moisture management

They do not require any increased management, as they are adsorbent yet can dry rapidly with correct ventilation due to their porous structure.

Caking and litter conditioning

As with all bedding materials, wood shavings may require mechanical conditioning to address caking if it is not managed correctly and/or becomes too wet from chicken excreta, outside

moisture or extraneous water from broken/poorly maintained infrastructure. Extra management may be required, as larger particle sizes may be more susceptible to caking.

Litter reuse

Reuse with recycled wood chips has not been common in Australia, as most reuse has occurred in QLD and NSW, where wood chip use is minimal. It has, however, been successfully reused in other countries.

Spent litter management

Useful as a fertiliser under Australian conditions due to its consistency and being a wood-based product, which makes it generally free of weed seeds and other pests.

It is less desirable for use in energy generation using anaerobic digestion, as the timber component will not readily digest. However, the manure and wood components will generate energy in combustion processes, provided the moisture content is low.

Sawdust

Introduction <p>Sawdust is a waste product from the timber industry and can be from softwood or hardwood. It has been widely used and is considered a good bedding material in Australia when available. It is sometimes used as a top-dressing in straw-based litter systems.</p>
Characteristics <p>Variable bulk density with hardwood (300-350 kg/m³) and pine (150-200 kg/m³); Small particle size; Soft and compressible; Low thermal conductivity; High adsorbency; Generally slower drying rates but greater water holding capacity than shavings due to higher bulk density; Moderate to high friability.</p>
Contaminants and pests <p>Generally free from pests, weed seeds and diseases if stored correctly before use. There is no evidence that it is more or less susceptible to litter beetle infestations than other bedding material.</p>
Sourcing and pre-treatment <p>The supply of sawdust material has traditionally been consistent in QLD, NSW, VIC, and TAS that have substantial timber industries. In recent years it has, however, become more limited in supply and more expensive in some areas. In 2017, the price per cubic metre (m³) on-farm was \$18-30.</p> <p>One issue with sawdust is that it can be an inconsistent product. Larger particle sizes from timber mills mean that it may need screening/sieving prior to use. If not removed, excessive number of larger particles make it more susceptible to caking. Long, sharp splinters can also cause physical injury to the chickens.</p> <p>Moisture content on delivery can also be an issue, especially with hardwood, and it may require drying prior to use to prevent caking and the need for additional conditioning during the grow-out cycle. Higher moisture content during storage and transport makes it more susceptible to mould.</p>
Ventilation and moisture management <p>Sawdust (particularly hardwood) can hold significantly more water than shavings and drying times will generally be slower. This may require additional scarifying/conditioning to release excess moisture.</p>
Caking and litter conditioning <p>As with all bedding materials, mechanical litter conditioning may be required to address caking if not managed correctly and/or it becomes too wet from chicken excreta, outside moisture or extraneous water from broken/poorly maintained infrastructure. If it is a consistent product with limited large particles and low moisture content, and with its good friability characteristics, it is generally less susceptible to caking than chopped/crushed straws and grasses.</p>
Litter reuse <p>Along with shavings, it is commonly used in litter reuse practices in Australia. It has been successful, provided adequate pasteurisation and moisture removal are practiced between grow-out cycles. It is sometimes blended with shaving material as part of the reuse practice.</p>
Spent litter management <p>Useful as a fertiliser under Australian conditions. Being a wood-based product makes it generally free of weed seeds and other pests.</p> <p>It is less desirable for use in energy generation using anaerobic digestion, as the timber component will not readily digest. However, the manure and wood components will generate energy in combustion processes, provided the moisture content is low.</p>

Chopped straw

Introduction

Most chopped straw used for bedding in Australia are based on cereal crops (barley and wheat), however some grass straw is also used. To be an effective litter material, it needs to be chopped and/or crushed prior to use to avoid severe matting and subsequent caking. Chopped straw is commonly used in southern states, particularly SA and WA.

