Australian Government

Rural Industries Research and Development Corporation

Chicken Litter

Issues Associated with Sourcing and Use

A report for the Rural Industries Research and Development Corporation

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Foreword

The poultry industry and community are concerned about the management of chicken litter from the perspectives of sourcing the initial bedding material and the utilisation of the waste product. The community wants “clean” food and is concerned about such issues as odour emissions from sheds and the potential contamination of water tables and streams with nutrients and pathogenic organisms from litter being spread on land.

The meat chicken industry spends $10.78 million annually on bedding material and receives about $0.71 million in return for the used litter. This leaves a cost of $10.07 million annually for bedding material. About 1.17 million m^3 of bedding material is used by the industry each year and with approximately 1.60 million m^3 of chicken litter is available for utilisation.

This project has developed a prioritised list of research or other actions to address chicken litter issues associated with the sourcing of bedding material, chicken shed litter management practices and the utilisation of litter. It also highlights opportunities for litter utilisation and contains a review of the literature and other information on chicken litter from the sourcing of bedding material through to utilisation.

This project was funded from industry revenue that is matched by funds provided by the Australian Government.

This report, an addition to RIRDC’s diverse range of over 1500 research publications, forms part of our chicken meat R&D program, which aims to support increased sustainability and profitability in the chicken meat industry by focussing research and development on those areas that will enable the industry to become more efficient and globally competitive and that will assist in the development of good industry and product images.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/reports/index.htm
- purchases at www.rirdc.gov.au/eshop

Peter O’Brien
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Executive Summary

What the report is about

This report identifies and discusses a range of issues associated with the sourcing, management, disposal and use of litter in the Australian meat chicken industry. It provides a prioritised list of research or other actions to address chicken litter issues associated with the sourcing of bedding material, chicken shed litter management practices and the utilisation of litter. It also highlights opportunities for litter utilisation and contains a review of the literature and other information on chicken litter from the sourcing of bedding material through to utilisation.

Who is the report targeted at?

The report was designed to provide information to help the RIRDC Chicken Meat Advisory Committee evaluate the needs and priorities for further research into the availability of and alternatives for meat chicken bedding materials, and the use, management and disposal of litter. This project will therefore provide a framework for future activities by the RIRDC in the area of chicken litter use and management.

However, the report will also provide a valuable source of information for chicken growers and other industry participants on the management of litter and the potential impact of litter management practices on bird health, food safety and litter quality and acceptability to end-users. It will also be of value to researchers interested in identifying research needs and opportunities in this area, and to litter end-users and regulators concerned about potential risks and benefits associated with the use of litter as fertiliser and soil amendment, and for other purposes.

Background

The Australian poultry industry and the community generally are concerned about the management of chicken litter, from sourcing the initial bedding material through to utilisation of the by-product. There is the potential to value add to chicken litter, increase returns from it and reduce litter costs to chicken growers.

The community however, has some concerns about litter being spread on land, the associated odour emissions and the potential contamination of water tables and streams with nutrients and pathogenic organisms.

Consumers are demanding "clean" food. Farmers must guarantee, through participation in quality assurance programs, that their produce (milk, vegetables etc) is not contaminated with microbes likely to cause disease or contain undesirable antibiotic and chemical residues.

Government bodies expect that when chicken litter is applied to land as a fertiliser or soil conditioner that:

- the rate of application will be based on crop removal of nutrients and trace elements;
- it will not pose a risk to the environment due to the accumulation of nutrients, salts or heavy metals;
- it will not pose a risk to public health through application to edible crops.

Around the world, the use of composted organic materials is gaining economic credibility in mainstream agriculture. It is apparent that a growth in demand for composted green organic products is occurring in parts of Australia. There is an opportunity for the chicken and litter value adding industry to participate in this growth by developing suitable products incorporating chicken litter.

Future regulations on greenhouse gas emissions may affect the way chicken litter is managed to minimise greenhouse gases and ammonia release into the atmosphere.

Australian soils are infertile, low in organic matter and have a relatively poor soil surface structure. It is more desirable in the longer term to utilise chicken litter to improve soils than to burn it as an energy source as green energy, or to otherwise dispose of it as a 'waste' product of chicken production. The use of chicken litter as fertiliser would improve soil quality and the carbon level in soils and reduce the amount of carbon dioxide in the atmosphere. Returning secondary organic resources such as chicken litter to the land will increase the economic, environmental and social sustainability of Australian agriculture and food production.

The meat chicken industry spends $10.78 million annually on bedding material and receives about $0.71 million in return for the used litter. This leaves a cost of $10.07 million annually for bedding material. There is the potential to value add to used litter and reduce the cost to industry for litter. About 1.17 million m^3 of bedding material is used by the industry each year with approximately 1.60 million m^3 of chicken litter available for utilisation.

Objectives

The objective of this project was to develop a prioritised list of research or other actions required to address a range of identified chicken litter issues associated with the sourcing of bedding material, chicken shed litter management practices and the utilisation of litter.

Methods

An email discussion group was established by the project team to assist in the development of a list of issues and to communicate information about the project and chicken litter to participants. It also assisted in ascertaining what was known about the topic. A literature search using library services and the internet provided more information. A survey of the industry quantified the current situation. These activities were followed by a workshop to prioritise the issues and actions/research required to address them. The issues considered at the workshop were:

- Public health issues,
- Quality assurance issues,
- Environmental issues,
- Single litter use and reuse of litter.

Key findings and their implications

Public health issues

Poultry litter can contain a number of pathogens and other materials that are a potential risk to public health (heavy metals, antimicrobial agents including the genes that confer resistance to these agents and endocrine disruptors). The range of pathogens present in poultry litter is less than that present in both human effluent and the effluent produced by other intensive animal industries.

The pathogens and health risks that are of most concern to the litter contractors, value adders and end users are:

Campylobacter jejuni
Clostridium botulinum
Salmonella spp.
Antibiotic resistance genes (in both normal flora and pathogens)

Both composting and partial composting (defined as achieving a temperature of 55°C for at least three days) achieve a reduction in the pathogen load of chicken litter. Partial composting or deep stacking has the potential to pasteurise chicken litter ensuring that it is free from pathogens and providing a product at a cost likely to be acceptable for application to vegetables, fruit, crops and soils used for growing pastures for stock.

Quality assurance

Qualitative and Quantitative Risk Assessment methods offer a valid and useful method for the establishment of guidelines for the safe use of poultry litter.

There is potential for further market development of litter products if the industry can produce used litter of consistent quality. The litter contractors require used litter of consistent and known quality so that they can prepare and supply a product that consistently meets the requirements of their particular market and which meets relevant standards.

There is a need for chicken growers to be aware of the quality standards for used litter required by litter contractors and value adders to ensure that they can produce a product meeting the standards required by their customers.

The traditional litter contractors may require additional skills and knowledge to be able to effectively implement quality assurance programs appropriate to the changing needs of their end users.

Quality assurance of chicken litter production and processing systems will be crucial in ensuring long term market access and financial returns.

Environmental concerns

Poultry litter has useful properties as a fertiliser and soil amendment and has been used for many years in the production of a range of crops and products for human consumption. However concerns exist regarding litter contaminants, including heavy metals and pathogens.

Application rates in some situations, such as sandy soils and turf farming, have exceeded plant requirements with the potential for environmental damage from infiltration and run off of excess nutrients. Stricter guidelines in the future will restrict application rates to crop uptake and removals requiring supplementation with inorganic fertilisers to match crop nutrient demand.

The application of unprocessed poultry litter to vegetable and some fruit crops has declined sharply in recent years due to concerns over the microbial safety of food crops produced.

Processes including composting, pelleting and blending of chicken litter have been developed to produce value-added products for specialised, high value markets.

Energy recovery from the biomass in poultry litter as heat for electricity generation provides an alternative use for poultry litter although destroying valuable plant nutrients and soil organic matter in the process.

Single use and reuse of litter

Single use of litter is practiced by about 70 percent of the chicken industry. Those advocating this practice claim that single batch clean out and disinfection result in the most productive performance, lower downgrade level, more consistent performance and lower cost per kg of chicken produced.

Reuse of litter as a bedding material has the potential to reduce litter costs and ease pressure on new bedding material supplies in the States where supplies are restricted.

The critical test with litter reuse is whether chicken performance, biosecurity and bird health can be maintained. From an economic viewpoint, the changed performance, increased vaccination costs, and the use of litter additives must balance the savings in litter costs.

Some processors are practicing partial or full reuse of litter where it is considered that the farm's biosecurity is high and disease and poor hygiene risk status low.

To implement a reused litter program, good management is essential to minimise stress on chickens and to reduce the risk and impact of a disease on the flock. A healthy immune system is also essential to ensure good chick performance and the ability of the chick to withstand disease challenge. Litter reuse may result in the chickens being exposed, during the first few weeks of the chick's life, to relatively low levels of pathogens, stimulating an immune response which will protect the bird against infection in later life.

There is considerable evidence that reused litter may pose less of a risk in terms of food safety pathogens (as opposed to the chicken pathogens mentioned above) than single use litter, providing litter is well managed and maintained in a dry state.

As dry used litter is generally antibacterial in nature, for pathogenic bacteria at least, there is a strong argument that litter reuse is not associated with any increased use of antibiotics.

There are potential alternative bedding materials available to meet any shortfall in supply that may occur due to pressure from the green waste and biomass energy industry or if the use of single batch litter increases. These alternatives, such as sand, the fibre remaining after tea tree oil distillation, soya bean hulls, peanut hulls and straw, require evaluating to determine their suitability and viability for use in Australia.

The key to maintaining pathogen risk at a low level is litter dryness. It is a key issue for both food safety and flock health. The biggest issue in both the USA and in Australia with reuse of litter is managing the potential for increased litter moisture and higher ammonia levels.

Moisture management in the shed affects litter dryness. Management of equipment and ventilation is critical in maintaining dry litter. The drier the litter the more dust is created in the shed. The damper the litter the more ammonia and odour is generated. Dust and ammonia have the potential to pose health problems for both chickens and staff working in the sheds. Ammonia levels of 5 ppm or more are detrimental to day old chicks and levels of 25 ppm will lower performance of growing chickens.

Field experience and published evidence indicate that some litter additives can reduce ammonia levels in the chicken shed. These additives require moisture to activate the process of tying up the ammonia. Too much moisture and they are used up too quickly. Too little and they do not work quickly enough.

There is conflicting evidence about whether the use of these additives leads to improvements in chick performance. Research results suggest that improvements in chick performance tend to be recorded in situations where the levels of ammonia in the shed atmosphere are higher than those generally experienced in meat chicken houses in Australia in which the litter and ventilation are well managed.

The use of litter treatments is cost effective for winter batches placed on reused litter in the USA. Both local and overseas experience suggests that litter treatments are not cost effective for single litter use where litter moisture management and ventilation are good.

The use of some litter additives should be seen as an aid to litter management, not the answer to poor management of ventilation and litter moisture. Good ventilation and management of litter moisture is part of ensuring the litter treatment works effectively.

Recommendations

The following are recommendations for future research or other action:

- That RIRDC support research to establish the prevalence and level of the priority pathogens of humans in chicken litter and the incidence of antibiotic resistance genes in litter bacteria (both normal flora and pathogens).
- That RIRDC support research into methods of on-farm partial composting of chicken litter that is effective in pathogen reduction.
- That RIRDC commission the development of interim guidelines for safe, sustainable use of chicken litter

1. Introduction

Chicken litter is defined as a mixture of the source material used for the initial bedding placed on the floor of a clean shed, and the excreta, feathers and other detritus from the chickens plus wasted feed and water.

There is approximately 4,274,000 m^2 of shedding devoted to meat chicken production in Australia in more than 2,750 sheds. Based on 5.5 batches per shed per annum about 0.95 million m^3 of bedding material is used by the industry each year and with approximately 1.66 million m^3 of chicken litter available for utilisation (see Table 1).

Table 1. Volume of new bedding material purchased and used litter generated per annum.

Type	Bedding material type (m^3)					
	sawdust	shavings	rice hulls	Straw	paper	total
New	236,370	486,065	188,325	43,420	2,970	957,150
Used	470,070	774,560	329,860	80,030	5,950	1,660,470

The average price paid for new bedding material is $11.71/m^3$ (see Table 2). The industry spends $10.78 million annually on bedding material and receives about $0.71 million in return for the used litter. This leaves a cost of $10.07 million annually for bedding material.

Table 2. The cost of new bedding material per State.

State	New Bedding Material Cost ($/m^3$)					
	Sawdust	Shavings	Rice Hulls	Straw	Paper	Average
NSW	$11.00-14.50	$11.00-16.00	$8.00-18.50	$12.00	$11.00	$13.63
QLD	$11.00-14.00	$11.00-14.00		$11.00	$11.00	$11.75
SA		$11.50-13.50		$6.00-9.00		$11.19
TAS	$7.80					$7.80
VIC		$6.70	$7.50			$7.10
WA	$10.00-14.50					$14.30

Management of chicken litter, from sourcing the initial bedding material through to utilisation of the waste product, is a concern to the Australian, and indeed the world, poultry industry and community.

In some areas of Australia fresh clean bedding material is in short supply. This can potentially be addressed by developing alternative bedding material supplies or by reusing litter. Using litter once costs more than reusing litter. However, the key question is; can we adopt the overseas practice of litter reuse and still maintain the same chick performance and reduce litter costs?

Communities in chicken growing areas are concerned about the odour coming from chicken sheds. They are also concerned about litter being spread on land resulting in odour emissions and the potential contamination of water tables and streams with nutrients and pathogenic organisms.

Consumers are demanding “clean” food. Farmers have to guarantee that their produce (milk, vegetables etc) is not contaminated with microbes likely to cause disease or contain undesirable chemical residues. Quality assurance (QA) programs are being implemented along the food chain. As the drive to adopt these QA programs progresses, questions are increasingly being asked about whether chicken litter utilisation practices may be compromising product quality or safety.

Environmental concerns raised by the community and government are being gradually being addressed by Environmental Protection Agencies, Departments of Natural Resources, Land Care groups and Water Catchment Co-ordinating Committees throughout Australia. The attitude of Australian Federal and State

Governments is that chicken litter is waste generated by the poultry industry. Therefore it is the responsibility of the industry to ensure this waste is utilised in ways which address both environmental and food quality concerns.

The expectation government bodies have towards the application of chicken litter on land as a fertiliser or soil conditioner is that:

- the rate of application is based on crop removal of nutrients and trace elements;
- it will not pose a risk to the environment due to the accumulation of nutrients, salts or heavy metals;
- it will not pose a risk to public health through application to crops.

Around the world the use of composted organic material is gaining economic credibility in mainstream agriculture. It is apparent that a growth in demand for composted green organic products is occurring in parts of Australia. The chicken and litter value adding industry need to participate in this growth by developing suitable products incorporating chicken litter that are safe and fit for purpose.

In the future, regulations on greenhouse gas emissions may affect the way chicken litter is managed to minimise greenhouse gases and ammonia release into the atmosphere. The speed at which this occurs will be driven by the Commonwealth Government's National Greenhouse Strategy (NGS).

It is generally accepted that Australian soils are infertile, low in organic matter and have a relatively poor soil surface structure. Hence, it has been strongly argued that it is more desirable to utilise chicken litter to improve soils than to burn it as an energy source as green energy. The use of chicken litter would improve soil quality and the carbon level in soils and reduce the amount of carbon dioxide in the atmosphere. Returning secondary organic resources such as chicken litter to the land will increase the economic, environmental and social sustainability of Australian agriculture and our food production.

The benefits of recycling secondary organic materials (SOR) by land application are related to:

- improved soil quality and resistance to erosion;
- improved ability of the soil to retain available plant nutrients and moisture; it can also reduce the impact of soil salinity on plant growth;
- improved soil and hence plant health as a result of increased beneficial microbial activity;
- potentially reduced use of, or dependence on, chemical fertilisers and pesticides including fumigants and growth regulators.

2. Objective

To develop a prioritised list of research or other actions to be undertaken to address a range of chicken litter issues associated with the sourcing of bedding material, chicken shed litter management practices and the utilisation of litter.

3. Methodology

3.1 Introduction

The process used to develop a list of actions involved several steps. These steps were to:
- identify the issues and problems associated with chicken litter, sourcing, management and utilisation;
- ascertain what is known about chicken litter;
- ascertain the industry situation;
- determine actions to address the issues;
- prioritise the actions.

An email discussion group was established to develop a list of issues and to communicate information about the project and chicken litter. It also assisted in ascertaining what was known about the topic. A literature search using library services and the internet provided more information. A survey of the industry quantified the current situation. These activities were followed by a workshop to decide on what action needed to be taken on the issues identified and to place priorities on these actions.

3.2 Email Discussion Group

A closed email discussion group was run to develop a list of issues to be discussed at the workshop.

The Department of Primary Industries and Fisheries' List Source Software that is provided on its World Wide Web interface was used to manage the email discussion group.

Members of the email group came from the livestock production and growing sector of the industry, researchers, government agencies, litter contractors and value adders, end users and quality assurance representatives from the agriculture and horticulture industry.

The aim in running the group was to:
- collect information;
- develop a list of issues;
- inform participants on the issues and how the project would be undertaken.

An overview was written and distributed to the email group participants to help them to focus on the task. About every two weeks the discussion in the group was evaluated and this determined the information and questions that were emailed out to the group next. This process was repeated three times. A list of issues was developed from the email discussion for consideration at the workshop. These were sorted into common themes. These themes became the issues to be posed for discussion at the workshop.

3.3 Survey

A survey of key chicken growers, processors and litter contractors was undertaken. The objective was to obtain information on the costs, quantities, types used, management practices and utilisation of chicken litter in Australia.

3.4 Current Knowledge

A literature search and a search of internet web pages was undertaken to ascertain current knowledge and worldwide trends in the sourcing, on farm management and utilisation of chicken litter.

The information collected in the searches and the email discussion group was evaluated and incorporated into briefing papers distributed prior to the workshop. These papers were later edited and extra information added in response to the comments/outcomes of the workshop and form part of this report.

3.5 Workshop

The next stage was to hold a one day workshop for up to thirty people to confirm the list of issues and to determine actions required to address each issue and to prioritise these actions. Workshop attendees were to be drawn from the participants in the email discussion group.

The workshop attendees were divided into small groups and, following a short presentation of each issue briefing paper, they were asked to consider the questions posed for each issue and to report their views to the larger group. These reports were then collated and a list of prioritised actions developed by the workshop participants.

4. Results

4.1 Email Discussion Group

The discussion group was initiated with a welcome message that included what the project was about, the objectives, the process that would be used, what was expected of members and how an email discussion worked. Participants then received a copy of "An Overview of Current Concerns with Chicken Litter in Australia" to stimulate discussion. The information in the overview is incorporated in the more detailed information about chicken litter in this report.

The discussion was evaluated about every two weeks, questions posed to the group, more information provided if available and members who had specific knowledge prompted with questions to assist them provide comment to the group. This step was repeated three times.

The process was managed to ensure that the group was providing the information they possessed and was identifying the issues and problems. Problem solving was not encouraged.

From the discussion a set of issue themes and points for discussion were developed. These became the workshop discussion issues reported in that section of this report.

