



Composting Every Day Mortality and Other Wastes from Layer Farms

A report for the
Australian Egg Corporation Limited

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Foreword

Changing management and disposal options within the Egg Industry have led to interest in composting among Egg producers. Composting is seen as a low input waste disposal system that has many benefits, including reduced biosecurity risk, timely waste disposal and the production of a valuable end product for use on an egg producer's own land or for sale off farm. This report provides the findings from an Egg Producer Research, Innovation and Development project that investigated composting as a means for disposing of wastes including daily mortalities, spent hens and egg waste on farm.

This project was funded from industry revenue which is matched by funds provided by the Federal Government.

This report is an addition to AECL's range of research publications and forms part of our R&D program, which aims to support improved efficiency, sustainability, product quality, education and technology transfer in the Australian egg industry.

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Executive Summary

Composting is a viable alternative method for disposing of daily mortalities, spent hens, egg waste and other waste produced on egg farms. Under controlled systems with the correct management, good results can be achieved and a safe, nutrient rich soil amendment produced for reuse on-farm or sale to other farmers. This project involved on-farm compost trials at nine farms across Australia. All farmers attended an initial training workshop where the principles of composting were presented and the project was completed with a second workshop where farmers were able to report their results and share experience with composting.

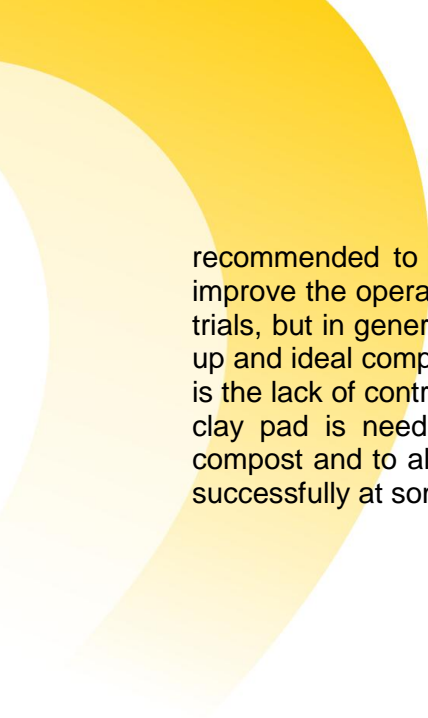
Trials were monitored with temperature logging equipment and the compost was sampled for analysis of pathogen and nutrient levels. Successful composting, as defined for this project, was to meet the following broad criteria: i) To produce a microbiologically safe material for reuse in 'low risk' agricultural systems (such as broad acre cropping and grazed pastures), ii) to improve the environmental outcomes for layer farms compared with other waste management options, iii) to assess the value of the compost as a nutrient source, and iv) to find a process that is relatively low in management input and cost.

With respect to the assessment criteria used in this project, very few of the samples analysed could be considered safe for reuse in a grazing context because of the risk of botulism. The *Cl. botulinum* toxin (type C and D) was identified in one sample in the trial. This toxin is highly toxic to livestock, particularly cattle. Other pathogen levels were generally below the level naturally present in poultry manure. In general there were insufficient temperature records to ensure pasteurisation however, and in some samples bones and undecomposed flesh were observed. This being said, many of the trials may have shown significantly better results 1-2 months after the sampling was carried out, provided ideal composting conditions were maintained. In most case study trials, the material produced would be considered 'partially composted' as it does not meet the Australian composting standards.

Provided the correct guidelines are followed for establishing compost sites and managing the composting process, the environmental outcomes from composting are believed to be superior to burial in most cases.