Due to its high risk of caking, chopped straw requires more maintenance and management to keep the litter dry and friable than other commonly used litters. While it is not a preferred litter, growers have established additional management practises to improve its effectiveness.

Characteristics

Lightweight; Medium particle size; Soft and compressible; Low thermal conductivity; Good adsorbency when chopped to less than 20 mm; Slower drying rates than shavings if not actively managed; Moderate to high friability if actively managed.

Some processor companies prefer wheat straw over barley straw for its perceived improved adsorptive qualities.

Contaminants and pests

More likely to attract pests during storage prior to use than wood-based (shavings, sawdust) products because any seeds will be attractive to rodents and wild birds. It is also naturally more susceptible to mould than other shavings. Quality control is required to ensure low moisture content during baling and that the product is covered/placed in a shed before use.

Has an increased risk of residual chemicals and pesticides if applied during cropping.

There is no evidence that it is more or less susceptible to litter beetle infestations than other bedding material.

Sourcing and pre-treatment

Straw is generally readily available in most states. There have been issues with reliable supply at a competitive price in recent years due to severe drought conditions, as there is not only a lack of overall supply, but growers face increased competition from livestock producers. In 2017, the price per cubic metre (m³) on-farm was \$10-15, with these prices tripling in some areas in 2019.

Straw-based bedding materials require pre-treatment to reduce the particle lengths to less than 20 mm. This is generally done by chopping and/or crushing bales of hay. Reducing the particle size improves its adsorbency and reduces caking problems during the growing cycle.

Ventilation and moisture management

Even with chopping/crushing, straw-based litter will generally require more management to avoid caking issues than other commonly used litters. This will include regular scarifying/conditioning to release excess moisture and break up material on the surface that is beginning to cake. Some producers have found it beneficial to add a layer of sawdust over chopped straw to reduce caking problems, particularly in cooler, wet winters in southern Australia.

Caking and litter conditioning

Chopped straw is more susceptible to caking than other bedding materials and will require more diligent monitoring and conditioning/scarifying than shavings.

Provided that it is effectively chopped to reduce the particle size to less than 20 mm and it has a low moisture content (<15% wet basis), producers have effectively used straw without excessive caking.

Litter reuse

Reuse with chopped straw has not been common in Australia, as most reuse has occurred in QLD and NSW, where straw use is minimal. It has, however, been successfully reused in the USA.

Spent litter management

Useful as a fertiliser under Australian conditions but will likely have more weed seed contamination than wood-based (shavings, sawdust) products. This, however, can be overcome with effective composting before application.

It is more desirable for use in energy generation than timber-based material using anaerobic digestion, as the straw will more readily digest than timber. The manure and straw components will also generate energy in combustion processes, provided moisture levels are low.

Rice hulls

Introduction <p>Rice hulls are a proven good litter material. Where they are regionally available, they are the preferred bedding material for many growers.</p>
Characteristics <p>Lightweight; Medium particle size; Soft and compressible; Low thermal conductivity; low adsorbency (with water being held between particles rather than within them); Good drying rates; High friability if actively managed.</p>
Contaminants and pests <p>More likely to attract pests during storage prior to use than wood-based (shavings, sawdust) products and is more attractive to rodents and wild birds.</p> <p>There is no evidence that it is more or less susceptible to litter beetle infestations than other litter bedding material.</p>
Sourcing and pre-treatment <p>Rice hulls are generally only available within a reasonable transport distance from the rice-growing region of the Riverina. As with straw, there have been issues with a reliable supply at a competitive price in recent years. This is due to severe drought conditions, as there is not only a lack of overall supply, but growers face increased competition from other livestock production (pigs and horse stables). In 2017, the price per cubic metre (m³) on-farm was \$15-25.</p>
Ventilation and moisture management <p>Rice hulls do not require any additional ventilation management due to their large surface area, which promotes rapid drying.</p>
Caking and litter conditioning <p>As with all bedding materials, it can be susceptible to caking if not managed correctly and/or becomes too wet from chicken excreta, outside moisture or extraneous water from broken/poorly maintained infrastructure, thus conditioning may be required. Due to its good friability and consistency, it is less susceptible to caking than straw.</p>
Litter reuse <p>Reuse with rice hulls has not been common in Australia, as most reuse has occurred outside of rice-growing areas. It has, however, been successfully reused overseas.</p>
Spent litter management <p>Useful as a fertiliser under Australian conditions but will likely have more weed seed contamination than wood-based (shavings, sawdust) products. This, however, can be overcome with effective composting before application.</p> <p>Rice hulls are more desirable for use in energy generation using anaerobic digestion than timber-based litter, as they will more readily digest than timber. The manure and rice hull component will also generate energy in combustion processes, provided moisture levels are low.</p>