The email discussion group started with 48 members. They were drawn from meat chicken growers, processors, litter contractors and value adders, end users, researchers, regulators, food safety assurers, community and selected overseas researchers. The numbers quickly grew to 80 through members nominating people who they considered could add to the discussion.

About 18 percent of the email discussion group members participated in the discussion by providing comments or information. This was higher than the 10 percent participation rate experienced in other discussion groups run by the Department of Primary Industries and Fisheries.

It took longer than planned for people to respond with comments or information to each set of questions or tasks mailed out. This is because of the workload of most people and the time they have available for extra activities.

Comments from the participants indicated that the email discussion was worthwhile even though most members felt they were unable or unwilling to comment. Comments made were "I've learnt a lot", "I did not know there was so much known", "I didn't realise what some people know about it", "there has been good information come through and I've distributed it to my staff".

The discussion group improved people's knowledge about chicken litter, gave them a better understanding about the issues, a realisation that other people had similar problems and willingness to share and work towards a common goal.

Of the 32 people invited to the workshop in Sydney, 24 (including the three facilitator/presenters) were able to attend.

4.2 Workshop Discussion Issues

The following are the issues and discussion points for consideration by the workshop members that were developed by the email discussion group.

Public and environmental health issues associated with poultry litter

Points identified for discussion:

- Are there gaps in our knowledge of the public health risks associated with poultry litter being used as a soil conditioner or fertiliser?
- If there are gaps, what research is needed to address those gaps?

- What steps can be taken, in a public relations sense, to ensure that the value of poultry litter as a soil conditioner and fertiliser is fully appreciated by the end-users and the broader community?
- Does risk management offer a means of ensuring that poultry litter can be safely used as a soil conditioner and fertiliser with minimal impact on public health and on the general environment?

Litter management and the need for quality assurance programs to meet the needs of litter end users and the food industry

Points identified for discussion:

- What can be done to improve litter management in chicken sheds to reduce ammonia, dust and damp litter conditions?
- Is there a place for litter additives in the management of litter quality in meat chicken sheds?
- Are adequate quality assurance systems in place to ensure the litter contractors and composters receive litter which meets their standards to guarantee environmentally friendly and safe food utilisation of chicken litter?

Environmental issues associated with poultry litter

Points identified for discussion:

- What can be done to address the reduction in market and return for unprocessed poultry litter into the agricultural industries?
- Is sufficient knowledge and information on the Australian system available to address concerns over the use of unprocessed poultry litter?
- Are sufficient quality systems in place both on farm and off farm to ensure that poultry litter can be promoted by the industry as a safe fertiliser and soil amendment for use in the food production industries?
- What responsibility does the industry have for environmental friendly and safe food utilisation of poultry litter?

The feasibility of replacing single use of litter with the reuse of chicken litter for bedding material as the standard practice in Australia

Points for discussion:

- Do we have the knowledge and technology to reuse litter safely from a poultry health and a safe food viewpoint?
- Are there gaps in our knowledge about reusing litter safely?
- If there are gaps, what research needs to be done?
- What strategies are required to ensure supplies of new bedding material are available if the chicken meat industry needs to move back to single batch use?
- What strategies are required to ensure litter contractors and value adders are able to cope with changes to supply of used litter?
- Are litter treatments or additives effective and economical?

4.3 Survey

The results of the survey of chicken growers, processors and litter contractors are included in relevant sections representing the briefing papers used at the workshop. This was a simple and quick survey with the objective of obtaining sufficient data to give a picture of the cost, type and quantity of bedding material used, the depth placed in sheds, reuse, quantity disposed of and dollars received, method of utilisation and problems being encountered.

4.4 Current Knowledge

The information in the briefing papers was collated and developed from the email discussion group overview, searches of scientific and technical publications, searches of appropriate sites on the internet and from personal communication with industry and research people in Australia and overseas.

4.5 Workshop

The discussion was open and constructive with participants accepting each other's viewpoints and was focused on the objectives. The workshop established relationships between the participants from the chicken industry, researchers, litter contractors/value adders and end users.

The workshop discussion points were amended and confirmed by the workshop participants at the start of the workshop. These are presented in the section Workshop Discussion Issues.

The briefing papers used to supply background information on each issue are included in the relevant section of the report. These have been edited and further information added as a result of the workshop discussion.

Each small group recorded its proposed actions and comments about each issue on butcher's paper. These were presented to all groups at the end of each session. After the workshop these were collated and confirmed by participants as representing the group outcomes (see the Composite Group Outcomes).

At the end of the workshop the suggested actions/comments that were common amongst the small group outcomes were listed, edited, confirmed and prioritised for each major issue by the large group. These are presented in this report as the prioritised action list for issues discussed at the workshop.

4.6 Prioritised Action List for Issues Discussed at Chicken Litter Workshop

The prioritised action list developed from the issues discussed at the workshop is presented below. The actions are listed in order of priority for action under each workshop issue.

Public health issues

1. Identify the real and perceived risks associated with the utilisation of chicken litter.
2. Risk assessment methodology is a suitable approach to underpin the development of safe guidelines for utilisation.
3. Need for detailed knowledge of the levels of priority pathogens (*Salmonella*, *Campylobacter* and *Listeria*) and prevalence of antibiotic resistance in litter bacteria, and of heavy metals in chicken litter
4. Develop guidelines to allow safe, sustainable use of chicken litter.
5. There is a need to recognise that there are many end uses and guidelines will vary accordingly (cooked versus raw food crops; pasture etc).
6. PR campaign needed which targets end-users, regulators and the general community. RIRDC to act as source of information for this.

Quality assurance issues

1. Need to assemble information on current standards applicable to each use.
2. Need to identify what are the needs of each end user.
3. Agreed need for review of composting / pasteurisation efficacy of poultry litter in terms of pathogen survival.
4. Quality assurance systems needed that target end user requirements – important to ensure that litter is used according to usage standards.

Note:

- Need to keep overall focus on poultry production
- Best Practice Management for chickens = Best Practice Management for litter quality
- General agreement that the use of additives is only relevant if cost / benefit is favourable to chicken production.

Environmental issues

1. Need to understand the market for chicken litter – who uses the product and how much do they use?

2. Not enough information available to prepare guidelines – some of this information can be gathered from chicken integrator companies and overseas some may need to be generated locally. The big issue was seen to be pathogens.
3. Need for guidelines that show how litter can be stored, transported and used in a safe and sustainable manner (with awareness of variety of end uses)

Note:
- Industries need to be pro-active in the creation and development of Codes of Practice and/or Guidelines and in accepting responsibility (will avoid legislative action)
- Responsibility must be shared by all parties.

Single and reuse of litter
1. Need to organise a sharing of the information available from within integrator companies.
2. Research needed in reducing ammonia release particularly during chick brooding in reuse situations (both management systems and use of additives).
3. RIRDC research into alternative bedding materials may be needed such as tea tree mulch.
4. RIRDC funded evaluation of single and reuse of litter – (seen to be a low priority).

Note:
- General agreement reached that most of the information and knowledge on litter reuse exists.
- Market intelligence – refer to Environmental issues.
- New bedding availability is a supply / demand issue – prices may rise if demand increases due to increased single use of litter.

4.7 Recommendations for Future Research or Other Action

1. That research be undertaken to establish the prevalence and level of the priority pathogens in chicken litter and the incidence of antibiotic resistance genes in litter bacteria (both normal flora and pathogens)

It was noted that the Horticulture Research and Development Committee (HRDC) is already supporting research by the Victorian Department of Natural Resources and Environment in this general area. There may be an opportunity to link with this existing research. Therefore the HRDC research program should be expanded, if necessary, to ensure quantification as well as simple presence of pathogens is performed and that antibiotic resistance is examined.

2. That research be undertaken into methods of on-farm partial composting of chicken litter that is effective in pathogen reduction

There is a growing pressure from regulatory bodies as well as end users to ensure that chicken litter has been processed to some degree to reduce the numbers of pathogens present to an acceptable level. There are clear signals that regulators in some Australian states as well as in overseas countries are actively considering recommending the prevention of the application of untreated animal wastes to any agricultural land. There is an urgent need to ensure the validity of cost-effective, on-farm procedures such as deep stacking of litter under Australian conditions. A pro-active independent research program on this topic is vital to ensure the continued use of chicken litter as an organic fertiliser at a cost acceptable to the end user.

3. That RIRDC commission the development of interim guidelines for safe, sustainable use of chicken litter

The meat chicken industry has a responsibility to promote the safe and sustainable use of its products. Currently, the industry is unable to reliably inform potential users of the contents of chicken litter, as to how they should handle and store the material or how, when and how much to apply. Poor practices (and poorly informed actions) by end users will ultimately impact on the meat chicken industry itself.

Guidance needs to be provided to end users on appropriate practices to minimise risk to the ultimate consumer, the community and the environment. Based on average analyses of chicken litter or using the results of specific, case by case analysis (work book approach), guidance on appropriate application levels and application methods for differing scenarios needs to be provided to ensure sustainable use of chicken litter.

These guidelines will need to be up dated over time with improvements in knowledge and changing requirements.

4. That RIRDC facilitate communication between the meat chicken industry and litter contractors/value adders to develop effective links between the quality assurance programs implemented by both groups

Meat chicken processors and growers and litter contractors/value adders have or are developing quality assurance programs within their own areas of operation to ensure that the products they each sell meet the standards required by their end users.

The quality assurance programs used by both groups, which currently have different objectives, need to be linked to ensure continuity in a quality assurance program for the production of and utilisation of chicken litter. Litter contractors and value adders need to know the history of the litter. They need assurances about the level of pathogens and chemicals likely to be present in the litter when it leaves the chicken farm. This includes what pesticide, pharmaceutical and chemical risks may be associated with the product. They also have problems with variation in moisture content of litter and physical contaminants and uneven shed floors. These add to their handling and processing costs.

With the chicken industry's help, the litter value adders will have the potential to make a product at lower cost, ask more for it and pass some of this to the chicken growers. It is about the chicken industry seeing litter as a product with potential for value adding, rather than as a waste.

5. Supporting Documents

5.1 Potential Public Health Risks Associated with Poultry Litter

Introduction

A range of pathogens may potentially be present in poultry litter. Some of these organisms are pathogens of humans, others of poultry and yet others of poultry and humans. For the purpose of this paper, we will concentrate on those pathogens that are relevant to public health or animals exposed to chicken litter. A list of the main organisms of concern and their relevance to human health is set out below. An assessment of whether, under Australian conditions, these organisms are likely to be present in litter and have a significant role in public health issues associated with litter reuse is also provided.

Three other areas of concern viz. antibiotics and antibiotic resistance genes, heavy metals and hormones/endocrine disruptors, are also covered.

Tables showing the available data on the poultry litter and pathogens are provided so the text provides only brief notes. For the other issues, the text contains more details and references.

Potential pathogens

Campylobacter coli/jejuni

- Major cause of human gastro-enteritis.
- Poultry are a primary reservoir – however, can be normal harmless flora in chickens as well as a potential cause of disease.
- Fragile organism that is unlikely to survive any drying or heating process. Known to survive on pasture for 10-20 days.
- Important pathogen in litter reuse applications due to a low infectious dose and relatively high incidence in humans and almost universal presence in meat chickens.

Clostridium spp.

- *Clostridium perfringens* can cause gas gangrene as well as food poisoning.
- *Clostridium perfringens*, particularly type A, causes necrotic enteritis of chickens.
- Botulism (*Cl. botulinum*) is also important disease of both humans and animals. The types associated with human cases (types A, B, E and F) are not the types associated with chickens (types C and D). However, other animals eg dairy cattle are at risk from *Cl. botulinum* types C and D.
- Both *Cl. perfringens* and *Cl. botulinum* are widely distributed in the general environment, including chicken sheds.
- *Clostridium* spp. are spore forming organisms with a capacity to survive for prolonged periods in the environment.
- Heat resistance is an important issue with *Cl. botulinum*. Vegetative cells are killed by 5 minutes at 60^{o}C, its toxin inactivated by 5 minutes at 85^{o}C and spores by 10 minutes at 110-112^{o}C (this is a rough guide only – kill rate is influenced by pH, initial numbers and other factors).
- *Clostridium botulinum* is an important pathogen in litter reuse applications due to the potential severity of botulism outbreaks in susceptible animals such as cattle.
- *Clostridium perfringens* is a low risk pathogen as there is no strong existing linkage of human infections to poultry products or poultry litter.

Cryptosporidium

- *Cryptosporidium parvum* is an important and prominent pathogen in human infections and has been associated with the reuse of human waste as well as exposure of humans to cattle, sheep and pig waste. Watery diarrhoea and fever are the typical signs of human infections with *C. parvum*. *Cryptosporidium parvum* does not infect chickens.
- *Cryptosporidium baileyi* can infect the cloaca and the bursa of Fabricus of chickens. Histological lesions can be present but there are typically no gross lesions or any overt signs of disease. There are reports that cryptosporidiosis can adversely affect the performance of meat chickens. Respiratory cryptosporidiosis can occur and can result in high morbidity and mortality if associated with other respiratory disease agents. Infection with *C. baileyi* has been widely reported where ever intensive

chicken production occurs and where relevant diagnostic tools have been used. *Cryptosporidium baileyi* is regarded as non-pathogenic for humans. The only known case of human infection with *C. baileyi* was a patient suffering AIDS.

- Due to a lack of human pathogenicity, cryptosporidiosis is a low priority issue in litter reuse applications.

Escherichia coli

- *E. coli* disease in man is usually due to strains only associated with man. In recent years, there has been the emergence in humans of particular subtypes of *E. coli* - the so-called EHEC (enterohaemorrhagic *E. coli*). As EHEC are defined as strains that have caused human disease, the forms of *E. coli* present in animals and capable of becoming EHEC are known as VTEC (verotoxin producing *E. coli*) or more commonly STEC (shiga-toxin producing *E. coli*). The best known of the EHEC strains is the 0157 type that has caused problems in the USA in hamburger meat. These strains, mainly associated with inadequately cooked beef and sheep products, can cause serious conditions such as haemolytic urealytic syndrome (HUS).
- *E. coli* is a common, normal inhabitant of the gut of most mammals and birds. Most *E. coli* serotypes isolated from poultry are pathogenic for birds only and are not recognised as important causes of infections in other animals including humans. There is very little evidence that STEC are normally present in chickens.
- Chickens are susceptible to colonisation with *E. coli* O157:H7. Natural contamination of chicken meat with this organism has been found overseas and a food-borne outbreak of diarrhoeal disease associated with turkey meat has occurred in the USA.
- *E. coli* can survive for up to 21 days on pasture.
- *E. coli* is not likely to be an important pathogen in a litter use sense, due to low prevalence of strains which present a public health risk in chickens. However, public awareness of EHEC is such that the organism must be part of any considerations of litter reuse applications.

Erysipelothrix rhusiopathiae

- Causes erysipeloid, a local skin lesion that occurs chiefly as an occupational disease of persons engaged in handling and processing meat, poultry and fish
- Erysipelas of birds (an acute, fulminating infection of few individuals within a flock) is of more importance in turkeys than in chickens.
- Known to survive for up to 14 days on pasture.
- Low prevalence means that this organism is not likely to play any significant role in litter reuse applications.

Listeria

- In non-pregnant humans, *Listeria monocytogenes* causes meningitis, encephalitis or septicaemia. In pregnant women, *L. monocytogenes* can cause a flu-like septicaemia that can result in an infected foetus with the end result being abortion, stillbirth or premature birth.
- Outbreaks of listeriosis (caused by *Listeria monocytogenes*) are sporadic in poultry
- Rarely reported in Australian poultry.
- Unlikely to be a significant pathogen in litter reuse scenarios.

Mycobacterium

- In AIDS patients, *Mycobacterium avium* infection is common. However, most human infections are associated with *M. avium* serovar 1 while *M. avium* serovar 2 is the most common form isolated from chickens.
- Emerging issue in food safety is *Mycobacterium paratuberculosis* because of concerns that this agent may be linked with Crohn's disease. *M. paratuberculosis* is not known to occur in poultry.
- Tuberculosis of poultry, caused by *Mycobacterium avium*, is rare in Australia and USA.
- The rarity of the organism means that *Mycobacterium* is not likely to be a significant pathogen in litter reuse scenarios.

Pasteurella multocida

- *Pasteurella multocida* infection is rare in humans, generally being associated with cellulitis resulting from animal bites.

- *Pasteurella multocida* causes fowl cholera, a severe septicaemic disease of chickens. The organism is a common inhabitant of the upper respiratory tract of many warm-blooded animals.
- It is a generally fragile organism.
- The fragile nature of the organism combined with the usual exposure route for humans (animal bites or licks) mean that *P. multocida* is not likely to play a significant role in litter reuse scenarios.

Salmonella spp.
- Salmonellosis of humans is typically an acute gastro-enteritis following the consumption of contaminated food. It is usually a self-limiting illness and fatalities are uncommon.
- Infections due to Salmonella are not a common cause of disease in poultry in Australia. The Australian poultry industry is free of such diseases as pullorum disease and fowl typhoid (caused by *S.* Pullorum and *S.* Gallinarum respectively). As well, *S.* Enteritidis, a form of *Salmonella* that caused severe human disease overseas, is essentially absent from the Australian commercial poultry industry.
- Nevertheless, it is widely recognised that poultry can harbour *Salmonella* organisms and thus act as a reservoir with the potential for transmission to humans. In the USA, isolations of *Salmonella* are reported more often from poultry and poultry products than any other animal product.
- *Salmonella* have been shown to be capable of surviving for up to 53 days on pasture.
- While the serovars of *Salmonella* that are associated with human infections in Australia are not the common serovars likely to be found in Australian poultry litter, the public awareness of this organism makes *Salmonella* an important pathogen in litter reuse applications.

Brachyspira (Serpulina) pilosicoli
- *B. pilosicoli* has been isolated from the blood of critically ill patients as well as from biopsies of homosexual men with minor non-specific gastro-intestinal symptoms.
- Recent evidence in Australia suggests that *B. pilosicoli* infection is common in meat breeders and laying hens.
- Known to survive for up to 210 days in soil containing 10 percent pig faeces.
- As infection in meat chickens is unknown (disease is restricted to older birds), *B. pilosicoli* is not likely to be a significant pathogen in litter reuse applications.

Staphylococcus aureus
- *S. aureus* is a common cause of food poisoning in humans.
- *S. aureus* infections are common in poultry. Approximately 50 percent of poultry isolates of *S. aureus* produce enterotoxins capable of causing food poisoning in humans. There existing evidence is that *s. aureus* food poisoning outbreaks associated with poultry products are due to human strains of *s. aureus* that are either endemic in the poultry processing plant or sourced from the hands of the processor workers.
- *S. aureus* is a relatively resistant organism
- *S. aureus* is not likely to be a significant pathogen in litter reuse applications.

Yersinia pseudotuberculosis
- Causes mesenteric lymphadenitis, diarrhoea and septicaemia in humans
- Sporadic cause of acute septicaemia in poultry (avian pseudotuberculosis)
- It is a rare organism in Australian poultry
- Unlikely to play a role in litter reuse applications.