Nutrient analysis results show that compost is a valuable by-product that can be valuable for re-use on agricultural crops and pastures, provided pathogen levels are controlled. Observation of compost samples suggested that most would benefit from screening prior to spreading to remove large particles of compost materials and undecomposed bones. Nitrogen levels in the sampled compost piles ranged from 1.1-4.3% (average 2.1%) with most of the variation being related to manure content in the composting mix. Likewise, phosphorus levels were related to the proportion of manure in compost mix and varied from 0.1 – 1.8% (average 1.1%). Other nutrients of interest include calcium, which averaged 5.9%. Many farmers used manure as a primary material for composting, however, the most successful composting was done using sawdust or barn litter and this material is recommended if available, though fine grade green waste can also be used.

Composting mortalities and other poultry farm wastes can be done for low cost and with a small amount of management input. However, procedures need to be strictly followed and the correct materials need to be used to ensure a safe product is produced. Training is



recommended to establish the process correctly and correct set-up of infrastructure will improve the operation significantly. Many different arrangements were used in the on-farm trials, but in general the turned piles or windrows offered the best system for minimum set-up and ideal composting conditions. However, one downside to outdoor piles and windrows is the lack of control over moisture. It was clear from trials in wet regions that a compacted, clay pad is needed for effective composting to reduce moisture being drawn into the compost and to allow for machinery operation on the compost site. Small bins were used successfully at some sites and offer a good solution for composting near to poultry sheds.

1. Introduction

1.1. Composting in the Australian Egg Industry

In recent years the egg industry in Australia has moved to using composting as a means of managing a range of waste products from the system. Composting is used to manage mortalities, spent hens and egg waste in addition to manure and litter.

Composting has been adopted as a low cost means of waste management, with the advantage of producing a valuable soil conditioner and nutrient source as the end product.

There are several drivers behind the adoption of composting. With respect to mortalities and spent hens, the diminishing availability of rendering services and the lack of capacity for processing spent hens within the required timeframe. Modern egg production requires complete depopulation of sheds in 4-5 days, resulting in up to 20,000 spent hens per day for disposal.

Environmental impact concerns have also been raised over the more traditional means of carcass disposal such as burial or incineration, making composting an attractive option. Composting offers biosecurity advantages over other means of disposal, and is currently being recommended for disposal of diseased birds under the revised AUSVETPLAN, though this needs to be done in close consultation with the relevant authorities.

Composting manure and litter may improve the quality of the end product for some uses, such as application to horticultural crops, however demand for 'raw' manure and litter for reuse in agricultural sectors is still strong, and has increased in response to higher fertiliser prices. In Western Australia, composting of layer manure before reuse has been heavily promoted and legislated to reduce the incidence of stable flies in highly populated areas. Composting large volumes of manure or litter should be driven by market demand and requirements (e.g. horticulture) for this product and a willingness to pay for the additional cost involved in production. A lack of this market demand for composted product may cause greater costs of production to be placed on the producer for waste management.

There are several different methods that can be used to compost wastes on-farm. These vary greatly with the compost material used, the scale of the operation and the desired quality of the final product. A summary of general composting information and specific carcass compost literature is included as a background to the on farm trails reported in following sections.

1.2. The Composting Process

Composting involves the biological breakdown of organic materials in a relatively short number of weeks, producing a safe, nutrient-rich humus like soil conditioner and plant nutrient source. Provided the process is done correctly, composting can significantly reduce or eradicate harmful pathogens, reducing biosecurity risks.

Composting requires several basic elements, including:

- The correct range in carbon:nitrogen (C:N) ratios
- Oxygen supply
- Correct moisture levels

Carbon to Nitrogen Ratio

Composting is carried out by micro-organisms that feed on carbonaceous materials. In order to consume these materials, the micro-organisms require a supply of elemental nitrogen which they use to form proteins necessary for life. The ratio of carbon to nitrogen (C:N) is therefore a key determinant for developing a composting mix. Where carbon (C) is oversupplied, the process will be carried out very slowly because the rate of microbial breakdown of the material will be limited by nitrogen (N). If nitrogen is oversupplied, this is not likely to limit the rate of composting, however significant amounts of N may be lost to the atmosphere in the form of ammonia because it is not held in the compost material by the micro-organisms.