Appendix C – Troubleshooting guide for litter management

Problem	Potential solution/s
<p>Bedding material is becoming more difficult to source at a reasonable price.</p>	<p>Consider the use of alternative litter sources after carrying out a risk assessment of its safety regarding meat chicken performance and health, human health, and the environment.</p> <p>Consider trialling partial reuse with your processor by using effective pasteurisation and clean litter in the brooding area. Minor ventilation configuration may be required to ensure that ammonia released from the reused litter is drawn away from the brooding area.</p> <p>Seek alternative sale opportunities for spent litter to increase its value and offset the cost of the bedding material.</p>
<p>Bedding material has been delivered and is moist.</p>	<p>Avoid stockpiling unless it is necessary, in which case store in a dry and aerated location. Spread the bedding material into a thin layer as soon as possible, and once spread, use ventilation and heat to remove excess moisture. Turning, mixing and/or forced aeration during this phase will help to rapidly release moisture.</p> <p>Provide feedback to the supplier on the issue to see if it can be rectified and ask them about their policies and procedures relating to the manufacture, storage, and distribution of the bedding material.</p>
<p>Bedding is becoming wet before chick placement while heating the sheds.</p>	<p>Heating the floor and litter in the brooding area before placement is essential to avoid condensation in the litter. It is as important as heating the air to the correct temperature for the health and comfort of young chicks. If the temperature of the floor is below the dew point, condensation will form in the litter. Because of higher targeted relative humidity during brooding, the floor temperature (and full litter depth) must be within 3-4 °C of the air temperature in the sheds to stay above the dew point.</p> <p>De-stratification fans, circulation fans or radiant/tube heaters will assist with heating the floor and litter to the optimum temperature.</p>
<p>Switching to a straw-based litter has caused increasing levels of caking.</p>	<p>Straw-based litter needs to be chopped to lengths less than 20 mm. Longer particle lengths are more prone to caking, especially early in the grow-out when young chickens do not have the size or strength to work the litter and keep it friable. Check the particle size of the straw after chopping/crushing.</p> <p>Also try blending straw litter with other bedding materials. Some southern Australia producers have had good results adding a sawdust layer over the straw before placement to reduce caking problems.</p>
<p>Litter is moist and ammonia levels are increasing to levels close to prescribed standards.</p>	<p>Systematically increase ventilation time or fan speed (for variable-speed fans) until sufficient ammonia and moisture extraction is achieved. When increased ventilation is used to remove ammonia and moisture from the sheds.</p>