Rotavirus
- Rotavirus is a major cause of enteritis and diarrhoea in humans, particularly young children.
- Rotaviruses (as well as atypical rotavirus and rotavirus-like viruses) are now accepted as the cause of enteritis and diarrhoea in chickens.
- Little knowledge on the prevalence of rotavirus in Australian chickens. General overseas experience is that the infection is ubiquitous.
- Generally accepted that avian rotaviruses do not infect mammalian hosts.

Antibiotics and antibiotic resistance genes
- Antibiotic resistant forms of *Salmonella, Campylobacter, E. coli* and *Listeria* are either known to exist or are suspected to exist.

- The movement of antibiotic resistance genes across bacterial species raises the possibility of normal flora bacteria passing on resistance to pathogens.
- There is emerging evidence of a link between animal production facilities and infections in humans associated with antibiotic resistant bacteria. This includes a recent US case of child infected with a *Salmonella* resistant to 13 antibiotics for which the source of infection was suggested as cattle on the family property.
- No data available on levels of antibiotic resistance in bacteria isolated from Australian poultry litter.
- No data available on levels of antibiotics in Australian poultry litter. The available information on the characteristics of the antibiotics used in the meat chicken industry (including antimicrobial growth promotants and anti-coccidial agents) indicates that these agents are likely to be present at only low levels and with short half-life in meat chicken litter.
- Four Georgia poultry houses were studied in a 1996 study. The researchers examined 32 faecal coliforms, 21 *Pseudomonas aeruginosa*, 22 *Yersinia enterocolitica*, 9 *Aeromonas hydrophila* and 7 *Campylobacter jejuni*. One hundred percent of these isolates showed some form of multiple antibiotic resistance. The researchers conclude that antimicrobial drug resistance is a major issue in litter re-utilisation in the USA. The researchers did find in previous work that litter stored for 2 – 16 weeks showed a reduction in bacterial numbers. They conclude that reduction or elimination of bacteria by some form of litter treatment is required to reduce the risks associated with antibiotic-resistant bacteria in litter (Kelley *et al*., 1997).
- There is a growing view that some antibiotic resistance genes are energy conserving – meaning that they can convey an evolutionary advantage even in the absence of the antibiotic itself. This raises the possibility of the bacteria (pathogens or normal flora) retaining the resistance gene even in the absence of the antibiotic.
- Overall, the published literature suggests that it is likely that the presence of antibiotic resistance genes in litter bacteria (both pathogens and normal flora) is of more importance than the actual antibiotic itself.

Hormones and endocrine disruptors

- The hormones covered here occur naturally and are not growth hormones added to feed. No hormones of any sort are administered to meat chickens in feed or any other way in Australia.
- When present in high concentrations e.g. in discharges from sewage treatment plants, hormones in the environment are linked with adverse health effects on fish (Jenkins *et al.*, 2006).
- While elevated soil levels of estradiol can be detected after application of poultry litter, the levels return to background levels within 14 days (Finlay-Moore *et al.*, 2000) This rapid degradation of estradiol appears to be a common feature in soil environments (Colucci *et al.,* 2001).
- Elevated estradiol and testosterone levels are not always present following litter application e.g. Jenkins *et al.* (2006) found no elevation in soil levels following litter application.
- Grass buffer strips have been shown to be effective in significantly decreasing the run-off concentrations of estradiol from litter applications (Nichols *et al.*, 1998).
- On the basis that elevated levels of estradiol and testosterone do not always occur following litter application; that when elevated levels do occur they return to background levels quickly and that simple management strategies (vegetative buffer strips) can control run-off, the issue of hormones and endocrine disruptors is a low priority.

Heavy metals

- Studies on the levels of selected heavy metals in meat chicken litter have been performed in both New South Wales and Victoria. The detailed results of these studies have not been placed in the public domain.
- Both studies found broadly similar results. Key results were that copper and zinc levels could sometimes reach values near the recommended guidelines for unrestricted compost use (guidelines vary a little from State to State). Generally, arsenic levels are below recommended guideline levels. No other heavy metal is a cause for concern.

Pathogens/health risks

High Priority Pathogens/Health Risks Potentially Associated with Chicken Litter

Campylobacter jejuni
Clostridium botulinum

Salmonella spp.
Antibiotic resistance genes (in both normal flora and pathogens)

Medium Priority Pathogens/Health Risks Potentially Associated with Chicken Litter
Cryptosporidium spp.
Listeria spp.
Heavy metals – arsenic, copper, zinc

Low Priority Pathogens/Health Risks Potentially Associated with Chicken Litter
Brachyspira (Serpulina) pilosicoli
Clostridium perfringens
Erysipelothrix rhusiopathiae
Mycobacterium spp.
Pasteurella multocida
Staphylococcus aureus
Yersinia pseudotuberculosis
Hormones and endocrine disruptors

5.2 Impact of Composting on Pathogens

Introduction

Composting is a natural process in which microorganisms, using water and oxygen, decompose and stabilise organic matter. During this aerobic process, carbon is released as CO_2, resulting in a narrowing of the carbon:nitrogen (C:N) ratio and there is a concentration of refractory organic matter, N and inert material (ash).

Partial and full composting

In this section, the literature on the impact of either full or partial composting on pathogens will be reviewed. For the purpose of this review, partial composting is defined as a process such as deep stacking of the litter for period of one to two weeks. Composting is defined as a process in which the litter is mixed with a carbon source and then either passively or actively aerated over a period of ten to twelve weeks.

Pathogen killing mechanisms

With either partial composting or full composting, there is a range of potential mechanisms that could kill any pathogens present. These mechanisms include heat, microbial competition, nutrient destruction/depletion, and antagonism from indigenous microorganisms and time. Of these potential mechanisms, it is generally accepted that temperature and time have the major effects in pathogen killing. Antagonism from indigenous organisms and nutrient destruction/depletion are regarded as the major mechanisms for ensuring that pathogens do not re-grow.

A widely accepted rule is that a minimum temperature of 55^{o}C for at least three days would result in a highly efficient kill of pathogens.

An alternative guideline of 60^{o}C for 30 minutes has been suggested as a better basis for ensuring pathogen killing.

Pathogen re-growth

Pathogen re-growth is a newly emerging area of concern. Attention in this area has focussed on the fact that several studies have demonstrated that surviving *Salmonella* organisms in stored compost can re-grow to levels that pose health hazards. Recent work has suggested that the main control force preventing or limiting the re-growth of pathogens (ie *Salmonella* specifically) in compost is the indigenous microbial population (Sidhu *et al*., 2001).

As the indigenous population of compost declines with prolonged storage, the potential for *Salmonella* re-growth increases with prolonged storage of compost. Hence, the current recommendation of Sidhu *et al*. (2001) is to have only minimal storage of compost after maturation has been achieved.

Full composting

Flynn and Wood (1996) have evaluated the composting of wood shaving and rice hull based poultry litters. The study evaluated the impact of composting these two litter forms with wheat straw, peanut hulls, pine bark or paper mill sludge as the carbon source. Wheat straw was the only one of the four carbon sources that did not result in temperatures above 40^{o}C. Peanut hulls and pine bark resulted in temperatures of greater than 60^{o}C.

Hence, even with full composting, there is a need to ensure that the chosen carbon substrate will result in an acceptable minimum temperature for pathogen destruction.

Partial composting

The intention of partial composting (deep stacking is an alternative name) is to achieve pathogen reduction/killing. The time period typically used in this technique means that there is no major effect on C:N ratio or the other nutrient aspects of full composting.

Californian studies have demonstrated that deep stacked litter can rapidly kill pathogens – spiked *Campylobacter* survived only two hours, spiked *E. coli* survived 32 hours and spiked *Salmonella* survived 28 hours (Jeffrey *et al.,* 2001). This same group has developed a predictive model that indicates that the most important factor influencing the temperature profile of stacked litter is water activity (Aw). Piles with a high Aw will be 20^{o}C hotter than piles with a low Aw.

Similar results have been reported in deep stacked studies performed in Pakistan (Chaudhry *et al.,* 1998). This study found that deep stacked litter with 35 percent and 25 percent Aw reached 60^{o}C but litter with 15 percent Aw did not. After one week, deep stacked litter at all three Aw levels contained no detectable coliforms or faecal coliforms (initial levels were 10^3 to 10^4 per gram).

5.3 An assessment of the risk of used poultry litter resulting in the transfer of pathogens into the food chain

Introduction
Meat chicken litter has traditionally been used as an organic fertiliser in the intensive horticultural and cropping industries and in broad acre pastoral agriculture.

The increasing community focus on food safety has resulted in a need to ensure that the use of meat chicken litter does not result in any unacceptable risk of the transfer of pathogens into the food chain.

This section is the first step in the process of a qualitative risk assessment that would assist the poultry industry and the end users of chicken litter establish guidelines to ensure that no unacceptable risk of pathogen transfer into the food chain results from the use of meat chicken litter as an organic fertiliser and/or soil conditioner.

Information needed for a complete risk assessment
A complete risk assessment would need detailed information on the following
- level of the various pathogens in chicken litter
- die-off of pathogens in litter (during storage, composting or partial composting etc)
- survival of pathogens once litter has been applied (to soil, to pasture etc)
- infectious dose of the pathogen
- route of entry into the food chain

A UK Ministry of Agriculture Fisheries and Food report that has looked at the broad issue of animal manures and food safety (Nicholson *et al.* 2000) has concluded that so little information is available in the above key areas that a formal numerical risk assessment is not possible.

However, a qualitative risk assessment that uses the available knowledge is possible. The performance of such an assessment has several outcomes

- Key areas that require further research can be identified
- Guidelines based on the risk assessment can be developed while awaiting the outcomes of the on-going research.

Pathogens to be considered
There is a large list of pathogens that are potentially present in chicken litter that may cause human infections (see previous section).

Attempting to perform a risk assessment for all of these potential pathogens is of little practical value as some of the pathogens are rarely encountered, have high infectious doses and/or are known to have poor survivability in litter or the environment. Based on the priority listing in an earlier section of this document, the following organisms have been selected for consideration in this assessment:
Campylobacter jejuni
Clostridium botulinum
Cryptosporidium spp.
Listeria spp.
Salmonella spp.

Information on prevalence, levels and survival characteristics of the selected pathogens
There is little in the way of definitive knowledge on the prevalence, levels or litter survival characteristics of the selected pathogens either in the Australian context or the broad international context. A summary of the available data for these pathogens is presented in Tables 6 and 7.

Survival in soil

There is a reasonable body of knowledge on the survival of most of the pathogens selected as high priority. The available information is not necessarily all based on the use of poultry litter/manure – often the available figures are based on cattle or pig manure. The following is a summary of the available knowledge on soil survival

Campylobacter jejuni – maximum of 20 days (cattle manure)
Clostridium botulinum – indefinite due to spores – organism highly adapted to environmental survival
Cryptosporidium spp – 2-4 weeks (experimental estimation)
Listeria spp. – 300-700 days (30-40% of undisturbed soils positive)
Salmonella spp. – 300 days (cattle manure)

Infectious dose

The simple presence of a pathogen does not necessarily mean that infection will result. The pathogen must be present at high enough numbers to ensure that an infection will result. This effect of numbers is quantified as the ID_{50} – the number of organisms needed to ensure that 50% of the exposed population are infected. There is a reasonable knowledge of the ID_{50} of the selected pathogens and the information is set out below.

Table 3. The infectious dose for selected pathogens.

Pathogen	ID_{50}
Campylobacter jejuni	900
Cryptosporidium parvum	150
Listeria spp.	2,100,000
Salmonella spp	100,000

Note: As botulism is associated with preformed toxin, in general, the ID_{50} is not relevant.

Routes of entry of pathogens into the food chain

While potentially there are many different ways that any pathogens in used chicken litter may enter the food chain, the main risk areas have been identified as:

- Application of litter (untreated, partially composted or composted) directly to growing crops or incorporated in soil prior to crop sowing.
- Application of litter to pasture that is then grazed by livestock.

In the scenario with growing crops, there is a greater risk for food crops that are either eaten raw or which may receive only minimal processing before consumption. The food crops that appear to be a greater risk include lettuce, radish, onions, pulses, cabbage, cauliflower, broccoli, celery, carrots, herbs, garlic, shallot, spinach, asparagus, soft fruits (eg strawberries).

Qualitative risk assessment

A first step in the attempt to develop a qualitative risk assessment for the selected pathogens is shown in Tables 4 and 5. The assessment has been performed only for the risk food crops where there is a possibility of minimal processing before consumption. In these Tables, partial composting indicates some form of treatment such as deep stacking that is designed to achieve a reduction in pathogen levels but not the balancing of nutrients that is associated with full composting. The assessment has been based on that performed by Nicholson *et al.* (2000) and modified where necessary to reflect Australian conditions.

Summary

- Poultry litter can contain a number of pathogens that are of significance in terms of public health
- The range of pathogens present in poultry litter is less than that present in both human effluent and the effluent produced by other intensive animal industries.
- As well as pathogens, poultry litter can contain other materials that are a risk to public health – heavy metals, antimicrobial agents (as well as the genes that confer resistance to these agents), hormones and endocrine disruptors.

- The pathogens and health risks that are the highest priority are:
  - *Campylobacter jejuni*
  - *Clostridium botulinum*
  - *Salmonella* spp.
  - Antibiotic resistance genes (in both normal flora and pathogens)
- Both composting and partial composting (defined as achieving a temperature of 55^{o}C for at least three days) are methods of achieving a reduction in the pathogen load of chicken litter.
- Qualitative and Quantitative Risk Assessment methods offer a valid and useful method for the establishment of guidelines for the safe use of poultry litter.

Table 4. Qualitative risk assessment† of human disease from pathogen transfer to crops* grown in contact with soil that has received poultry litter (modified from Nicholson *et al.,* 2000).

Pathogen	No composting or application restriction	Partial composting** (no application restriction)	Composting (no application restriction)	No application within 90 days (no composting)	Composting and application > 90 days
Campylobacter	4	1	1	1	1
Salmonella	4	2	2	2	1
Listeria	2	1	1	1	1

†Risk score is as follows 4 - high risk; 3 - medium risk; 2 - low risk; 1 – negligible risk

*Crops grown in contact with soil and which may only have minimal processing before consumption include lettuce, radish, onions, beans, cabbage, cauliflower, broccoli, celery, carrots, herbs, garlic, shallot, spinach, asparagus, soft fruits (eg strawberries).

** Partial composting is defined as a treatment that achieves a minimum temperature of 55^{o}C for at least three days eg deep stacking of litter.

Table 5. Qualitative risk assessment† for the risk of pathogen transfers to grazing or foraging livestock on pasture/forage that has received poultry litter (modified from Nicholson *et al.,* 2000).

Pathogen	No composting or animal withholding period	Partial Composting*	Animals withheld for 3 weeks		Forage production land (hay, silage etc)
		No animal withholding period	No composting	Partial composting*	
Campylobacter	4	1	1	1	1
Clostridium botulinum	5	3	3	2	1
Salmonella	3	2	2	1	1
Listeria	2	1	2	1	1

†Risk score is as follows 5 – very high risk; 4 - high risk; 3 - medium risk; 2 - low risk; 1 – negligible risk

* Partial composting is defined as a treatment that achieves a minimum temperature of 55°C for at least three days eg deep stacking of litter.

Table 6. International data on poultry litter pathogens

Pathogen	Priority	Prevalence in litter	Survival in litter	Numbers in faeces
Salmonella	High	0-100% of samples collected from 9 farms Majority of isolates *S.* Typhimurium, *S.* Blockley[1]		-
		0-100% Majority of isolates *S.* Typhimurium[2]		
		17% of 70 clean litter samples in shed 23% of 70 litter samples after 5 d of chicken growth 24% of 75 litter samples after 6 wk of chicken growth– Majority of isolates *S.* Infantis (61%)[3]	18 months in artificially spiked litter held at 11 & 25°C [6] 13 days in artificially spiked litter held at 38°C [6]	
		55% of 45 sheds with single use shavings, 50% of 3 sheds with reused shavings, 60% of 16 sheds with single use straw Majority of isolates *S.* Heidelberg; *S.* Infantis [4]		
		4% of 50 litter samples from a meat-breeder farm 33% of 54 litter samples from a layer-breeder farm Majority of isolates *S.* Java[5]	28 hours in three artificially spiked *stacked* litter piles (Average temperature ranged from 49-68°C)[9]	
		72% of 118 litter samples from occupied sheds 0% of 14 litter samples from empty sheds Majority of isolates *S.* Blockley[7]		
		Absent in 86 litter samples from 86 farms (64 composted, 18 not composted and 4 of uncertain state)[12]		
		Not detected in 24 samples of dried poultry litter [11]		

Table 6. International data on poultry litter pathogens

Pathogen	Priority	Prevalence in litter	Survival in litter	Numbers in faeces
Campylobacter	High	8% of 60 litter samples collected from 4 sheds with *Campylobacter* positive chickens [8]	2 hours in three artificially spiked *stacked* litter piles[9] (Average temperature ranged from 49-68°C)[9]	10^6 – 10^9 cfu/g[10]
		6% of 16 litter samples collected from 5 sheds with *Campylobacter* positive chickens [19]		
		Not detected in 24 samples of dried poultry litter [11]		
STEC	*Not Rated	Not detected in 24 samples of dried poultry litter [11]	32 hours in three artificially spiked *stacked* litter piles[9] (Average temperature ranged from 49-68°C) – not STEC[9]	-
		Not detected in 86 litter samples from 86 farms (64 composted, 18 not composted and 4 of uncertain state)[12]		
Clostridium botulinum	High	**Type C spores[16], Type C toxin[17] and Type C vegetative cells[18] all known to be present		
Cryptosporidium	Medium			10^6 oocyst/g in artificial infections with *C. baileyi*[13]
Listeria	Medium	1.5% of 67 litter samples for positive for *L. monocytogenes*[15]		
		7.5% of 67 litter samples for positive for *L. inocua*[15]		

* STEC has been included in this Table only for completeness of the data set. Chickens are not regarded as being a host of STEC.
** Type C botulism is not a major threat to human health. Type C botulism is important for cattle.