Generally, a C:N ratio of between 15 and 40:1 will provide for effective composting. This can be achieved by balancing high nitrogen source materials with low nitrogen source materials. Examples of high nitrogen source materials include caged layer manure, poultry carcasses, egg waste and mill waste, while low nitrogen source materials include sawdust, straw and green waste.

In addition to developing a mix with the correct proportion of C:N, the carbon also needs to be in a form that is available for consumption by microbes. Materials that have a low proportion of lignin to cellulose generally break down more rapidly, as do materials with a higher surface area to volume ratio. Chopped straw or sawdust both provide an ideal composting material, as do finer grades of green waste. However, coarse woodchips and green waste are not suitable because much of the carbon will not be available in the compost mix.

A typical mix for composting manure, together with calculations of the C:N ratio have been included in Table 1 below. This mix has a C:N ratio of 17:1 which represents a good balance between securing nitrogen in the composting process and minimising the amount of carbon material required. In order to achieve this C:N ratio, approximately 2 parts (by bulk) of a high carbon source material such as sawdust is required per 1 part of caged layer manure.

Table 1. Calculations of C:N Ratio for a Sawdust / Manure Compost Mix

	Material 1	Material 2	Composition of Compost mix
Material type	Sawdust	Caged layer manure	
% in mix (by bulk)	65%	35%	100%
Bulk density (kg/m ³)	180	750	
% Dry Matter	90%	70%	
Dry mass (kg)	105	184	289
C (%)	80%	30%	48%
C (kg)	84	55	139
N (%)	0.0001%	4.6%	2.9%
N (kg)	0.01	8.5	8.5
C:N ratio	80000:1	6.5:1	17:1

Many materials used as compost feedstock require blending to achieve the correct C:N ratio, however some materials such as barn litter may have a C:N ratio that is close to ideal, requiring no additional mixing.

Carbon naturally occurs in a range of forms. The form the carbon is stored in can influence the efficiency of composting, as some forms are more readily degraded than others. For example, the carbon found in straw is readily degradable and will compost quickly, while cellulose or lignin fibres found in wood will take longer to compost. Cardboard waste from egg processing can be used as a carbon source, however the material needs to be shredded before composting to increase the surface area. This will improve the efficiency of the composting process. The physical characteristics of a bulking material will also affect the availability of carbon for composting. Materials with a low surface area to volume ratio (such as wood chips) will be much more resistant to breakdown than materials with a high surface area to volume ratio such as sawdust.



Photograph 1. Shows a variety of compost materials including spent litter, mill waste and sawdust as feed stock for composting.

Table 2. Characteristics of some common compost materials

Material type	Approximate dry bulk density (kg/m ³)	Approximate moisture (%)	Approximate Carbon (%)	Approximate Nitrogen (%)
Green waste	250	< 10	55-70 ^a	0.2
Sawdust	200	< 10	80	0.0001
Straw (wheat)	110	< 10	50-70	0.4
Barn litter	550	25	35-55	4.1
Caged layer manure	550	30	29	4.6

Source: NRAES 1992. Numbers have been converted from imperial to metric

^a Carbon in green waste can be in a form that is not available for composting. It is important to select a fine grade green waste with a high proportion of small particle size material.

Oxygen

Beneficial bacteria required for composting are aerobic and will quickly die if there is too little oxygen available. If low oxygen conditions are experienced in a composting pile or windrow, aerobic bacteria will be replaced with anaerobic bacteria, which produce odorous compounds.

Supplying adequate oxygen in a compost pile or windrow can be done by maintaining adequate porosity, correct moisture levels and sufficient turning. Porosity is determined by the type of material being used in the compost mix. For example, straw generally has a high level of porosity, while sawdust has lower porosity. In some cases blending materials will help improve porosity and air flow. However, if porosity is too high the pile will dry very quickly, which can slow the process and increase the need for additional water.