	<p>temperature and humidity must be maintained to a standard appropriate to the age of the chickens. Aim to maintain relative humidity at 40-60%.</p> <p>Additional conditioning may also be required to release trapped moisture in the litter. This may temporarily exacerbate ammonia levels.</p> <p>If practicing litter reuse, consider using pre-treatment litter additives, such as dry acids that lower litter pH and hence reduce ammonia emissions.</p>
<p>Litter is becoming wet near the air inlets.</p>	<p>Ensure incoming air has a low relative humidity (<60%). This requires warming the air and ensuring that it is well mixed as it enters the air inlets. This is achieved by:</p> <ul style="list-style-type: none"> • Retaining heat (from the chickens and heaters) and/or adding heat to the sheds to increase the water holding capacity of the air. • Adjust mini-vents to achieve suitable static pressure (25 Pa) to ensure air entering through the mini-vents has an air speed of 3-6 m/s so that it can reach the roof apex, where the hottest air will pool. • Adjust mini-vents so that they are sealed when closed, but open sufficiently so that air is directed across the ceiling and doesn't hit the ceiling and drop near the wall. • If it is not possible to achieve the required air pressure and mini-vent opening, consider latching closed every second vent, especially early in the grow-out when ventilation rates are minimal. <p>Stirring or circulation fans may help adequately mix the air within the sheds and improve uniformity of heating if the mini-vents do not adequately mix the air within the sheds.</p> <p>Reduce relative humidity later in the grow-out by only relying on the evaporative cooling system (pads and foggers) when necessary. Only use evaporative cooling when air speed alone is insufficient to cool the chickens.</p>
<p>Litter is becoming wet near pop-holes on free range sheds.</p>	<p>Ensure sufficient drainage around sheds for stormwater to rapidly drain away. Incorporate bedding material at these locations. If litter moisture is still too wet, replace litter in these areas with fresh, dry bedding material.</p>
<p>Litter is becoming wet under drinkers.</p>	<p>Check drinker height daily to ensure it is the correct height for the chickens. If cup and bell (least preferable) drinkers are used:</p> <ul style="list-style-type: none"> • ensure that the lip of the drinker is at the same level as the chickens' backs in a standing position, and • ensure water level is 5 mm below the lip at chick delivery and adjust to 12.5 mm by day 7 to prevent spillage. <p>If nipple drinkers (most preferred) are used:</p> <ul style="list-style-type: none"> • set height at chicks' eye levels for the first few hours of age. • in the early stages of brooding, adjust drinker height to just above head height. After this, maintain height above chicks' heads to ensure they are reaching (not straining) to reach the drinker and their feet are always flat while drinking. Turning their heads to the side while drinking will cause spillage: • adjust pressure so there is a droplet of water suspended from the nipple. <p>Drinker nipples have a limited life (~10 years) and should be replaced at scheduled intervals. Consider replacing drinker nipples in areas of the sheds where litter is the wettest and observe if the floor conditions improve. This is</p>

	<p>likely a sign that the drinker nipples are nearing the end of their life and replacement should be scheduled.</p> <p>Ensure there is adequate and even pressure in the lines. These lines require regular cleaning between growth cycles. Carefully adjusting regulators and having multiple supply points can help minimise spillage.</p>
<p>Litter is starting to become wet and the ambient conditions are damp and cold. These conditions are predicted for several days.</p>	<p>Consider providing heating or retaining heat (e.g. from the chickens) in sheds to improve moisture removal, as warmer air holds more water. If possible, consider using mini-vent ventilation rather than tunnel ventilation to better control fresh air mixing and heating evenly.</p> <p>This may also require increased fan speeds to ensure chicken thermal comfort is maintained.</p> <p>This may also require the use of destratification/circulation fans to mix warm air.</p>
<p>When litter is turned it quickly begins to smear and cake again.</p>	<p>Litter needs to be kept in a friable state to allow the chickens to turn the litter over via scratching and digging. Regularly conditioning litter has the effect of aerating the litter, which in turn will release gases and moisture. Once litter becomes wet and caked, it can be difficult to rectify the problem via conditioning. Attempts to remediate overly wet and caked litter via turning and mixing alone are likely to be futile.</p> <p>When litter becomes wet, it gets sticky and cohesive and will compact easily. The only way to make it more friable is to reduce its moisture content. If the wet caked litter is surrounded by drier litter, it is essential to mix the wet and dry materials together, to hopefully achieve a litter moisture content that is below the threshold where it is sticky. This is one of the essential outcomes of litter conditioning. Some farmers have reported success with litter conditioning after upgrading from smaller equipment to wider equipment, because it is better at mixing dry and wet litter.</p> <p>To take advantage of the release of water from recently turned litter, plan to undertake litter conditioning activities in mid to late morning. Consider the following as well:</p> <ul style="list-style-type: none"> • Avoid litter conditioning at night and in the early morning when the potential for evaporation is lower. These times may also not be desirable to increase ventilation rate to exhaust released gases and water, due to colder air outside (depends on the time of the grow-out). Night-time and early morning are also times when there is a higher risk of causing odour impacts, which may be made worse when releasing odorous gases during litter conditioning. • Avoid litter conditioning late in the afternoon when there will be only a short window of time to ventilate moisture and gases that are released by conditioning.
<p>Rising damp is making it difficult to maintain dry and friable litter.</p>	<p>Consider concreting shed floors and/or provide guttering to direct water away from sheds. Also ensure there is effective drainage around sheds.</p>
<p>Large beetle infestation encountered.</p>	<p>Repair damaged floors from beetles between growth cycles by re-compacting damaged areas.</p> <p>When using chemicals to control litter beetles, rotate the type based on active ingredients to avoid pesticide resistance.</p>