Table 6. International data on poultry litter pathogens

References

1. Higgins *et al.* (1981)
2. Olesiuk *et al.* (1971)
3. Bhatia *et al.* (1979)
4. Long *et al.* (1980
5. Barbour & Nabbut (1982)
6. Williams & Benson (1978)
7. Limawongpranee *et al.* (1999)
8. Gregory *et al* (1997)
9. Jeffrey *et al.* (2001)
10. Jacobs-Reitsma *et al.* (1995)
11. Jeffrey *et al.* (1998)
12. Martin *et al.* (1998)
13. Taylor *et al.* (1994)
14. Varga *et al.* (1995)
15. Petersen & Madsen (2000)
16. Okamoto *et al.* (1999)
17. Ortolani *et al.* (1997)
18. Lobato *et al.* (1995)
19. Ring *et al.* (2005)

Table 7. Australian data on poultry litter pathogens

Pathogen	Priority	Prevalence in litter	Survival in litter	Numbers in litter
Salmonella	High	94% of 16 litter samples collected from 2 sheds prior to chicken placement(1) 93% of 15 litter samples collected from 2 sheds at 14 days after chicken placement(1) 100% of 15 litter samples collected from 2 sheds at 21 days after chicken placement(1) 96% of 15 litter samples collected from 2 sheds at 14 days after chicken placement(1) Majority of isolates : *S*. Anatum, *S*. Derby, *S*. Singapore, *S*. Cubana(1)		
Campylobacter	High		Numbers in litter monitored over time after removal of *C. jejuni* colonised chicks(2) At 0 hrs 2.9 X 10^6 cfu/g(2) At 24 hrs 2.8 X 10^3 cfu/g(2) At 48 hrs 5.3 X 10^2 cfu/g(2) At 72 hrs < 5 cfu/g(2)	10^4-10^6 cfu/g – artificial infection(2)

References
1. Simmons & Byrnes (1972)
2. Shanker *et al.* (1990)

5.4 Litter Management and the Need for Quality Assurance Programs

The Australian poultry industry and the community generally are concerned about the management of chicken litter, from sourcing the initial bedding material through to utilisation of the by-product.

The community however, has some concerns about litter being spread on land, the associated odour emissions and the potential contamination of water tables and streams with nutrients and pathogenic organisms.

Consumers are demanding “clean” food. Farmers must guarantee, through participation in quality assurance programs, that their produce (milk, vegetables etc) is not contaminated with microbes likely to cause disease or contain undesirable antibiotic and chemical residues.

Government bodies expect that when chicken litter is applied to land as a fertiliser or soil conditioner that:

- the rate of application will be based on crop removal of nutrients and trace elements;
- it will not pose a risk to the environment due to the accumulation of nutrients, salts or heavy metals;
- it will not pose a risk to public health through application to edible crops.

In Australia, litter is a cost to the industry of $10.7 million annually. The chicken grower pays for the new bedding material and usually receives nothing for the litter removed from the shed.

There is potential for product and market development if the industry can produce used litter of consistent quality. The litter contractors require used litter of consistent and known quality so that they can design and make a product that consistently meets the requirements of their market and relevant standards.

Poultry manure contains a broad range of plant nutrients that make it suited to use as a general fertiliser for vegetable crops and pastures.

The quality of used litter is affected by its nutrient value, physical appearance, moisture content, friability, the presence of lumpy material and the depth and type of fresh bedding applied in the shed. The physical appearance of litter is affected by the number of batches of chickens that have been placed on it. Reused litter is darker and therefore supposedly will contain more plant nutrients. These qualities all affect the final sale value of the litter irrespective of whether it is raw or untreated or has been treated in some way.

There are new competitors in the alternative by-product fertiliser or soil conditioner market in which chicken litter is placed. Production of biosolids from sewage treatment plants and composted green waste are increasing as local authorities, required to meet new environmental standards, try to find alternative uses for wastes dumped at land fill tips.

Composted green waste is not necessarily a direct competitor with composted chicken litter because of a lower nitrogen value. It is more a soil conditioner. Green waste and chicken litter can be blended to make a composted product with a fertiliser value that is acceptable to the horticulture industry. The green waste provides the carbon to provide the correct carbon to nitrogen ratio for making good compost. The chicken litter provides the fertiliser value, particularly nitrogen and phosphorous.

The bio-solid and green waste producers have the resources from local authority rates and tip fees for dumping to subsidise the disposal of their products. Their easily accessible urban markets are limited in size and agriculture is seen as a large market with many opportunities. They are or will be selling products that meet current EPA and food safety guidelines or standards. The green image linked to compost and green waste would be useful for the poultry industry to build-on with utilisation of chicken litter.

New bedding material

The type of material used as bedding depends on what is available, suitability and cost in the localities where chickens are grown (see Table 8). It must be clean, dry and free from chemicals, preservatives and insecticides. Materials commonly used are rice hulls, timber shavings, sawdust, chopped straw and shredded paper. Moisture content can be a problem particularly with sawdust.

Table 8. Type of new bedding material used per state (based on shed floor space).

State	New Bedding Material Type Used (%)				
	Sawdust	Shavings	Rice Hulls	Straw	Paper
NSW	40.2	34.7	23.7	1.0	0.4
QLD	26.4	71.2	0.0	0.9	1.5
SA	0.0	65.9	0.0	34.1	0.0
TAS	100.0	0.0	0.0	0.0	0.0
VIC	0.0	50.0	50.0	0.0	0.0
WA	100.0	0.0	0.0	0.0	0.0

The cost of new bedding material delivered on farm varies from \$6.70 to \$18.50 per tonne. The highest cost states are New South Wales and Western Australia with Victoria and Tasmania the lowest (see Table 2 in the Introduction) This is a reflection of availability and transport distance and costs.

Alternative bedding materials

Possible options for making up any shortfall in supply are increasing the use of straw, paper, sand and tea tree fibre. Straw is reported to be high in the fungus *Aspergillus* if there are damp conditions in the period prior to grain harvest. Litter tends to be damper and cake quicker if paper is used as a bedding material. Other bedding materials that have been tried overseas are soya bean hulls and peanut hulls.

A product called Litter Plus made from ground recycled wood pallets subjected to a thermal friction process and dried is available in the USA. When compared to pine shavings the results were similar except there was more caking with Litter Plus.

Alum sludge (20 percent) and/or zeolites (10 percent) have been mixed for wood shavings as a bedding material without any detrimental effects on chicken performance, or quality and litter characteristics. Alum sludge is a co-product from the purification of drinking water.

Sand is used in countries with limited forest resources. Researchers at Auburn University have investigated the feasibility of using sand (washed, mortar or building grade) as a bedding material for meat chickens. There was no difference in chicken performance, processing quality and yield when compared to chickens placed on pine shavings. There were no significant differences in litter moisture, ammonia production and litter temperature. Coliform and aerobic plate counts were significantly reduced on sand litter. There was both a lower incidence and activity of darkling beetles with the sand litter.

A depth of 100 mm of sand was used in the field trials. Very little sand is removed from the house during caking and no top dressing was required. Since sand is heavier it continuously sifts the lighter, dried organic material to the top. The most important characteristic of sand bedding is its durability and long life. This could be enhanced with periodic cleaning to remove the light organic matter and heat sterilisation.

Tea tree bedding, the fibrous material (leaf and chopped stalk) remaining after steam distillation to remove the oil has been tried in North Queensland and the Northern Rivers area in New South Wales. Results indicate that both litter and chicken performance are at least equal to hardwood sawdust. It is damp as is hardwood sawdust, and there are problems with cold litter during brooding. *Aspergillus* is a problem that is managed by spraying the litter with diluted tea tree oil after spreading in the shed. The disinfectant properties of tea tree oil apparently kill, or prevent the growth of, *Aspergillus*.

Bedding depth

The depth of new litter or bedding material placed on the shed floor varies between growers, processors, states and locality. Unevenness in the depth of bedding spread on house floors presents a problem for litter contractors and value adders. Uneven floors add to the problem. The unevenness in the thickness causes inconsistency in the product in that it leads to patches of bedding material that contain no manure requiring the litter to be mixed at added cost before the contractor can sell it.

More litter is required to absorb moisture in regions that have cold wet winters. A minimum of 50 mm is considered adequate to provide sufficient absorbent material for the chickens to start on and to avoid caking in Queensland, New South Wales, South Australia (drier winter region) and Western Australia. In Victoria, Tasmania and parts of South Australia which have cold wet winters, a depth of 75 mm is required to absorb the extra moisture. A survey of the industry shows that the depth of bedding material used in Queensland, New South Wales, South Australia (drier winter region) and Western Australia is 40-50 mm. In Victoria, and Tasmania it varies between 65-75 mm and for South Australia (wet winter region) it is 70-75 mm (see Table 9).

Table 9. Depth of new bedding material is spread on shed floor by State.

State	New Bedding Material Depth (mm)				
	Sawdust	Shavings	Rice Hulls	Straw	Paper
NSW	40-50	40-50	40-50		40-50
QLD	40-50	40-50		40-50	40-50
SA		50-70		75	
TAS	65-75				
VIC		65	65	65	
WA	40				

Bedding material and used litter volumes

Information was collected about the volume of various bedding materials placed in houses and for litter collected from farms.

The volume of bedding material placed per unit area of house floor space varies according to type of bedding material, depth of bedding desired and how much the material "fluffs up" when spread on the floor. Shavings in particular will fluff up when spread. The figures in Table 10 give an indication of the volume of bedding materials used according to depth spread on the house floor.

Moisture content of the litter is the main effect on the volume of single batch litter removed from a shed. For dry litter the ratio of volume of new bedding material placed in the shed to the volume of litter removed is in the range of 1:1.9 to 1:2.1. For damp or wet litter the ratio is 1:1.4 to 1:1.7 (see Table 10). Damp litter tends to compact more than dry litter.

In the context of the data collected in the survey the terms wet and dry are used in a broad sense. Dry litter means litter which is friable through to dusty. Wet being litter holds together when compressed in the hand, compacts easily or is sticky.

The data available suggests that for reused dry litter where the first batch of bedding material is spread at 40-65 mm, then the volume removed from the shed is approximately equal to the volume of the first batch of bedding material plus the volume of original bedding material multiplied by the number of batches of chickens placed. This applies for two to six batches of chickens.

Table 10. Bedding material and used litter volumes for single batch litter (m^3 of bedding or litter per 1000 m^2 of shed floor area).

Bedding Material	Depth in shed (mm)	$m^3/1000\ m^2$ floor area Bedding Placed	litter removed (bedding & manure)	Ratio bedding:litter
Rice hulls average	65	47.8	79.7	1:1.7
Sawdust	50	33.7	67.3	1:2.0
Shavings wet	50	48.2	69.3	1:1.5
Shavings dry	65	62.5	119.1	1:1.9
Sawdust	50	32.4	64.9	1:1.2
Shavings	70	59.8	-	-
Shavings dry	50	25.5	52.7	1:2.1
Shavings wet	50	25.5	44.6	1:1.7

Litter bulk density

The bulk density of the bedding materials, sawdust and shavings varies according to moisture content, type and quality of the timber used. It depends on whether the timber has been dried prior to processing or the sawdust or shavings dried after processing. Wet sawing of timber or logs wet due to rain also result in damp sawdust. Rice hulls, paper and straw are always dry when delivered to the farm (see Table 11).

Table 11. Bulk densities of bedding materials (m^3/t)

Bedding Material	Density (Cubic metres per tonne)
Shavings southern dry	12.00
Shavings southern wet	6.00
Rice hulls	10.00
Sawdust hardwood	2.50
Sawdust hardwood wet sawn	2.00
Sawdust hoop pine	2.50
Shavings northern	4.65
Sawdust Jarrah wet	1.75
Sawdust Jarrah dry	2.20

Information collected suggests that the bulk density of used litter is in the range of 2-2.5 m^3 per tonne. Moisture content is the main cause of the variation. The bedding source material and the depth placed may cause small variation.

Litter dryness

Moisture management in the shed affects litter dryness. As the litter becomes damper more ammonia is released and the nitrogen content of the litter decreases. At the other extreme as dryness increases the atmosphere in the shed gets dustier.

Management of drinkers, foggers and house ventilation rate is critical in maintaining dry litter. The drier the litter, the more dust is created in the shed. The damper the litter, the more ammonia and odour is generated. Dust and ammonia can potentially pose health problems for both chickens and staff working in the sheds.

Damp new bedding material encourages the growth of the fungus *Aspergillus*, a potential cause of disease in young chickens. Damp litter is also cold, which creates problems in getting chickens started well. Overall, damp litter is detrimental to chicken welfare, chicken health and productive performance.

Feed ingredients, drinking water salt content and management of drinkers, foggers, evaporative cool pads and ventilation influence litter moisture content. It is also affected by humid warm and cold weather.

Litter contaminants

Lumps of wood, pieces of metal and plastic and rocks are contaminants in raw litter which have to be removed before it can be further processed because of the risk of damage to equipment.

Poultry carcasses are also a contaminant of chicken litter. Carcass contamination can be minimised by paying attention to the daily collection of mortalities and collecting any carcasses remaining after final kill out. Untreated litter spread directly on pastures has been implicated in deaths of dairy and beef cattle due to botulism due to the chicken carcasses left in the litter. The presence of carcasses can result in extra handling and downgrading of the product and a lower monetary value when sold by the litter contractor.

Nutrition

Improved poultry diet formulation techniques and additives are being developed to achieve more efficient use of the protein and phosphorous in the diet and to reduce the amount of these nutrients, particularly phosphorous, in the litter.

Feed additives such as the enzyme phytase, enzyme mixes and vitamin D_3 metabolites are now available which maximise the availability of phosphorous to meat chickens. New feed ingredients that are low in phytate phosphorous are being developed and tested. Lowering of the phosphorous content of litter will lower what end users are prepared to pay for litter in those cases where the monetary value is based on the nitrogen, phosphorous and potassium content.

Nutritional additives to poultry diets provide a source of a range of heavy metals in litter. However, results of analysis of litter undertaken in a Victorian study showed that heavy metal levels in litter are generally well below the maximum levels prescribed in composting and manure standards. However, copper levels were on occasion marginal. Attention should be given to feed ingredient monitoring and diet formulation to ensure that heavy metal levels continue to remain within allowable limits.

Options for litter utilisation

The options available for the utilisation of chicken litter are:

- raw or untreated litter applied to land as a fertiliser or soil conditioner;
- pasteurised litter;
- composted litter;
- pasteurised litter mixes;
- composted litter mixes;
- pellets;
- enhanced pellets;
- fuel for combustion to supply heat or to generate electricity;
- generation of methane gas for combustion to supply heat or to generate electricity.

For more information on litter utilisation see the section on Environmental Issues.

Irrespective of the final use for chicken litter, end users are asking for assurances that there are no pathogens or chemicals considered harmful to man in chicken litter. These assurances enable them to produce an end product to the standard required by their market.

The adoption of partial composting or composting to provide a pathogen free product will require additional management, technical and marketing skills to be developed or sourced by the traditional litter contractor. There are indications that operators with these skills available are expanding their business to cater for a new market.

Nutrient levels in litter

The levels of nitrogen, phosphorous and potassium in the final product are related to the type and amount of initial bedding material and manure content (single or multi-batch). Nutrient levels are influenced by litter moisture content during and at the end of the batch/es of chickens and method of storage after litter removal from the shed. The higher the moisture content, the more ammonia is released and the less nitrogen that remains. Nitrogen losses continue to occur during storage even if the litter is stacked in large stockpiles. Phosphorous and potassium losses are negligible unless the litter gets wet, with losses then occuring due to leaching.

Analysis results of single batch litter made available by litter value adders shows nitrogen levels of 2.4-4.2%, phosphorous 1.6-2.4% and potassium 1.9-2.1%. This is similar to overseas data. The nitrogen content of single batch litter sourced from farms contracted to the same processor ranges from 3.2-4.8%. Given the standardisation of feed, litter source, and farm management practices this variation is difficult to explain. Three possibilities are the climatic seasonal differences, litter moisture management differences between farms and differences in feed wastage between farms.

There is little difference in the nitrogen and phosphorous content of single batch and reused litter (2-4 batches) where the depth of bedding material used at the start was 40-50 mm. The use of greater depths of bedding material has a dilution effect with single batch litter. This creates a problem for resellers of raw litter. If there appears to be bedding material present or the litter is lighter in colour then crop farmers believe it must contain less nitrogen.

Heavy metals and other quality criteria

The levels of certain heavy metals in particular, copper, zinc and arsenic in litter have occasionally been found to approach maximum contamination levels in the standards and guidelines used by the composting and fertiliser industry (see section on Potential Health Risks and Composting Standards). Litter contractors would like to see a quality assurance program introduced which incorporates farm and nutritional management practices. In the absence of a quality assurance program they feel that they need to know the history of the litter, including the bedding material type, source and depth used, how it was managed in the shed and any chemicals, pesticides and antibiotics that might have been applied to it or the flock(s) on it. This would make it easier for them to manage the composting process, reduce monitoring costs and produce a more consistent product that meets their customer's needs.

Food safety

The level of pathogens present in chicken litter can be reduced by two methods; either by pasteurisation (deep stacking) or by composting.

Pasteurisation uses the heat of the composting process to kill pathogens and weed seeds. It is done under aerobic and thermophilic conditions such that the whole mass of constantly moist material is subjected to at least three consecutive days at a minimum temperature of 55^{o}C. The outer material is turned to the inside of the windrow or heap so that the whole mass is subjected to a minimum of three turns with the internal temperature reaching a minimum of 55^{o}C for three consecutive days before each turn. This process takes at least ten days compared to the 10-12 weeks for composting.

Composting is the process of stacking or windrowing and aerating the litter by turning while maintaining an appropriate carbon to nitrogen (C:N) ratio and moisture content to allow a biological process to break down the manure into humus.

Pasteurisation will give a product similar to chicken litter in terms of nutrient levels but with the advantage of pathogen removal. Pasteurisation process is cheaper than composting and takes less time.

The profile of major nutrients in chicken litter does not exactly match plant requirements. Therefore, care must be taken with its application to ensure that excess nitrogen and phosphorous does not move into the water table. Effectively, the phosphorous required by the plants is matched to the amount provided in the litter.

For more information on the effectiveness of these processes in destroying pathogens refer to the paper on the Impact of Composting on Pathogens.

Summary

- The community has some concerns about odour and dust coming from chicken sheds, litter being spread on land and associated odour emissions, the potential contamination of water tables and streams with nutrients and pathogenic organisms from litter and contamination of food produced using litter as a fertiliser input with pathogens, antibiotic and chemical residues.

- There is a need to link the quality assurance programs applying to chicken growing to those being implemented by the litter contractors and value adders.

- Current quality assurance chicken growing and litter utilisation programs may need to be adjusted to ensure that community concerns about litter utilisation are addressed.

- The traditional litter contractors will require additional skills and knowledge to be able to effectively implement a quality assurance program appropriate to the needs of end users.

- Partial composting or deep stacking has the potential to pasteurise chicken litter to ensure that it is free of pathogens and provide a product at a lower cost than composting. A lower cost product has the potential to increase use for application to land used for growing vegetables, fruit and pastures for stock.

- Quality assurance programs for chicken litter production and value adding and utilisation will be crucial in ensuring long term market access and financial returns for litter.

5.5 Environmental Issues

Introduction

Environmental issues facing the meat chicken industry include:

- air quality concerns regarding emissions of greenhouse gases, particulate and volatile compounds including volatile organic compounds (VOC) and ammonia;
- community amenity concerns regarding emissions of odours, pathogens, endotoxins, noise, light and insects;
- soil and water quality concerns regarding nutrient movement from production facilities and storage areas and nutrient movement and heavy metal, pathogen and anti-microbial contamination from land application of poultry litter.

This paper will be restricted to those issues relating to poultry litter.