To ensure a good supply of oxygen in the pile, it is important to keep the moisture below 60%. If the pile is too wet, often the first sign is the production of an odour coming from the pile. This is because water fills the pore space in the pile, limiting oxygen supply. Over supply of moisture will be evident where moisture is flowing from piles or windrows. In this case the pile will need to be turned frequently or dry bulking material added until moisture levels decrease. It is a good idea to wet the feathers of the birds when placing them in the windrow. This will ensure that they break down quickly.

Turning the compost pile periodically allows oxygen to move through the pile, which in turn helps the overall composting process. Turning also increases the porosity in the pile, which may have been reduced because of settling. Frequency of turning will be influenced by a variety of factors including porosity, moisture level and desired level of management input. Requirement for turning is best determined by temperature, as any limit to the process will result in declining temperatures in the pile.

Moisture

Water is an essential ingredient in the compost mix, and generally needs to be added during the process depending on the moisture in the initial material. For example, there is

high level of moisture in the fresh carcasses, and it is important not to add too much additional water initially for carcass composting. Dry material such as litter or manure / litter mixes are likely to require 1,000-3,000 L / m³ of starting material, though this may be lower where rainfall supplements the system. Successful carcass composting has been carried out without the addition of extra moisture (particularly in the first stage of the process), so this may need to be trialled to work out the best method.

Rainfall may also influence the level of moisture within the compost pile. Although the capture of rainfall can reduce some of the requirement for additional moisture to be added, it is important that excessive rainfall does not contribute to the compost (particularly in high rainfall areas) to avoid anaerobic conditions. Shaping the top of the windrow or pile can influence the amount of rainfall captured.

Temperature

Once the ingredients of the composting mix are added in the correct ratios, the composting process will carry on naturally as the micro-organisms begin to breakdown the material. The first sign that the composting process is working is the generation of heat in the pile. Temperatures should reach 50-65°C within days of establishing the composting piles. Temperatures above about 50°C stimulate the growth of the thermophilic bacteria, promoting break-down, destroying pathogens and weed seeds.

1.3. Carcass Composting

Management

Carcass composting follows the same principles of other composting processes, however there are several ways in which to carry out the process depending on the end goals. Carcass composting can be used to dispose of daily mortalities through to spent hens, and these processes operate at very different scales. Carcass composting requires different practices because of the nature of the material. Carcasses are potentially odorous and may pose a biosecurity and pathogen risk. They may also attract vermin if not properly managed.

To manage these concerns, the carcass composting process needs to follow some key guidelines including:

- Birds must be composted fresh (daily) or stored in a fridge/freezer prior to composting to avoid a build-up of pathogens. It is imperative that birds are not heaped and left to begin decomposing prior to composting, as this will increase the risk of *Clostridium botulinum*.
- Compost piles must maintain complete coverage of the birds with a significant buffer between the carcasses and the surrounding environment (minimum of 300mm of bulking material).
- The compost must have adequate moisture, oxygen, carbon and nitrogen to compost effectively, as demonstrated by high temperatures within the compost pile (greater than 55°C).
- Compost piles or windrows must be kept aerobic.

These conditions must be met to safely compost carcasses and avoid the risk of botulism. However, meeting these conditions is not adequate to ensure effective composting or

pasteurisation of the compost material. In addition to this, the conditions of the Australian Standard for Composts (AS 4454) require:

- Compost piles must be turned a minimum of three times and reach temperatures of 55°C for 3 consecutive days after each turning to pasteurise the material.
- The compost process must go for a minimum of six weeks.

Farmers may choose to partially compost their material without meeting the requirements of the AS 4454, but this will leave some risk from pathogen contamination. The level of pathogen contamination will determine the end use of the product (eg. horticulture vs grazing vs broad acre cropping).

In addition to the general discussion in the previous section, there are some requirements specific to composting carcasses that will be discussed in the following sections.