	<p>Use an integrated pest management approach for the control of litter beetles. This would include good housekeeping in the first instance, the use of chemicals, and the regular inspection and resealing of shed floors.</p>
<p>The person I sell my spent litter to wants to know if it is safe.</p>	<p>Have the litter analysed to determine it is safe.</p> <p>Provide information to the end user, such as the publication Land application of Chicken Litter: A Guide for Users (Wiedemann, 2015b), about the likely contaminants and the safe use of spent litter.</p>
<p>I have recently concreted the floors in my sheds and now my litter is wetter.</p>	<p>Concrete floors have different thermal insulation and water transmitting properties than compacted earth floors. In general, concrete floors may take longer to warm up than earth floors, and will not absorb water as easily. Think what happens if you tip a bucket of water on a concrete floor, compared with an earth floor. Which absorbs water quicker and which stays wetter longer?</p> <p>Some growers who have recently concreted their floors now find that their litter is wetter and cakes easier.</p> <p>Because concrete floors are more resistant to absorbing water, all water going onto the litter must be removed using shed ventilation. Earth floors are more forgiving, and adsorb some moisture that would be released slowly during the grow-out and when the sheds are cleaned.</p> <p>It is necessary to pre-heat the concrete floor before placing chickens in sheds to avoid condensation within the litter. Ensure the temperature of the concrete floor, and the full litter depth profile (from the base to the surface) is within 3-4 °C of the air temperature when brooding starts, to keep the temperature of the litter above the dew point.</p> <p>Carefully monitor litter moisture content and caking, and increase heating and ventilation before it gets too wet. Dig through the litter to the base and ensure that water is not forming/condensing at the bottom of the litter.</p> <p>Some growers have found that they needed to change their drinker nipples to ones with a lower flow rate to manage litter moisture content. Consider the potential need and cost of replacing drinker nipples and the cost of concreting the floor of sheds.</p>

Appendix D – Example agreement for the removal and utilisation of spent litter from a meat chicken farm

(Adapted from similar guidance provided by the NSW DPI)

Example agreement for removal and utilisation of litter from a meat chicken farm (adapted from form developed by NSW DPI)

The information and conditions listed below are designed to help protect the environment; reduce impacts on individuals and communities; comply with biosecurity legislation and support the continued use of spent litter as a valuable fertiliser and soil amendment. These conditions apply to spent litter removed from meat chicken operations.

The spent litter covered by this agreement was removed on _____ (date) from the meat chicken farm managed by:

_____ (name) located at _____ (address)

Amount of spent litter removed: _____

The end-user of this spent litter accepts that:

- A. Spent litter may have limitations of use under state Biosecurity legislation. Consult the relevant Biosecurity legislation in your state for local requirements.
- B. The use of spent litter may be subject to limitations of use under state Waste legislation. Consult the relevant Waste legislation in your state for relevant requirements.
- C. Nutrients in each batch of spent litter can be highly variable and the supplier makes no claims as to the nutrient content, quality and suitability of purpose of the litter supplied.
- D. Litter should be analysed to accurately determine nutrient content.
- E. Spent litter contains potentially harmful pathogens. The end-user has a duty of care to prevent illness or harm to themselves, the community and to anyone else associated with the use of the litter.
- F. Spent litter contains heavy metals. Over application of litter may result in a build-up of heavy metals in soil.
- G. Spent litter may be harmful to humans, animals and the environment. The end-user accepts responsibility for these risks and will take all necessary precautions to prevent harm to humans, animals and the environment.
- H. Spent litter is classed as Restricted Animal Material (RAM). It is illegal to feed litter to ruminants or to allow ruminants to have access to spent litter, even if it is composted.
- I. Following application a minimum 21 day withholding period should apply. Ruminants must not have access to the application sites for at least 21 days. If litter remains accessible to ruminants after 21 days the withholding period must be extended.
- J. Movement of spent litter or nutrients, pathogens or any other material in litter into surface or groundwater is an offence under state Environmental Protection Acts.
- K. Spent litter handling, storage and use should comply with the 'Best Practice Litter Management Manual for Australian Meat Chicken Farms available on the [AgriFutures Australia website](#).

The following specific conditions apply to the storage and use of spent litter for any purpose:

- 1. Spent litter should not be stored or spread within 300m of poultry sheds.
- 2. Litter which has not been fully pasteurised or composted should not be stored or spread on areas adjacent to poultry farms.
- 3. Litter storage and/or processing areas:
 - a. Should be placed as far away as practicable from residences not associated with the property
 - b. Must not be accessible to ruminant livestock
 - c. Should have an impermeable base to prevent nutrient leaching and groundwater contamination
 - d. Should have a diversion bank above the site to prevent stormwater from entering the storage site
 - e. Should be banded to contain and divert contaminated runoff from the stored litter
 - f. Should capture any contaminated runoff from the storage site in a dam, pond or equivalent structure.
- 4. Do not spread raw spent litter directly onto emerging crops or onto vegetables or horticultural produce. For current guidelines and withholding periods consult www.freshcare.com.au or other accredited fresh produce codes of practice.
- 5. Paddocks receiving litter should be soil tested at least every 3 years to monitor nutrient and heavy metal levels.
- 6. Application rates should not exceed the nutrient requirements of the plants over the long-term. This should account for the safe storage of phosphorus in soil between application events and for the plants ability to use the available nitrogen in the litter. This nutrient budget should be based on soil test results, together with documented agronomic advice.
- 7. Spreaders or equivalent equipment should be properly calibrated to ensure litter is correctly and uniformly applied.
- 8. Litter material and nutrients and pathogens from litter must not enter surface or groundwater. Avoid spreading litter in drainage lines and depressions which funnel surface water into waterways. Litter should not be spread close to waterways, dams and drainage areas. A minimum 20 m buffer distance is recommended from waterways, dams and drainage areas. Where the potential of water and nutrient and other contaminants being entrained in the runoff is greater (e.g. sloping paddocks, poor groundcover, high risk of erosion) a wider buffer distance is required. Greater distances are required when spreading litter in the vicinity of waterways or water storages that provide public drinking water supplies. Consult with the local water authority to clarify the distance required.
- 9. Vehicles which transport and spread spent litter must be covered to reduce odour, dust and pollution.
- 10. Avoid spreading litter too close to neighbouring residences. Inform neighbours when spreading, and avoid spreading on weekends if neighbours may be impacted.
- 11. Monitor weather conditions and forecasts. Avoid spreading in windy conditions that may result in dust or odour drift.
- 12. Do not spread when rainwater runoff is forecast or expected, for example just prior to or during heavy rainfall.
- 13. Keep accurate records of dates and locations when spreading litter.

I _____ (name) am the person removing litter from the meat chicken farm and accept and understand the conditions listed above. If I am not the end-user I accept responsibility for providing a copy of this agreement to the end-user of the spent litter.

(signature) (date)

(address) (phone)