Poultry litter properties

The nutrient content of chicken litter makes it a valuable fertiliser for pasture and crop production. Chicken litter also has a soil conditioning value that is considered important as it adds humus. The addition of organic matter to soil promotes both crop and soil health, enhances the soil structure and improves the availability of nutrients to plants. It is difficult to define how much these effects are worth financially to the end user, as the value depends on the crop to be grown and the soil type, nutrient and organic matter status. The monetary value of poultry litter as a chemical fertiliser based on its nitrogen, phosphorous and potassium (NPK) analysis is relatively easily defined. However, the availability of these nutrients for plant growth will occur over a period of time. The nutrient content of poultry litter will be influenced by single litter use versus reuse within the sheds, amount and type of original bedding material added and litter management and feed formulation practices.

The levels of certain heavy metals, in particular; copper, zinc and arsenic, detected in litter have occasionally been found to approach maximum levels allowable in Environmental Protection Agency or Composting Standards. Discussions between processors and litter contractors have helped to manage the problem. Litter contractors would like to see a quality assurance program incorporating farm and nutritional management.

Improved poultry diet formulation strategies are being developed to achieve more efficient use of the protein and phosphorous in the diet and to reduce the amount of these nutrients excreted by poultry. Phytase has been added to diets to increase the availability of organic phosphorous to the birds. This reduces the amount of inorganic phosphorus added to ensure adequate phosphorus for growth, thereby reducing the excess phosphorus that is excreted in the manure.

Some microbial inhibitors and other chemical additives, when added to the litter, can reduce the rate of release of ammonia in litter. The moisture content and pH of the litter are critical in the effectiveness of these cultures. Certain clays (zeolite) have the ability to lower litter moisture and absorb ammonia. The addition of acidifying agents to the litter lowers litter pH and reduces ammonia volatilisation.

Litter $ value

Most growers in Australia get nothing for litter after the cost of removal from the chicken shed is deducted. In some instances, growers who may act as litter contractors and have arrangements with local end users and receive some return for their services.

The cost of raw litter delivered to the end user ranges from $8-19 per cubic metre. The higher figure probably represents its maximum value based on comparison with the cost of chemical fertilisers. It is spread on pastures or land used for tree, vine, vegetable or broad acre crops. Transport is the largest cost component in handling or supplying raw litter.

The average bulk sale value for compost made from litter is $30 per cubic metre. The largest cost component is transport and turning costs incurred during the composting process. It takes about 3 cubic metres of chicken litter to make one tonne of compost. This value can be increased substantially through value adding such as pelleting and speciality products focused on the home gardener market.

Options for litter utilisation

Most of the chicken litter produced in Australia is utilised off the poultry farms. Direct application of untreated poultry litter to agricultural production (small crops, tree crops, grain crops and pastures), golf courses and home gardens is the traditional and most popular method for utilising chicken litter. In Australia, the horticultural industries have used large quantities of poultry litter in their production systems. The survey showed that 11% of the litter was applied to pasture, 29% to horticultural crops, 6% to broad acre crops, 5% was composted and 49% went to litter contractors with no knowledge of end use.

Extensive direct application of poultry litter at high rates on pastures in areas surrounding poultry production areas in the United States has contributed to degradation of the environment in these areas. Application of nutrients in excess of plant uptake and requirements in areas of light soils and shallow water tables has resulted, in these areas, in nutrient movement through the soil profile into the ground water and in overland flow into surface water. These nutrients have contributed to eutrophication of water bodies and degradation of environmental values.

Community and government pressures on the poultry industry for clean air and water and safe food are forcing the poultry industry and litter contractors to look at more acceptable options to utilise litter. The development and implementation of quality assurance programs within the horticultural industries, combined with concerns and uncertainty regarding potential pathogens contained in poultry litter (and other unprocessed organic fertilisers) has resulted in a sudden and substantial reduction in the amount of poultry litter being utilised.

The apparent alternatives to direct utilisation of used litter as a fertiliser and soil amendment are livestock feed, composting, pelleting, enhanced pellets, compost mixes, electricity generation, gasification and direct heat.

Livestock Feed

The use of poultry litter as a feed ingredient for ruminants is illegal in Australia. In the USA, the feeding of litter is legal, providing it has been adequately composted and the composting process is defined by legislation.

Compost

Composting can turn poultry litter to a more marketable, value added, environmentally acceptable product. Chicken litter has a comparatively high nitrogen level that makes it valuable for making compost. Composting is the process of stacking or windrowing and aerating the litter by turning while maintaining an appropriate carbon to nitrogen (C:N) ratio and moisture content to allow a biological process to break down the manure into humus. During the process, heat, water and carbon dioxide are generated. It is important that the temperature is maintained within a prescribed range to ensure that the heat kills pathogens, insect eggs and weed seeds.

Nutrients in organic forms are mineralised to plant available and inorganic forms during the composting process. The used litter and other ingredients turn into dark brown compost with a low moisture content and low odour potential. The end product is unrecognisable as having originally been chicken litter. As compost is made from a blend of both carbon and nitrogen rich materials, nutrient balances can be readily designed that are more closely tailored to crop requirements. The nitrogen content of compost is almost totally organic and this also minimises nitrate nitrogen leaching. Using conventional windrow techniques, it takes approximately 12 weeks to make stabilised compost. Composting reduces the mass of the initial litter, in turn decreasing the cost of storage and transport. Many Australian litter contractors are either composting some of the litter or have links with composters.

Production of compost of consistent quality has to be done in a controlled manner with the right facilities to avoid contamination and on a site acceptable to the community and government regulators. Compost production is an environmentally relevant activity and commercial production facilities will require appropriate licences/approvals under the relevant state environmental legislation. Composting facilities can pose the potential for soil and water pollution through run off and infiltration of nutrients and air pollution from dust and odour. Appropriate facility design and diligent management can address and minimise these potential concerns.

Composted litter can be spread on land, sold as bulk compost for commercial use or bagged and sold through garden centres for use by householders. However, concerns still exist regarding contaminants (pathogens, toxins, heavy metals, inclusions) in the finished composts. Horticulturalists, dairy farmers and beef producers in some States are seeking assurances that there are no pathogens or chemicals considered harmful to man in composted litter.

Pellets

Pelleting litter concentrates nutrients, slows their release slightly and makes it easier to handle the product. If done correctly, the heat applied during pelleting sterilises the pellets, increasing safety in handling, transport and use. Either raw or composted litter can be pelleted. There are seven pelleting plants in Australia. One in NSW has production capacity for 100,000 tonnes of pellets per annum made from layer manure, chicken and breeder litter.

A major US chicken company recently opened a joint venture plant in Delaware that will produce 73,000 tonnes of pelleted fertiliser from 85,000 tonnes of litter each year. The pellets will be road or rail freighted to the Midwest and Southeast to support crop production on nutrient deficient soils.

Enhanced Pellets

The addition of non-organic compounds to pellets provides a product for a specific application. For example, the addition of an inorganic nitrogen fertiliser can provide a balanced fertiliser for application to pasture. Because the product is balanced to the crop requirements, less needs to be applied per hectare and phosphorous is not applied in excess, an environmental positive, because otherwise excess phosphorus becomes an undesirable contaminant in waterways.

Soil Blends

Poultry litter either unprocessed or composted can be added to sand and clay to produce potting mixes and soils for the horticultural, recreational and landscaping industries.

Electricity Generation

Electricity is being generated from poultry manure in England and Scotland. Such plants have been proposed for Australia, including ones that would burn all animal manures. Australian chicken grower groups and processors have or are investigating the feasibility of utilising the litter produced by their organisation for energy production. The proposal is to either build a generation plant or to take a contract with a power station nearby.

The trading of biomass and “green” electricity is driving interest and investment in electricity generation using litter. The electricity plants in the United Kingdom (and other countries) are subsidised by the government through renewable energy policies.

The benefits of using litter for electricity generation are considered to be environmental. The process reduces, in particular, disposal problems where agricultural demand for litter is seasonal or less than that produced.

A litter fired power plant in Western Australia has been proposed as a viable and environmentally responsible way to utilise chicken litter in that region. This is due to the stable fly problem, sandy soils, the threat to possible markets for composted chicken litter from composted green wastes and the transport distance to grazing and broad acres agricultural land. It is particularly driven by government legislation put in place to reduce the stable fly problem. Ideal breeding conditions for the stable fly are provided through the use of litter on the sandy soils around Perth and the virtually constant watering provided in small crop production industries.

Burning litter eliminates a number of the problems associated with land application. The emissions from a power station are lower in sulphur, chlorine and heavy metals compared with coal. However, there is still carbon dioxide emission that does not make the process pollution neutral. The energy equivalent of poultry litter is about half that of soft coal.

Prices paid to farmers for litter in the UK vary between £5-7 per tonne. It varies according to distance from the plant, litter quality, litter moisture content and time of year. The distance from which power plants will source litter varies up to 68 km. This transport distance is closely aligned with the power plant's operating costs.

Combustion of litter produces an ash that contains its original phosphate and potash but none of the nitrogen. It has potential as a useful fertiliser, worth about £40 per tonne. The maximum value of litter as a fertiliser in the UK is £12-80 per tonne based on NPK equivalent comparison to chemical fertilisers.

Gasification
Several companies have developed gasification systems that can use poultry litter for methane generation from biomass. A large US chicken producer has announced that it will build a gasification plant to produce steam for its protein conversion plant, using 74,000 tonnes of litter.

Direct Heat
Burning poultry litter to provide heat for warming poultry sheds has been considered. Processes using small-scale fluidised bed technology or burning litter pellets in pellet stoves are being investigated and commercialised.

Environmental concerns

Pathogens
Evidence exists that poultry litter or manure can contain several human pathogens. Pathogen species that may occur in these wastes have been found to survive in some soils for months. The potential risks associated with pathogens in poultry litter are addressed in the separate Public Health issues paper.

Experimentation has also demonstrated that pathogens can be transported by run-off water. This is through the same processes that can result in the mobilisation of soil particles and particulate nutrients. Whether this poses a significant risk to water users is yet to be demonstrated. Management to control transport of pathogens by run-off water is likely to be similar to the techniques used to control nutrient export by run-off.

Nutrients
The concerns with nutrients are those associated with the possible contamination of water resources, either by leaching or run off. Most attention to date has focussed on nitrogen and phosphorus. Eutrophication is the main cause of impaired water quality. Eutrophication is the natural aging of lakes or streams brought on by nutrient enrichment. This process can be greatly accelerated by human activities that increase nutrient flow into water.

Different nutrients and different forms of nutrients tend to differ in their vulnerability to leaching. For example, nitrate is undoubtedly more vulnerable to leaching than the ammonium ion, since different sign charges are associated with each. Ammonium tends to bind to the soil's often considerable cation exchange capacity. The phosphate ion is even more readily retained in soil than the ammonium ion, through a range of soil interactions known collectively as sorption. This soil chemistry based view of nutrient leaching, however, is by no means the complete picture. Soil structure plays an important role in determining how much of the nutrient is leached. When water saturates the soil surface (or ponds at some other depth in the soil), water will enter soil voids, cracks, old root channels, and worm burrows. Once water is flowing down these channels it provides a path for dissolved or suspended nutrients to bypass the soil's chemical capacity to retain nutrients. One useful rule of thumb to use when managing nutrients is that once a nutrient moves below a crop's active root zone, it is of no use to the crop, may be irretrievable, and has become a contaminant.

Run-off transport of nutrients can often be a more significant path for contamination of water resources. Several mechanisms may be responsible for run-off transport of nitrogen and phosphorous. These nutrients can be mobilised in dissolved forms or through the erosion of soil material. Nutrient accumulation in surface soil occurs with continued fertilisation either by inorganic fertilisers or livestock wastes.

Once moving, run-off borne nutrients are by no means guaranteed to reach surface water bodies. A number of processes are very capable of halting transport of nutrients in run-off before they reach surface water bodies, including:

- particle trapping by vegetation;
- reduction of run-off volume - it is well known that vegetation cover is a major factor in determining how much run-off is generated from an area of land. Fallow land will generate much greater volumes of run-off than a grassed area for the same rainfall event on a similar soil;
- trees can intercept subsurface lateral flow of nutrients; .
- overland flow itself actually exposes dissolved phosphorous and ammonium to reaction with the soil surface over which it flows, entrained particulate bound nutrients are also vulnerable to re-capture by the soil surface.

The key to inexpensive and effective control of transport of nutrients lies in effective control of applications to precisely meet crop requirements and to maximise crop development, effective monitoring, an effective assessment of the risk of a location and the application of appropriate preventative management techniques.

Regulation - now and the future

The amount of raw litter applied to pastures or a crop has been based primarily on the nitrogen content of the litter and the crop requirement for nitrogen. Little consideration has been given to the movement of the excess phosphorous or nitrogen into the water table or streams. Water catchment coordinating committees are now expressing concerns about the apparent uncontrolled application of chicken litter to land and the possible movement of nutrients into waterways.

In the Netherlands and Belgium, very strict controls are placed on the application of litter to land which results in significant excess litter problems. Strict nutrient budgets are required for intensive animal production facilities demonstrating sustainable utilisation of wastes. Excess poultry litter is exported to Eastern Europe. The Netherlands is considering selling to the British power plants.

Changes are also occurring in the USA and are being driven by the Federal EPA and the Clean Water Acts. This has resulted in several states introducing Nutrient Management or Water Quality Improvement Acts or adding a Poultry Waste Management Program section to current legislation. Under these changes farms of more than 10 acres or 20,000 chickens must have nutrient management plans. The Acts apply to chicken growers and people who apply litter to the land. They must have government certified nutrient management plans with a time frame for implementation. Some US states require regular certification of all land application operators including producers.

Environmental Management Plans
Environmental management plans (EMPs) have become a part of the application/approval process required by local authorities for new farms throughout Australia in the last few years. They may include the spreading of raw litter on pastures on the chicken farm, although this practice is not encouraged for biosecurity/hygiene reasons. The rates and timing of application of poultry litter to minimise odour, dust and nutrient run off problems are generally included in the EMP in non-specific terms. Non poultry farmers applying poultry litter to agricultural land do not currently require EMPs to cover this aspect of their operations.

Manure Utilisation Guidelines
Most Australian States have Poultry Farming Guidelines which give broad principles for poultry manure and litter utilisation and its application to agricultural land. The NSW Agriculture AgNote "Best Practice Guidelines for Using Poultry Litter on Pastures" gives specific details about the use and application of chicken litter on pastures and land generally. The Victorian Department of Department of Primary Industries has been considering developing detailed “Guidelines for Manure Management”. These guidelines will deal with manures from all intensive livestock operations including chicken litter.

North America, the United Kingdom and many EEC countries have very detailed guidelines and restrictions governing where, how and how much litter can be applied to land. The USDA Agricultural Waste Management Field Book provides detailed information covering laws, regulations, role of plants, soil, water and air in waste management, waste management systems, equipment and procedures. Individual US states also provide detailed guidance documents on land application, with some require regular certification of all land application operators including producers.

Historically, application rates of poultry litter (and other animal manures) in Australia have been calculated on the basis of supplying sufficient nitrogen for the crop. Increasing concern over the role of phosphorus in the eutrophication of water bodies has forced assessment of phosphorus balances of current application practices in many areas. Animal manures are seldom sources of nutrients that are balanced in terms of plant requirements with phosphorus (and potassium) usually being in excess if manures are applied to meet nitrogen requirements. Guidelines in Australia for the pig and lot feeding industry require consideration of phosphorus utilisation and storage in the soil. Guidelines in the US are currently being revised to include phosphorus utilisation.

Summary

- Poultry litter has useful properties as fertiliser and for soil amendment. However, some concerns exist regarding possible contaminants in the litter.
- Applications rates in some areas of the world have exceeded plant requirements resulting in environmental damage from infiltration and run off of excess nutrients. Increasingly strict guidelines will restrict application rates to crop uptake and removals requiring supplementation with inorganic fertilisers to match crop nutrient demand.
- Application of unprocessed poultry litter to vegetable and some fruit crops has declined sharply in recent years as a consequence of concerns about its impact on the microbial safety of food crops produced.
- Processes, including composting, pelleting and blending, have been developed to produce value-added products for specialised, high value markets.
- Energy recovery from the biomass in poultry litter as heat for electricity generation provides an alternative use for poultry litter, although valuable nutrients and soil organic matter are destroyed and wasted in the process.
- Quality assurance of poultry litter production and processing systems will be crucial in ensuring long term market access and financial returns.

5.6 Single Use Versus Reuse Of Litter

Reuse of old or used litter as bedding material (multi batch litter) is being practised by some sections of the Australian meat chicken industry and considered by others. Reuse of litter has the potential to reduce litter costs and ease pressure on new bedding material supplies in the States where supplies are tight. The net cost to the industry for bedding materials is $10.07 million per annum. The practices being trialled are variations of the partial reuse of litter practiced prior to wide adoption of single batch or single use of litter.

In 1999/2000 single use of litter was practised in about 80 percent of the floor space devoted to growing meat chickens in Australia and partial reuse by the remainder. Since then, single use has fallen to about 70 percent. The reduction includes a sector of the industry that is trialling various forms of reuse of litter or switching to partial reuse. Two percent of the floor space is devoted to a partial reuse practice that includes heaping and composting of litter during turnaround.

Some processors practice partial or full reuse where they consider the farm's biosecurity is high and disease and hygiene risk status low.

Single Use

Single use of litter is the most common practice in Australia. After each batch of chickens is picked up, the litter is removed from the shed and replaced by new bedding material. This practice is driven by the requirement for good hygiene and biosecurity. The concept is that single use litter will minimise the risk of carry over of disease to the next batch and to nearby farms. It should be noted that there is evidence that suggests reuse of litter may be just as safe, if not safer, than single use in terms of food-safety pathogens.

Partial and full reuse

Typically, partial reuse of litter in Australia involves the removal of old litter from the brooding section and spreading it in the growing section. New bedding material is then placed in the brooding section.

On some farms the used litter is heaped and composted for a few days and then levelled prior to disinfection and placement of the chickens. The idea is that the heat generated by the composting process is enough to pasteurise the litter. The effectiveness of this process in killing pathogens is unknown. Organisms remain on the surface of the litter heap that may be spread in the litter dust generated during spreading of the litter. This dust falls on the internal shed surfaces and equipment causing potential hygiene problems.

Some of the used litter from the chicken shed may be disposed of after each batch. After two to five batches the shed is fully cleaned out and the process is repeated. If there is a break in biosecurity or a disease incident the farm is completely cleaned out at the end of that batch. The farm will stay on single use litter until it is clear that the disease status is satisfactory.

With full reuse of old litter, caked litter is removed after depopulation and the shed may be washed down and disinfected, depending on circumstances. The used litter in the brooding section is either left as is or covered with 25 to 50mm of new bedding material. If there is a break in biosecurity or a disease incident the farm is completely cleaned out at the end of that batch.

Overseas situation

USA

Multi batch and single use of litter are both common practises in the United States. It is difficult to obtain an accurate assessment of current practices.

Multi batch is driven by tight bedding material supplies and lower production costs in terms of $/kg of chicken meat. There are differences between processors and growers in the procedures adopted and the shed clean down and disinfection programs. The litter is left in the house usually for about twelve months; that is for between 5-7 batches. Some processors allow more flocks than this between full clean outs. The caked or crusted litter is removed between flocks. Machines are available to do this. Many growers turn or stir the litter after removing the crust. This aids drying of the litter. Pesticides and litter treatment products are then applied. Minimal cleaning and washing of the house is carried out. This is done to minimise wetting of the litter particularly where turnaround time is less than seven days. The drinker system is also disinfected.

Some processors require 10-50 mm of fresh bedding material to be spread on top of the old litter either on the entire shed floor or just in the brooding area.

Fifty to one hundred and twenty five millimetres of new bedding material is placed on the shed floors after a full clean out. The depth is 50mm for single use litter.

Researchers at Auburn University are investigating the effectiveness of flaming the litter surface to reduce microbial load.

Recurrent dermatitis is a problem on some farms due to litter conditions. This is remedied by doing a full clean out.

In some areas, particularly during periods of high humidity, damp litter and ammonia can be a problem if attention is not paid to ventilation and drinker management. Brooder heaters may also be used to heat the shed air in cold wet weather after brooding is completed to assist litter drying. Litter treatments are also applied.

Litter beetles are considered to be more of a problem with reused litter. However they can be controlled with good management.

If there is a disease challenge during the batch then a full clean out is done.

Some of the differences between the USA and Australia are:
- less emphasis on feed conversion because of lower feed costs in the USA;
- downgrading percentage is more important in the USA because of the USDA individual bird inspection system; and
- vaccines are cheaper in the USA.

United Kingdom
In the United Kingdom pathogens in poultry rearing and subsequent processing is a very big issue at the moment. *Salmonella* has been a serious concern for several years. *Campylobacter* contamination of flocks is becoming quite prevalent. This organism causes large numbers of human infections in the UK (not necessarily all linked to poultry). For this reason, reuse of litter in intensive farming is not recommended.

Denmark
Danpo A/S, a meat chicken company in Denmark, is producing and marketing *Salmonella* and *Campylobacter* free chickens for a niche market in Europe and the United Kingdom. Growers receive a bonus payment if they produce chickens free of either or both of these pathogens. Danpo A/S uses strict biosecurity, hygiene and management procedures to maintain the free status. Day old chickens are placed in cleaned, disinfected houses.

Health
From a chick welfare and production performance viewpoint the following factors will modulate the input of litter re-use on flock health:
- hygiene and biosecurity standard of the integrators operation;
- health status of breeders;
- immune status of breeders;
- health and immune status of day old chicks;
- farm health, hygiene and biosecurity standards and risks;
- farmers management and husbandry skills at minimising stress;
- likely pathogen load on the farm.

Indications are that a full clean out and rigorous disinfection of the growing facilities after each flock will generally give better performance results. These improvements are 5-10 points of feed conversion, 1-2 days better growth, 1-2% lower mortality and lower processing downgrades.

Full clean out and rigorous disinfection is used on the path towards elimination of infectious disease from an integrated operation. However it requires consistency and considerable effort on behalf of the livestock management team.

Economics has a significant part to play in the decisions made with respect to litter reuse practice. At the end of the day the cost per kg of chicken ex the processing plant will determine how competitive the processor is and his long term future in the industry. The final choice of farming practices, hygiene, biosecurity procedures and litter practices will be weighed against the risks and costs.

As the batch of chickens grows the litter becomes seeded with pathogens that affect chick performance. Infectious laryngotracheitis (ILT), gangrenous dermatitis, infectious bursal disease (IBD), reovirus, infectious bronchitis, Mareks disease (MD) and botulism are some of the more serious viral and bacterial diseases that may be transmitted batch to batch through contaminated litter. Roundworms, tapeworms and coccidia are potential parasitic problems in reused litter, although these are infrequently a problem. Wet or damp litter increases the risk of a coccidiosis challenge by providing the environment that oocysts require to sporulate.

If reusing litter, ideally a 10-12 day break between batches to provide sufficient time for most of the bacteria and possibly some of the viruses to die and to minimise the risk of disease carry over. With good litter management the level of infectious bacterial organisms will have fallen to a level unlikely to cause disease in healthy chickens. However some of the viruses such as Mareks disease virus are persistent and can only be managed with rigorous clean out, disinfection and vaccination.

Depending on the farm situation, in terms of biosecurity and disease risk, an effective vaccination program may be required where litter is reused.

As used litter is generally antibacterial in nature, for pathogenic bacteria at least, there is a strong argument that litter reuse is not associated with any increased use of antibiotics.

Good management is essential to minimise stress on chickens and to reduce the effects of a disease outbreak on the chickens whether litter is used once or several times.

A healthy immune system is essential to good chick performance and the ability of the chick to withstand disease challenge. Depending on the individual farm health status, day old meat chickens must have high levels of maternal antibodies to some pathogens and must also be capable of responding to vaccines given early in their life.

Another issue that must be considered is that litter reuse may result in the chickens being exposed to relatively low pathogen levels during the first few weeks of the chick's life. This is a time when the chick has both maternal antibodies and is developing an acquired immune system. This gives the chicken a chance to properly respond to any pathogens present.

It has been suggested that covering old litter with new litter is almost cosmetic, since chickens quickly access the old litter beneath. The depth of new litter to place over reused litter is influenced by the amount of disease contamination in the old litter, depth of new material added, the chicks immune system health, chicks stress level and the time it takes for the chicks to scratch down to the old litter.

Damp litter, ammonia and ventilation

The key to maintaining pathogen risk at a low level is litter dryness. It is a key component of food safety and flock health.

Moisture management in the shed affects litter dryness. As the litter becomes damper more ammonia is released and the nitrogen content of the litter decreases. As dryness increases the atmosphere in the shed gets dustier. Dust from very dry litter is more likely to be a problem in localities that experience low humidity in either summer or winter.

Management of drinkers, foggers, evaporative cooling pads and shed ventilation rate is critical in maintaining dry litter. Litter dryness is also affected by humid warm and cold weather. The drier the litter the more dust is created in the shed. The damper the litter the more ammonia and odour is generated. Dust poses health problems to both chickens and staff working in the sheds.

Damp new bedding material encourages the growth of the fungus *Aspergillus*, a potential cause of disease in young chickens. Damp used litter also encourages the growth of *Aspergillus*, and some food-safety organisms such as *Salmonella*. Damp used litter is detrimental to chicken welfare, chicken health and productive performance.

Feed ingredients and drinking water salt content can influence litter moisture content.

The biggest problem in the USA and Australia with reuse of litter is increased litter moisture and higher ammonia levels. Damp litter is more likely to be a problem in localities that experience high humidity in either summer or winter and in sheds using foggers for evaporative cooling in summer. Shed ventilation is crucial in managing litter moisture. A good fan driven minimum ventilation system is essential for the entire brooding and growing period. The correct ventilation rates must be used from day old right through the batch. Once the litter is damp it is too late to take corrective action by increasing ventilation rates. At this stage ventilation will not dry the litter sufficiently without heating the shed air. In humid areas of the USA it is common practice to run the brooder heaters after brooding to maintain litter dryness.

In naturally ventilated houses it is very difficult to achieve good minimum ventilation rates accurately and consistently. This makes it difficult to maintain litter moisture at acceptable levels during cold humid weather.

Increased ammonia levels go hand in hand with increased litter moisture. Ammonia levels of 25 ppm will depress growth, increase feed conversion, predispose chickens to respiratory problems and increase condemnations at processing. Levels of 5 ppm or more are detrimental to day old chicks. High ammonia levels also increase the likelihood of complaints from neighbours about odour.

Darkling beetle

In Australia the evidence is unclear as to whether the darkling beetle is worse in single batch or multi batch litter. Ongoing industry funded research involving farm trials may clarify this.

Food safety

There is considerable evidence that reused litter may pose less of a risk in terms of food safety than single use litter, providing it is well managed. The literature presents a uniform finding that *Salmonella* survive for much longer periods in fresh litter (months) than in old litter (three weeks). Studies have shown that only very low levels of *Campylobacter* survive more than 72 hours in litter after removal of the chickens from the house.

Bedding material supplies

Maintaining a supply of clean bedding material supplies is critical to chicken production. If the industry moves towards reuse of litter then the bedding material suppliers will find a market for the excess bedding elsewhere. If the industry has to go back to single use it will be difficult to source the extra bedding needed because of the government and community push to increase green energy generation and the increasing number of power stations burning or capable of burning biomass (see new bedding materials in the Quality Assurance section of this report).

Litter contractors in NSW and Queensland are now entering into contractual arrangements with bedding material sources to ensure supplies and are putting in storage facilities to guarantee continual supply to their customers the chicken farmers.

Litter contractors also have contracts with the end users of old litter who need to guarantee their supply. Litter contractors now have to invest in improved storage and composting and processing facilities to meet Environmental Protection Agency requirements.

To reuse or not to reuse

The critical test with litter reuse is whether chicken performance, biosecurity and chicken health can be maintained. From an economic viewpoint, the reduced or increased performance, increased vaccination costs, and litter treatment costs must balance the savings in litter costs. Consideration must also be given to the long term effects on clean bedding material supplies.

Summary

- Single use of litter is practised by about 70 percent of the industry.
- Reuse of litter has the potential to reduce litter costs and ease pressure on new bedding material supplies in the States where supplies are tight.
- Australian experience suggests that single batch clean out and disinfection results in the most productive performance, lower downgrade level, more consistent performance and lower cost per kg of chicken produced.
- Some processors practice partial or full reuse of litter where it is considered the farm's standard for biosecurity and hygiene is high, and the disease risk is low.
- Good management is essential to minimise stress on chickens and to reduce the effects of a disease outbreak on the chickens whether litter is used once or several times.
- A healthy immune system is essential to good chick performance and the ability of the chick to withstand disease challenge.
- Litter reuse may result in the chickens being exposed to relatively low pathogen levels during the first few weeks of the chick's life; this may be beneficial.
- As used litter is generally antibacterial in nature, for pathogenic bacteria at least, there is a strong argument that litter reuse is not associated with any increased use of antibiotics.
- There is considerable evidence that reused litter may pose less of a risk in terms of food safety than single use litter, providing litter moisture levels are well managed to ensure dry litter.
- The key to maintaining pathogen risk at low level is litter dryness. It is a key component for both food safety and flock health.
- The biggest problem with reuse of litter is increased litter moisture and higher ammonia levels in the shed. Ammonia levels of 25 ppm will depress growth, increase feed conversion, predispose chickens to respiratory problems and increase condemnations at processing. Levels of 5 ppm or more are detrimental to day old chicks. High ammonia levels also increase the likelihood of complaints from neighbours about odour.
- There are potential alternative bedding materials available to meet any shortfall in supply, these may require that research be undertaken to determine their suitability and viability.
- Maintaining a supply of clean bedding material supplies is critical to chicken production. If the industry moves towards reuse of litter then the bedding material suppliers will find a market for the excess bedding elsewhere.
- The critical test with litter reuse is whether chicken performance, biosecurity and chicken health can be maintained. From an economic viewpoint, the reduced or increased performance, increased vaccination costs, and litter treatment must balance the savings in litter costs. Consideration must also be given to the long term effects on clean bedding material supplies.

5.7 Litter Additives or Treatments

Additives, also known as treatments or amendments, are made to chicken litter mainly to inhibit or slow down the release of ammonia from the droppings in the litter. Other advantages that treatments may have are reducing litter moisture content and odour emission, killing or inhibiting the growth of certain bacteria and turning soluble phosphorous into an insoluble form. Reducing the release of ammonia from the litter has the potential to increase the nitrogen content of the litter by 8%.

Litter treatment products that have been tried or are used are microbiological urease inhibitors, clinoptilolite forms of zeolite, acidifying agents and microbes that have the ability to tie up nitrogen.

US situation

The application of litter treatments is becoming standard practise in the USA where growers raise 4-6 batches on a single placement of litter. After each batch of chickens is picked up the cake is removed and the litter agitated or heaped to achieve some degree of drying by microbial composting. The litter is then levelled and an additive applied instead of 25-50 mm of new bedding material in the brooding area. Where half shed brooding is practiced the additive is applied in the growing section just prior to the chickens being given access to it. If the seal between the brooding and growing section will let ammonia through to the brooding section, then the additive is added to the growing section prior to chick placement.

Ammonia

Ammonia levels above 5 ppm are detrimental to chickens in the first week of their life. When growing chickens are exposed to levels above 25 ppm it causes reduced performance, predispose chickens to respiratory problems and increases condemnations at processing.

High ammonia emission from poultry houses leads to odour complaints from neighbours.

Ammonia released from livestock waste contributes to secondary particulate formation in the atmosphere by reacting with gaseous nitric acid and particulate sulphate to form ammonium nitrate and ammonium sulphate. Research suggests that particulate matter in the air may have effects on human health. Agricultural operations are a significant source of ammonia emissions in the USA and Europe and are of concern because of the concentration of both people and animals per land unit.

The rate of ammonia volatilisation from chicken litter depends on:

- litter pH, as pH increases ammonia release increases;
- moisture content of litter;
- wind speed over litter;
- temperature;
- ammonium concentration in the litter.

Litter pH has the following effects on ammonia release:

- pH below 7 – ammonia release is negligible;
- pH near 7 – ammonia release starts;
- pH 8 and above – ammonia release levels high.

Litter pH and micro organisms

The pH of litter has an affect on the types and numbers of micro organisms present. A pH below 6 inhibits growth of ammonifying, putrefaction or anaerobic bacteria and coliforms and a pH below 5 inhibits the growth of *Salmonella*.

Microbiological urease inhibitors

Microbiological urease inhibitors are products that inhibit or reduce the activity of micro organisms that convert urea to ammonia. Products which have been shown to work are paraformaldehyde flakes, certain volatile fatty acids, CHPT (cyclohexyphosphoric trimide) and PPDA (phenylphosphorodiamidate). Others have also been tried, and many have been proven effective. The disadvantage is that the effect only lasts six to seven days. For the effect to be maintained the inhibitors have to be applied weekly.

Organic acids

Organic acids such as citric, tartaric and salicylic acid have been tested and shown to have the potential to reduce ammonia synthesis and litter pH. However the effect only lasts for about seven days.

Acidifying agents

When added to the litter acidifying agents have the effect of lowering pH, reducing ammonia volatilisation and inhibiting the growth of some pathogenic bacteria. Reducing the volatilisation of ammonia reduces the amount of ammonia in the shed atmosphere.

These products quickly lower the litter pH to 5-6 or less, thereafter it gradually increases to a pH of 6-7 after seven days. The litter pH then remains at less than 7 until about 21-28 days after placement. The reduction in ammonia release lasts for 14-30 days. The affect on pH and ammonia release varies depending on litter moisture content and starting pH of the litter.

Research shows that alum, ferrous sulphate and phosphoric acid reduce ammonia release the most and sodium bisulphate to a lesser degree. All of these compounds, except phosphoric acid, lower the pH by releasing sulphuric acid when they come in contact with moisture.

Phosphoric acid will reduce ammonia but adds soluble phosphorous to litter and when applied to land releases phosphorous which increases eutrophication in waterways.

Ferrous sulphate is not recommended because it is toxic to chickens due to the high iron content.

The amount of iron in the ferric chloride application is much lower, compared to ferrous sulphate, making it non-toxic to chickens. However it is not as effective in reducing ammonia release.

Calcium hydroxide has been shown to reduce ammonia release slightly and calcium carbonate when included with alum was no better than alum alone in reducing ammonia.

Alum is more effective at rendering the phosphorous insoluble then any of the other acidifying agents tested. The phosphorus in the litter will still be available to plants and much less will be lost as soluble phosphorus in run off. At this time, controlling phosphorus levels in the soil is voluntary. There is no financial or legal incentive. It is thus difficult to put a dollar value on using alum to limit soluble phosphorus in litter.

There is some debate about the impact of alum on the environment. There are arguments that the alum is at least neutral or even beneficial to the environment. The use of alum-treated litter as a fertiliser does not affect aluminium uptake by plants, nor does it cause soil acidification. Aluminium is one of the most common elements found in our soils, making up between 1 and 10% of the soil. At the rates of litter used to fertilise row crops and pastures, the addition of alum-treated litter will not significantly increase the soil's aluminium content. A major environmental benefit to treating litter with alum is the reduced risk of soluble phosphorous and heavy metals (zinc and copper) and estrogens in the run off.

On the other hand there are environmental concerns about the use of alum as an additive. The specific concern is that in the aluminium in the soil may become soluble and move into the water table and then into waterways. The bioavailability or solubility of aluminium is a function of soil pH. Above pH 4.5-5.5 little soluble aluminium is present in the soil. If alum treated litter is placed on soils with low pH and low buffer capacity both the aluminium and the phosphorous could become soluble. This could also happen to soil in this condition naturally where the pH was corrected and alum treated litter applied and the soil gradually returning to its natural state after the cessation of farming.

The recommended rate for using alum in the USA is 10% of manure dry weight or 97.7 kg/100 m^2 of floor area.

A specific study in the USA investigated the effect of a particular commercial product called Poultry Litter Treatment (PLT), that contains an acidifying agent (sodium bisulphate), on the incidence of ascites. PLT was applied to the litter prior to chick placement at the recommended rate (24.5 kg per 100 m^2 of shed floor area). The litter was then sprayed with water to promote ammonia production. Deaths due to ascites were 31% in the untreated pens and 5% in the treated pens. Ammonia in the house atmosphere during the first 22 days varied between 72-114 ppm for the control and 5-22 ppm for the treated pens.

Another USA study looked at the effect of an acidifying agent on the bacterial loading on the litter and the chickens at kill out. PLT was applied prior to placement and again at seven days prior to kill out. There was a significant reduction in *Escherichia coli* at 7 and 14 days age on the litter. The difference at kill out was not significant. No *Salmonella* were present on the litter at 7 and 14 days. The small difference at kill out was not significant. On-farm bird rinses at kill out gave differences for *Escherichia coli* and *Salmonella* that were not significant.

Another product, Poultry Guard (attapulgite/montmorellonite clay impregnated with sulphuric acid), has also been tested and found to be effective in reducing ammonia release.

Zeolite

Some types of clays known as the clinoptilolite forms of zeolite have the ability to store water in the cell structure and absorb ammonia. By storing water the litter moisture is reduced. They have the ability to release the stored water later on. Activated zeolite is able to absorb ammonia and release it at a rate that allows the ammonia to undergo nitrification and be up taken by plants. The ability of these types of zeolite to absorb and release water can be used to improve the water holding capacity of soils. Zeolite, when incorporated in pelleted or composted chicken litter, has the potential to deliver nutrients to plants as they are required and to improve soil condition.

Other products

Other commercial products consisting of calcium iron silicate, a mixture of sodium silicate and ethylene glycol and a product called Multi Litter Treatment actually increased ammonia release during tests.

Economic benefit

In cold humid winters such as are experienced in parts of the USA, the use of ventilation rates during brooding to maintain air and litter quality (control ammonia) are expensive because of the energy costs of heating the shed to maintain temperature. Research shows that the use of an acidifying agent such as alum or PLT is cost effective during winter under these conditions. There is no economic advantage in using additives during summer.

Research also showed that the nitrogen content of the used litter increased by up to 8% when acidifying agents were used. Because of the variability in the nitrogen content of litter coming from chicken sheds it is unlikely that any increase in nitrogen content will be obvious.

The cost of additives in the USA is reported to be US$220-460 per ton or US$11.80-17.20 per 100 m^2.

Summary

- Field experience and published evidence indicate that there are a range of additives that can reduce ammonia levels in the chicken shed.
- The additives require moisture to activate the process of tying up the ammonia. Too much moisture and they are used up too quickly, too little and they do not work quickly enough.
- There is conflicting evidence about the improvement in chick performance resulting from the use of these additives. Research results suggest that improvements in chick performance attributable to the use of those treatments occur where the levels of ammonia in the shed atmosphere are higher than those experienced in meat chicken houses in Australia in which the litter and ventilation are well managed.
- Additives with the most potential for slowing or inhibiting ammonia release are alum, sodium bisulphate and clinoptilolite zeolite. Alum is the most effective acidifying agent for reducing ammonia release and in tying up phosphorous.

- Activated clinoptilolite zeolite has potential for use in sustainable farming systems due to its ability to improve the water holding capacity of soil and to release plant nutrients at a rate they can be utilised by plants in some soils. These properties may give it the potential to attract carbon credits. If incorporated into pelleted or composted litter it will produce it a more valuable product.
- Acidifying agents may have potential to reduce levels of *Salmonella, Escherichia coli* and *Campylobacter* organisms in the litter and therefore on chickens prior to slaughter.
- Experience and research in the USA suggests that numbers of darkling beetle are lower where additives are used.
- The use of litter treatments is cost effective for winter batches placed on reused litter in the USA. Both local and overseas experience suggests that litter treatments are not cost effective for single litter use where litter moisture management and ventilation are good.
- There may be a role for certain litter additives where neighbours are demanding a reduction in odour emissions from a meat chicken farm. However, further research is needed to demonstrate which additives have a beneficial effect in terms of odour rather than simply ammonia reduction.
- Good ventilation and management of litter moisture is part of ensuring that any litter treatment works effectively.
- The use of litter additives should be seen as an aid to litter management, not the answer to poor management of ventilation and litter moisture.

5.8 Standards for Composting, Soil Conditioners and Mulches

The standard used by the composting industry and the majority of resellers of chicken litter is "The Composts, Soil Conditioners and Mulches Australian Standard (AS4454-1999)" that is prepared by the Standards Australia Committee. It includes manures and chicken litter.

The objective of this standard is to provide manufacturers, local government bodies, consumers and farmers with the minimum requirements for the physical, chemical and biological properties of composts, soil conditioners and mulches, as well as labelling and marking requirements, in order to facilitate the beneficial recycling and use of organic materials with minimal adverse impact on public health and the environment.

The Standard sets out minimum requirements for composts, soil conditioners and mulches as well as 'best practice' procedures. By following these procedures, products of consistent quality can be produced.

Under these standards, if chicken litter is included in the compost, soil conditioner or mulch it must be composted or pasteurised and meet all the other requirements in the Standard including pathogen and heavy metal and chemical levels.

Composting is defined as the process whereby organic materials are pasteurised and microbiologically transformed under aerobic and thermophilic conditions for a period not less than six weeks.

Pasteurised product is organic material resulting from the controlled microbiological transformation of organic materials under aerobic and thermophilic conditions such that the whole mass of constantly moist material is subjected to at least three consecutive days at a minimum temperature of 55^{o}C.

This is achieved by one of the following:

(a) appropriate turning of outer material to the inside of the windrow so that the whole mass is subjected to a minimum of 3 turns with the internal temperature reaching a minimum of 55^{o}C for 3 consecutive days before each turn; or

(b) an equivalent thermal process that achieves the same level of pathogen reduction.

Pasteurisation is the process whereby organic materials are treated to kill plant and animal pathogens and weed propapules.

Manure is any organic product composed mainly of animal excreta. Manure can undergo either the 'composting' or 'pasteurisation' processes. A manure can also be additionally labelled as a 'mulch' or 'soil conditioner', depending on its intended use.

Mulch is any pasteurised organic product (excluding polymers such as plastics, rubber and coatings that do not degrade) that is suitable for placing on soil surfaces. Mulch has at least 70% by mass of its particles with a maximum size of greater than 15 mm.

Soil conditioner is any composted or pasteurised organic material that is suitable for adding to soils. This term also includes 'soil amendment', 'soil additive', 'soil improver' and similar terms, but excludes polymers such as plastics, rubber and coatings that do not biodegrade. Soil conditioners may be either 'composted soil conditioners' or 'pasteurised soil conditioners'. Soil conditioner has not more than 15% by mass of particles with a maximum size above 15 mm.

The Standard also states that all materials shall fully comply with the chemical contaminant and organic contaminant provisions of the current version of the State or Federal guidelines for use and disposal of biosolid products that are for unrestricted use, whichever is the more stringent. In addition, biosolids and manures should comply with the pathogen provisions of these guidelines.

The Australian Guidelines for Water Sewerage Systems – Biosolids Management prepared by the ARMCANZ Water Technology Committee, are the Federal guidelines that are used in some States.

The NSW EPA Environmental Guidelines – Use and Disposal of Biosolids Products (2000) apply in NSW. The Queensland Environmental Protection Agency uses the NSW guidelines and is developing its own.

The Victorian EPA Environmental Guidelines for Composting and Other Organic Recycling Facilities levels for heavy metals and pathogens are based on the Australian Guidelines.

Table 12. Limits for contaminants in compost, soil conditioners and mulches for unrestricted use (mg/kg).

Contaminant	ARMCANZ	NSW EPA	VIC EPA	Biological Farmers
Arsenic	20	20	20	15
Cadmium	3	3	3	20
Chromium (total)	400	100	50	1000
Copper	200	100	60	400
Lead	200	150	150	250
Mercury	1	1	1	2
Molybdenum	4	-	-	-
Nickel	60	60	60	100
Selenium	3	5	5	-
Zinc	250	200	200	1000
DDT/DDD/DDE	1	0.5	1.0	
Aldrin	0.2	0.2	0.2	
Dieldrin	0.2	0.2	0.2	
Chlordane	0.2	0.2	0.2	
Heptachlor	0.2	0.2	0.2	
HCB	0.2	0.2	0.2	
Lindane	0.2	0.2	0.2	
BHC	0.2	0.2	0.2	
PCBs	1	0.3	1.0	

ARMCANZ: Australian Guidelines for Sewerage Systems-Biosolids Management (1995)
NSW EPA: Environmental Guidelines for Use and Disposal of Biosolids (2000)
Victorian EPA: Environmental Guidelines for Composting and Other Organic Facilities
Biological Farmers Co-Operative Ltd: Standard for Organic and Biodynamic Produce

The Biological Farmers of Australia Standards for organic and biodynamic produce has levels for heavy metals that are equal to or higher than ARMCANZ, EPA NSW, Victorian EPA levels except for arsenic which is lower. The Biological Farmers of Australia agricultural chemical residues limits are 10% of the Maximum Residue Limit (MRL) for food as set by the Australian and New Zealand Food Authority (ANZFA).

Table 13. Pathogenic Organism Standards for Composts, soil conditioners and mulches for unrestricted use.

Organism	Standard
ARMCANZ	
Salmonella	<1 per 50 g of final product
Thermotolerant Coliforms	<100 MPN per gram of final product
NSW EPA	
Enteric viruses	<1 PFU per 4 grams total dry solids
Helminth ova (*Ascaris* sp.and *Taenia* sp.)	<1 per 4 grams total dry solids
E. coli	<100 MPN per gram (dry weight)
Faecal coliforms	<1,000 MPN per gram (dry weight)
Salmonella spp.	Not Detected in 50 grams of final product (dry weight)
VIC EPA	
Enteric Viruses	<1 per 100 gram sample
Ascrid + *Taenia* parasites	100% inactivation of eggs
E. coli	<100 MPN per gram of solids
Salmonella spp.	<1 MPN in 50 grams

MPN = most probable number
PFU = plaque-forming unit
< = less than

ARMCANZ: Australian Guidelines for Sewerage Systems-Biosolids Management (1995)
NSW EPA: Environmental Guidelines for Use and Disposal of Biosolids (2000)
Victorian EPA: Environmental Guidelines for Composting and Other Organic Facilities
Biological Farmers Co-Operative Ltd: Standard for Organic and Biodynamic Produce

No specific limits are given for pathogens in the Biological Farmers Co-Operative Ltd: Standard for Organic and Biodynamic Produce.

The pathogenic organism standard in AS4454 is under review because background levels of *E. coli*, *Salmonella* species and plant pathogens (such as *Phytophthora* species) vary in different compost materials.

5.9 Fertiliser/Soil Conditioners and Labelling

All States have legislation on fertilisers and soil conditioners to ensure that purchasers and users receive products of a quality and composition in keeping with that claimed on the label or advice note. It is implemented in either a Fertilisers Act or is included in an Agricultural and Veterinary Chemicals Act. This legislation will, in most circumstances, apply to the sale of chicken litter where it is sold as a fertiliser, soil conditioner or enhancer, or manure. If the sale is in bulk, an advice note must be attached to the delivery note or invoice.

For example the purposes of the Victorian Agricultural and Veterinary Chemicals (Control of Use) Act 1992 are:

- To impose controls in relation to the use, application, manufacture and sale of fertilisers for the purposes of :
  - Protecting the health of the general public and the users of those products
  - Protecting the environment
  - Protecting the health and welfare of animals
  - Protecting domestic and export trade in agricultural produce and livestock
  - Ensuring that a product is effective for the purposes described on its label

- Promoting uniformity of regulation throughout Australia
- To impose controls in relation to the production of agricultural produce to avoid the contamination of food for human consumption.

The Victorian Act defines a fertiliser as a substance that is manufactured, represented, sold or used as a means of directly or indirectly fertilising the soil, or supplying nutrients to plants, or conditioning the soil by altering the chemical, physical or biological composition of the soil.

A label is required with all fertilisers and soil conditions that are sold. The label is to include the name, description of the nature or type, the intended purpose or claim for use, an analysis of the ingredients and any relevant warnings. The analysis must include the element nitrogen, phosphorous, potassium and sulphur. In some states the level of heavy metals such as cadmium, mercury and lead are required. The amounts of other chemicals may be required depending on ingredients and purpose of the fertiliser.

If organically based, the percentage of organic materials must be included on the label. Even if it is pure animal manure a label may be needed.

6. Workshop Outcomes

6.1 Collated Group Outcomes for Each Issue

The outcomes from each small group at the workshop are presented below. They have been collated into the workshop issues and discussion points.

Public Health Issues Associated with Poultry Litter

(a) Are there gaps in our knowledge of the public health risks associated with poultry litter being used as a soil conditioner or fertiliser?

Group Responses

- There is a lack of publicly available independent information.
- Particularly relevant to side banding application of litter to crops.
- Microbiological risks identified by Dr Pat Blackall as requiring a proper risk assessment.
- Chemical composition of litter not generally available for Australian chicken litter.

(b) If there are gaps, what research is needed to address those gaps?

Group Responses

- Formal hazard analysis needs to be completed for identified and perceived risks to food safety and public health.
- Risks to end users (consumers of food or litter products users) should be the focus.
- Risks to employees/employers also to be considered.
- Risk assessment: quantify risks based on end use models and economics (worst case – best practice).
- Is research replicable in different locations/growing systems?
- Develop guidelines to manage identified risks at producer and end user levels.

What are the safe levels of microbes for:

- direct application (side banding)
  - non sensitive use
  - human food (cooked and uncooked)
  - grazing livestock
- incorporation of litter into soil
  - human food
  - grazing

What treatments are required for chicken litter for different end uses?

What needs to be done?

- Pool existing industry data available on chemical composition.
- Do a quantitative microbiological risk assessment of chicken litter.
- Develop safe use guidelines.

Research needed into:

- Epidemiology (including infective dose levels etc) of human pathogens in chicken litter including speciation and resistance genes.
- Heavy metal levels in single batch versus reused litter.
- Categorisation/standardisation of risk assessment methodology that is widely recognised by authorised bodies for various uses of chicken litter.
- Differentiation between current/existence levels versus innate resistance issues and resistance transfer issues.
- Practices that may allow the safe use of chicken litter for individual crop/land care/horticulture industry depending on phase/process of production.
- RIRDC can provide/initiate/disseminate publications to educate the public re public health concerns.

(c) *What steps can be taken, in a public relations sense, to ensure that the value of poultry litter as a soil conditioner and fertiliser is fully appreciated by end-users and the broad community?*

Develop public relations campaign to reinforce product benefits and risk management.

Develop an industry education web site.

Steps to take:
- Reinforce the existing recognition by the home gardener of "chook manure" as a good fertiliser.
- Regional issues need to be recognised.
- Application of "Safe use guidelines".
- Public relations exercise should be for the total chicken meat industry, not just environmental or quality assurance issues.

(d) *Does risk management offer a means of ensuring that poultry litter can be safely used as a soil conditioner and fertiliser with minimal impact on public health and on the general environment?*

Yes.

Yes.

Yes.

Yes.

Priority of the above issues:
The actions/comments were considered highly important in sections (b) and (c).

Litter Management and the Need for Quality Assurance Programs to Meet the Needs of Litter End Users and the Food Industry

Market research is needed on litter uses and the economics of these. This has an impact on all the issues.

Which is a better outcome for the community - chicken litter utilised as a fertiliser/soil conditioner or as a source of energy, or regarded and treated just as waste. If used as an energy source then public health and pathogens are not an issue.

(a) *What can be done to improve litter management in sheds to reduce ammonia, dust and damp conditions?*

Focus needs to be on chicken meat production – litter is a by-product.

Good management
Good nutrition
Good chicken health } = good litter condition

Need to develop minimum equipment standards for ventilation, cooling and drinkers to reduce ammonia and damp conditions. These will vary between regions and will also have impacts on chicken performance and odour issues.

Need:
- Drinker systems and ventilation standards.
- Data on manure composition ie. NIR measurements on manure?

(b) *Is there a place for litter additives in the management of litter quality in sheds?*

Feed management and best practice production systems have a greater impact on the quality of litter.

Perhaps, but must consider the cost of additives to the chicken grower and the benefits for chickens.

No – other than economics of chicken performance and possible environmental impacts.

The use of additives:
- Additive use must be dependent on cost/benefit to growers
- Concerns expressed re effect on processed chickens and on litter utilisation.
- Reasonable management and chicken growing facilities will negate the need for the use of additives.

Maybe, depending on market research, cost, efficacy and odour versus better litter quality.

(c) Are adequate quality assurance systems in place to ensure that the value adders receive litter which meets standards to guarantee environmentally friendly litter use and safe food?

No
- Quality assurance procedures need to be developed to ensure that product use is legal and sustainable.
- We need to know approximate chemical composition of chicken litter.

No
- Need to establish accurate and practical quality assurance systems, in relation to customer's requirements (that will vary according to end use).

No.

(d) Are there gaps in our knowledge/technology about pasteurisation and composting litter to ensure food safety?

Need to establish and discriminate what are the legal restrictions/requirements by State/Federal governments.

Yes.

Yes – in chicken industry. The technologies are available; however, they are not well recognised in the industry.

Yes – need information on costs and returns.

(e) If so, what research is needed?

For gaps in knowledge/technology refer to public health.

Need independent research or existing knowledge to be collated:
- to prove what is required
- to reduce microbes to an acceptable level (numerical levels)
- into written guidelines

Research on composting needed
- End use specific requirements (eg for turf, mushrooms etc)
- Development of standard operating procedures specific to chicken litter and end use requirements.

Research on composting and pasteurisation techniques to produce safe food and costs.

Priority of above issues:
The actions/comments were considered highly important in sections (a), (c), (d) and (e).

Environmental Issues Associated with Poultry Litter

(a) What can be done to address the reduction in market and return for unprocessed poultry litter into the agricultural industries?

Provide evidence of "safety" (including environmental) and guidelines for storage and use of litter.

Produce standards and guidelines for appropriate uses.

Do the following:
- Ascertain why there is a reduction in use
- Define the product and its perceived value
- Increase the perceived value through
  - education
  - safe use guidelines
  - explore alternative uses

Do a survey of manure usage /location/ tonnages.
Ascertain the limiting factors in utilisation of unprocessed litter:
- Pathogens
- Residues
- Odour

(b) Is sufficient knowledge and information on the Australian system available to address concerns regarding the use of unprocessed poultry litter?

Collate information on the features and benefits of its use.

Undertake research or a literature search for information on:
- Microbial die off rates in litter
- Withholding periods
- Application rates
- Pasteurisation
- Guidelines for end user storage

No, the information has not been collated but needs to be.

No
Need to do a survey of chicken litter usage/location/tonnages and establish what are limiting factors in litter utilisation:
- Pathogens
- Residues
- Odour

No
- Partial composting in shed effects on pathogen reduction needs recognition
- Validate overseas data on nitrogen leaching, phosphorous and runoff, the fixing of nitrogen and phosphorous and mineralisation and modelling for soil types for chicken litter application.

(c) Are sufficient quality systems in place both on farm and off farm to ensure that poultry litter can be promoted by the industry as a safe fertiliser and soil amendment for use in the food production industries?

No

No:

- Information on chemical composition needed
- Must address issue of antibiotics

No:
- the broad guidelines are not specific enough
- there is no documentation to follow through

(d) What responsibility does the industry have for environmentally friendly and safe utilisation of poultry litter?

The industry needs to take control to avoid legislative intervention.

We have a responsibility to provide advice on composition and guidelines for appropriate use of chicken litter.

Need to make the customer aware of product characteristics and make available safe use guidelines.

It is a shared responsibility for all stakeholders.

In WA, given the stable fly problem, sandy soils, the threat to possible markets for composted chicken litter from composted green wastes and the transport distance to grazing and broad acre agricultural land, the burning of litter for electricity generation was seen as the most viable and environmentally responsible way to utilise chicken litter.

Priority of above issues:
The actions/comments were considered highly important in sections (a), (b) and (d).

The Feasibility Of Replacing Single Use Of Litter With The Reuse Of Chicken Litter For Bedding Material As The Standard Practice In Australia.

(a) Do we have the knowledge and technology to reuse litter safely from a poultry health and food safety aspect?

Some data is available in the public domain and other data is commercially sensitive (management).*****
Experience with the reuse of litter in some operations suggests that it is feasible.

Yes and no – there are some gaps.
Yes for food safety but need more information on ammonia control aspect. *****

(b) Are there gaps in our knowledge about reusing litter safely?

There is a need to share data held by companies. *****

Yes

Yes – on ammonia management *****

Yes – there are some gaps, more practice is needed

(c) If there are gaps, then what research is needed?

No big gaps – company policies may over ride/set procedures

Research on ammonia reduction *****

Trial on chick performance needed before there is widespread reuse of litter

- Do we need virology research on possibility of increased virus mutations (Newcastle Disease) with litter reuse?

(d) *What strategies are required to ensure supplies of new bedding material are available if the industry needs to move back to single use?*

Commercial risk analysis on alternative markets and products.

Supply and demand will determine availability – pay more or find alternatives.

Danger – bedding material supply will disappear and price will go up. *

Develop alternative bedding materials eg. tea tree pulp after removal of oil (anti-microbial value?), sugar cane waste, sand and washable manure. *

(e) *What strategies are needed to ensure litter contractors/value adders are able to cope with changes in the supply of used litter?*

Commercial risk analysis of alternative markets and products.

There may be shifts in litter service suppliers eg. from sweeping to decaking/cake removal.

Price will increase for removal from farm.

Set up a service for modelling/estimating litter volumes available from growers and processors quarterly.

(f) *Are litter treatments effective & economical?*

Commercial risk analysis needed on alternative markets and products.

We don't know.

Not at the present time.

Possible integration of processors/growers and value adders in the use of additives which have benefit to end users. Cost borne by value adders and end users.

Priority of above issues:
The action/comments marked with an asterisk * were considered very important in sections (a), (b), (c) and (d).

6.2 List of Workshop Participants

Col Boston -Cordina Chicken Farms
Len Brajkovich -Broiler Growers Association – Western Australia
Pat Blackall - Dept Primary Industries and Fisheries Queensland
Ken Casey - Dept Primary Industries and Fisheries Queensland
Ashley Etherington - Bartter Enterprises
Ian Farran - Chicken Meat Program – RIRDC
Laura Fell - Farmers Federation – South Australia
Irene Gorman - Egg Program – RIRDC
Jack Houweling - Golden Cockerel
Vivien Kite - Chicken Meat Program – RIRDC
Margaret MacKenzie - Inghams Enterprises Pty Ltd,
Steve McGoldrick - Bartter Enterprises
Margie Milgate - Freshcare
Paul Morton - Baiada Poultry

Phillip Ould - Rice Hull Organic Fertilisers – Victoria
Terry Packard - Broiler Growers Association – Western Australia
Greg Parkinson - Dept Primary Industries – Victoria
Robert Prince - Arthur Yates
Brett Richter - Inghams Enterprises Pty Ltd
Geof Runge - Dept Primary Industries and Fisheries Queensland
Gary Sansom - Chicken Growers Association – Queensland
Stephen Saunders - Chicken Growers Association – Tasmania
Jo Sillince - Australian Chicken Growers Council
Garry Wilson - Chicken Growers Association – Victoria

7. References

7.1 Publications, Journals (cited in text or recommended as additional resource material)

A Guide to Victorian Fertiliser Standards. (2000). Natural Resources and Environment, Victoria.

Angel R. (2000). Feeding Poultry to Minimise Manure Phosphorus. Proceedings from Managing Nutrients and Pathogens from Animal Agriculture Conference. 185 –195.

Australian Standard Composts, soil conditioners and mulches. (1999). Standards Australia

Barbour, E.K. & Nabbut, N.H. (1982). Isolation of *Salmonella* and some other potential pathogens from two chicken breeding farms. *Avian Diseases,* 26:234-244.

Bhatia, T.R.S., McNabb, G.D., Wyman, H. & Nayar, G.P.S. (1979). *Salmonella* isolation from litter as an indicator of flock infection and carcass contamination. *Avian Diseases*, 23:838-847.

Bilgili, S.F., Hess, J.B., Eckmann, M.K. & Blake, J.P. (2000). Potential opportunities with a Sand-Based Litter. *Proceedings 2000 National Poultry Waste Management Symposium*. 268-272.

Bock, BR (2000). Economic and Technical Feasibility of Energy Production from Poultry Litter. *Proceedings 2000 National Poultry Waste Management Symposium*. 133-148.

Brennan, J.C. and Howett, S. (1990). *Environmental Guidelines for Poultry Producers*. Department of Planning and Management, Tasmania.

Carey, J.B., Burgess, R.P., Russo, R. A., Chavez, C., Niemeyer, T.P. & Coufal, C.D. (2000). Field Evaluation of Litter Conditions in Tunnel Ventilated Broiler Houses at the end of the Production Cycle. *Proceedings 2000 National Poultry Waste Management Symposium*. 340-343.

Chaudhry, S.M., Fontenot, J.P. & Nasser, Z. (1998). Effect of deep stacking and ensiling brolier litter on chemical composition and pathogenic organisms. *Animal Feed Science and Technology,* 74:155-167.

Codling, E.E., Chaney, R.L. & Mulchi, C.L. (2000). Use of Aluminium and Iron-Rich Residues to Immobilise Phosphorus in Poultry Litter and Litter-Amended Soils. *Journal of Environmental Quality.* 29:1924-1931.

Collins, Jr. E. R. (1999). Poultry Waste Management Handbook. *Natural Resource, Agriculture and Engineering Service.* Cornell University.

Colucci, M.S., Bork, H. & Topp, E. (2001). Persistence of estrogenic hormones in agricultural soils: I. 17β-estradiol and estrone. *Journal of Environmental Quality,* 30:2070-2076.

Environmental Guidelines Use and Disposal of Biosolids Products. (2000). NSW Environment Protection Authority.

Fertilisers Act 1985 No 5. (1999). NSW

Finlay-Moore, O., Hartel, P.G. & Cabrera, M.L. (2000). 17β-estradiol and testosterone in soil and runoff from grasslands amended with broiler litter. *Journal of Environmental Quality,* 29:1604-1611.

Flynn, R.P. & Wood, C.W. (1996) Temperature and chemical changes during composting broiler litter. *Compost Science and Utilization,* 4:62-67.

Gates, R.S., Pescatore, A.J, Food, M.J., Taraba, J.L., Liberty, K. & Cantor, A.H. (2000). The Effects of Feeding Low Protein Diets on Ammonia Emission and Total Ammoniacal Nitrogen in Broiler Litter. *Proceedings 2000 National Poultry Waste Management Symposium*. 378-384.

Gburek, W.J. (2000). Nutrient and Pathogen Transport in the Watershed. Proceedings from Managing Nutrients and Pathogens from Animal Agriculture Conference. 227 - 236.

Godwin, J.L., Carter, T.A. & Grimes, J.L. (2000). The use of Litter Plus® as a Bedding Material for Broilers. *Proceedings 2000 National Poultry Waste Management Symposium*. 344-352.

Gregory, E., Barnhart, H., Dreesen, D.W., Stern, N.J. & Corn, J.L. (1997). Epidemiological Study of *Campylobacter* spp. in Broilers: Source, Time of Colonization, and Prevalence. *Avian Diseases*, 41:890-898.

Grimes, T. (2000). Preventative Management Programs for Maintaining Health Adjuncts to Antibiotics. *Proceedings 2000 Poultry Information Exchange.* 89-94.

Griffiths, N. (1998). Best practice guidelines for using poultry litter on pastures. *NSW Agriculture Agnote DPI-212.*

Griffiths, N. (1998). Report Poultry Litter – A great resource or an environmental hazard. *NSW Agriculture.*

Guidelines for Sewerage Systems – Biosolids Management. *Occasional Paper WTC No 1/95.* (1995). Water Technology Committee of ARMCANZ.

Higgins, R., Malo, R., Rene-Roberge, & Gauthier, R. (1981). Studies on the dissemination of *Salmonella* in nine broiler flocks. *Avian Diseases*, 26:26-33.

Ivanov, I.E. (2001). Treatment of broiler litter with organic acids. *Research in Veterinary Science.* 70:169-173.

Jacobs-Reitsma, W.F., Van de Gissssen, N.M., Boulder, N.M. & Mulder, W.A.M. (1995) Epidemiology of *Campylobacter* spp. at two Dutch broiler farms. *Epidemiology & Infection*, 114:413-421.

Jeffrey, J.S., Kirk, J.H., Atwill, E.R. & Cullor, J.S. (1998). Prevalence of selected microbial pathogens in processed poultry waste used as dairy cattle feed. *Poultry Science,* 77:808-811.

Jeffrey, J.S., Lazano, J.C., Atwill, E.R. & Walton, E.H. (2001). Thermal events and physical characteristics of simply stacked poultry litter: implications for microbial safety. *Western Poultry Disease Conference*.

Jenkins, M.B., Endale, D.M., Schomberg, H.H. & Sharpe, R.R. (2006). Fecal bacteria and sex hormones in soil and runoff from cropped watersheds amended with poultry litter. *Science of The Total Environment,* 358:164-177.

Kelley, T.R., Pancorbo, O.C., Merka, W.C. & Barnhart, H.M. (1997). Antibacterial resistance of broiler litter isolates. *Poultry Science,* 77:243-247.

Kelley, T.R, Pancorbo, O.C., Merka, W.C., Thompson, S.A., Cabrera, M.L. & Barnhart, H.M. (1998) Accumulation of Elements in Fractionated Broiler Litter during Re-utilisation. *Journal Applied Poultry Science,* 7:27-34.

Limawongpranee, S., Hayashidani, H., Okatani, A.T., Hirota, C., Kaneko, K. & Ogawa, M. (1999). Contamination of *Salmonella blockley* in the environment of a poultry farm. *Avian Diseases,* 43:302-309.

Lobato, F.C.F., Almeida, A.C., Abreu, V.L.V. & Nascimento, R.A. (1995). An outbreak of botulism in cattle fed chicken litter. *Arquivo Brasileiro de Medicina Vetrinaria e Zootechnia*, 47:849-850.

Long, J.R., DeWitt, W.F. & Ruet, J.L. (1980). Studies on *Salmonella* from floor litter of 60 broiler chicken houses in Nova Scotia. *Canadian Veterinary Journal,* 21:91-94.

New South Wales Poultry Farming Guidelines. (1994). NSW Agriculture.

MacKenzie, M. (1996). Single batch cleanouts – How and why. *Proceedings 1996 Poultry Information Exchange Qld.* 159-169*.*

Mallinson, E.T., Joseph, S.W., Carr, L.E. & Wabeck, C.J. (May 19, 1997). Litter management is critical to food safety, performance. *Feedstuffs,* 47-50.

Martin, S.A., McCann, M.A. & Waltmann, W.D. (1998). Microbiological survey of Georgia poultry litter. *Journal of Applied Poultry Research*, 7:90-98.

Maurice, D.V., Lightsey, S.F., Hamrick, E. & Cox, J. (1998). Alum Sludge and Zeolite as Components of Broiler Litter. *Journal Applied Poultry Science,* 7:263-267.

McCubbin, D.R., Apelberg, B.J., Roe, S., & Divita, F. Jr. (2001). Livestock Ammonia Management and Particulate – related Health Benefits. *Proceedings of the Air & Waste Management Association's 94 Annual Conference & Exhibition, Florida, 2001.*

McWard, G.W., & Taylor, D.R. (2000). Acidified Clay Litter Amendment. *Journal Applied Poultry Research,* 9:518-529.

Mullins, G.L. (2000). Nutrient Management Plans – Poultry. Proceedings from Managing Nutrients and Pathogens from Animal Agriculture Conference. 421 - 433.

Nichols, D.J., Daniel, T.C., Edwards, D.R., Moore Jr., P.A. & Pote, D.H. (1998). Use of grass filter strips to reduce 17β-estradiol in runoff from fescue-applied poultry litter. *Journal of Soil and Water Conservation,* 53:74-77.

Nicholson, F. A., Hutchinson, M. L., Smith, K. A., Keevil, C. W., Chambers, B. J. & Moore, A. (2000). A study on farm manure applications to agricultural land and an assessment of the risks of pathogen transfer into the food chain. MAFF Project FS2526.

Okamoto, K., Adachi, K., Sato, K.I., & Chuma, T. (1999) Epidemiological factors in chicken botulism. *Journal of the Japanese Veterinary Medical Association*, 52:168-173.

Olesiuk, O.M., Snoeyenbos, G.H., & Smyser, C.F. (1971). Inhibitory effect of used litter on *Salmonella typhimurium* transmission in the chicken. *Avian Diseases*, 15:118-124.

Ortolani, E.L., Brito, L.A.B., Mori, C.S., Schalch, U., Pacheco, J. & Baldacci, L. (1997). Botulism outbreak associated with poultry litter consumption in three Brazilian cattle herds. *Veterinary & Human Toxicology*, 39:89-92.

Paulin, B. (2001). Agriculture Western Australia. Personal Communication

Petersen, L. & Madsen, M. (2000). *Listeria* spp. in broiler flocks: recovery rates and species distribution investigated by conventional culture and EiaFoss method. *International Journal of Food Microbiology*, 58:113-116.

Pope, M.J. & Cherry, T.E. (1999). An evaluation of the Presence of Pathogens on Broilers Raided on Poultry Litter Treatment® - Treated litter. *Journal of Poultry Science,* 79:1351-1355.

Quirke, T., Magette, W.L., Curran, T. & Dodd, V.A. (2000) Environmental Management Systems. *2000 Proceedings of the International Symposium Animal, Agricultural and Food Processing Wastes*, 476-483.

Ring, M., Zychowska, M.A. & Stephan, R. (2005). Dynamics of *Campylobacter* spp. spread investigated in 14 broiler flocks in Switzerland. *Avian Diseases*, 49:390-396.

Sauer, T.J., VanDevender, K., Maxwell, C.V., Daniels, M.B., Sharpley, A.N., Watkins, S.E., Hatfield, J.L., West, C.P. & Coffey, K.P. (2000). Phosphorus Balance Model to Predict Land Base Requirements for Sustainable Broiler Feeding Operations. *Proceedings of the International Symposium Animal, Agricultural and Food Processing Wastes*. 401-407.

Shanker, S., Lee, A. & Sorrell, T.C. (1990) Horizontal transmission of *Campylobacter jejuni* amongst broiler chicks: experimental studies. *Epidemiology and Infection*, 104:101-110.

Sharpley, A.N., Daniel, T., Sims, T., Lemunyou, R., Stevens, R., & Parry, R. Agricultural Phosphorous and Eutrophication. *United States Department of Agriculture Agricultural Research Service.* ARS-149, July 1999.

Sidhu, J., Gibbs, R.A., Ho, G.E. & Unkovich, I. (2001) The role of indigenous microorganisms in suppression of *Salmonella* regrowth in composted biosolids. *Water Research,* 35:913-920.

Simmons, G.C.& Byrnes, O.D.A. (1972) The origin of *Salmonella* in chickens and chicken carcases. *Australian Veterinary Journal*, 48:186-189.

Skrinjar, M., Ristić, M. & Grbić, Z. (1995). Contamination of broiler chicken's mash and litter with moulds, aflatoxins, ochratoxin A and zearalenone. *Acta Veterinaria Hungarica*, 43:117-124.

Standard Organic and Bio-dynamic Produce, version 3. (2000). *Biological Farmers of Australia Co-operative Ltd.*

Swain, B.K. & Sundaram, R.N.S. (2000). Effect of different types of litter material for rearing broilers. *British Journal of Poultry Science,* 41:261-262.

Taylor, M.A., Catchpole, J., Norton, C.C., & Green, J.A. (1994). Variation in oocyst output associated with *Cryptosporidium baileyi* infections in chickens. *Veterinary Parasitology*, 53:7-14.

Terzich, M., Quarles, C., Goodwin, M.A. & Brown, J. (1998). Effect of Poultry Litter Treatment® (PLT®) on death due to ascites in broilers. *Avian Diseases,* 42:385-387.

Terzich, M., Quarles, C., Goodwin, M.A. & Brown, J. (1998). Effect of Poultry Litter Treatment® (PLT®) on the development of respiratory tract lesions in broilers. *Avian Pathology,* 27:566-569.

The Environmental Code of Practice for Agriculture. 1-28. (1994). Queensland Farmers' Federation.

Varga, I., Sreter, T. & Bekesi, L. (1995). Quantitative method to assess *Cryptosporidium* oocyst shedding in the chicken model. *Parasitology Research,* 81:262-264.

Vervoort, R.W. & Keeler, A.G. (1999). The economics of land application of fresh and composted broiler litter with an environmental constraint. *Journal of Environmental Management,* 265-272.

Williams, J.E. & Benson, S.T. (1978). Survival of *Salmonella typhimurium*, in poultry feed and litter at three temperatures. *Avian Diseases*, 22:742-747.

Wilson, M.G. (2000). Technologies for Ammonia Control in Poultry Facilities. *Proceedings 2000 National Poultry Waste Management Symposium*. 241-248.

Worley, J.W., Risse, L.M, Cabrera, M.L., & Nolan, M.P. Jr. (1999). Bedding for Broiler chickens: Two Alternative Systems. *Journal American Society of Agricultural Engineers.* Vol. 15:687-693.

Worley, J.W., Cabrera, M.L., & Risse, L.M. (2000). Reduced levels of alum to amend broiler litter. *Applied Engineering in Agriculture,* 16:441-444.

Zhu, J., Schmidt, D.R., Randall, G. & Morey, V.R. (2000). Nutrient Concentrations in the Top Soil of Deep Bedded and Poultry Litter Systems. *Proceedings of the International Symposium Animal, Agricultural and Food Processing Wastes*. 702-709.

7.2 Useful Internet Sites

Animal Waste Management Field Handbook - USDA
http://www.ncg.nrcs.usda.gov/awmfh.html

Australian Greenhouse Office –Carbon/emissions trading
http://www.greenhouse.gov.au

Australian New Zealand Food Authority – Food Standards
http://www.anzfa.gov.au/

Bioenergy Australia – information on how sustainable energy sources like chicken litter are being utilised
www.users.bigpond.net.au/bioenergyaustralia

Current research by USDA – Agricultural Research Service – National Programs
http://www.nps.ars.usda.gov/menu.htm

Danpo – salmonella & campylobactor free chicken. (follow link, Danpo, Product safety, battling bacteria)
http://www.danpo.dk/danpo.uk/

Environmental guidelines for composting and other organic recycling facilities, Victoria
http://www.epa.vic.gov.au/

Environment Protection Authority, Victoria
http://www.epa.vic.gov.au/

Guides to watersheds and clean run off
http://www.ctic.purdue.edu/KYW/

Information on Australian situation including conference papers
http://www.recycledorganics.com.au/

Institute for Global environmental Strategies IGES – To good practice guidance and uncertainity management in national greenhouse gas inventories
http://www.ipcc-nggip.iges.or.jp/public/gp/gpgaum.htm

Integrated Biosystems are being investigated by the South Australian Research & Development Institute
http://www.roseworthy.adelaide.edu.au/~pharris/biosys/welcome.html

MAFF UK; Homepage
http://www.maff.gov.uk/

North Carolina State University – Livestock Waste Management Centre
http://www.bae.ncsu.edu/programs/extension/manure/awm/faculty/waste_mngmnt.htm

Review of recycled organic waste SA EPA

http://www.environment.sa.gov.au/epa/pdfs/organicwaste.pdf

Review of on farm disposal treatment risks
http://www.environment.sa.gov.au/epa/pdfs/chickenfarms.pdf

Silsoe Research Institute, UK – waste management, composting, integrated management systems for poultry. (go to science groups, waste or livestock)
http://www.sri.bbsrc.ac.uk/

USA EPA composting
http://www.epa.gov/epaoswer/non-hw/compost/index.htm

USDA site for info on buffer strips (select conservation buffers)
http://www.nrcs.usda.gov/

US EPA – information about Concentrated Animal Feeding Operations (CAFO's)
http://www.epa.gov/Region8/water/wastewater/cafohome/cafodownload/cafodocs/cafodocs.html

Victoria – Dept Natural Resources & Environment - Codes of Practice
http://www.nre.vic.gov.au/codes/