Carbon:Nitrogen Ratio

Poultry carcasses have a high level of nitrogen, and require a carbonaceous bulking material to effectively contain nitrogen from the decaying bird. This is best done using a sawdust, chopped straw, finely mulched green waste or barn litter. Straight layer manure is not a good material for carcass composting as this contains too little carbon for effective composting. However, manure can be added to a mix for carcass composting at low rates (less than 25% by bulk).

By mass, carcasses will require about twice as much carbon bulking material as carcasses. By bulk (volume), this equals about 3 parts bulking material to 1 part carcasses.

In addition to establishing the correct C:N ratio, a buffer using the carbon bulking material is essential for surrounding the carcasses to reduce scavenging by animals and to absorb excess liquids from the decaying carcasses. This improves on-farm biosecurity and creates a product that is safe for land application. As compost piles are likely to be cooler close to the edge, dead birds should be kept at least 300 mm from the edge of the pile.

Oxygen

Carcass composting requires careful management to ensure all carcasses are covered continuously from the surrounding environment. This can make oxygen supply challenging, as turning is more difficult than with normal composting. Generally, carcass compost piles are established and left for 1-3 months after the last carcass is added before turning. For successful composting to occur during this time, the pile must have adequate porosity to maintain the process. In a static pile, oxygen supply is primarily added by convection, where warm air rises through the pile drawing in fresh air from the base of the pile. This process can be aided by mixing porous material such as straw or coarse green waste into the bottom layer of the pile. This coarse material should not be added at more than about 25%, as the base of the pile needs to be able to absorb moisture from the composting birds. After an initial phase of static composting, piles can be turned to improve porosity and mixing. After piles are turned coverage of any exposed carcasses is essential for effective composting. This must be carried out, using additional bulking material or partially finished compost from a previous composting pile.

Turning

As previously mentioned, carcass composting can be carried out with or without turning piles. Turning is carried out to mix components and supply air, which can speed the breakdown of carcasses. Hen carcasses are likely to breakdown within 1-3 months without turning providing the right conditions exist in the pile, and the time span may be considerably shorter if the piles are turned frequently. It must be noted that when carcasses are turned, adequate bulking material must always be present to cover any carcasses that become exposed to prevent scavenging and odour production.

Because turning has a significant effect on the duration of the composting process, the decision to add this step is mostly driven by the number of carcasses that need to be disposed of and the amount of space available.

Moisture

Moisture is an optional requirement for carcass composting. Carcasses have a high amount of liquid which is released during decomposition, and additional moisture may be provided by rainfall if composting is done outdoors. Water can be added at the time of initiating the composting process in order to wet the feathers of the birds, however no additional water is likely to be needed during the static composting phase. Water may again be added at the point of turning after this phase.

Moisture can reach excessive levels in some cases where a compost site is exposed to rainfall and there is insufficient drainage. This can lead to unfavourable conditions for composting (anaerobic) and generation of unpleasant odours. For this reason it is important to establish outdoor composting sites with adequate drainage from the site to avoid moisture being drawn into the compost pile from below or infiltrating with rainfall from above. Runoff from the site also needs to be collected to minimise contamination of surface waters with nutrients, organic matter and pathogen. Some materials such as sawdust are very effective at shedding rainfall provided the piles or windrows are sufficiently peaked. Rain tends to seal the pile surface and reduce the aeration rate, and piles should be turned after rain to improve aeration.



Photograph 2. Outdoor compost site showing inadequate drainage.

Temperature

Carcass composting will develop high temperatures as do other forms of composting. However, as these temperatures are only experienced in the centre of the pile, it is advisable to maintain a 300mm buffer around the carcasses on the sides of a pile also to ensure all carcasses are in the area experiencing high temperatures. Temperature can be a useful means for monitoring the composting process. Turning is required when temperatures begin to fall below about 45 degrees C.

Figure 1 shows the compost pile responding to turning with a general increase in temperature after the turning process.

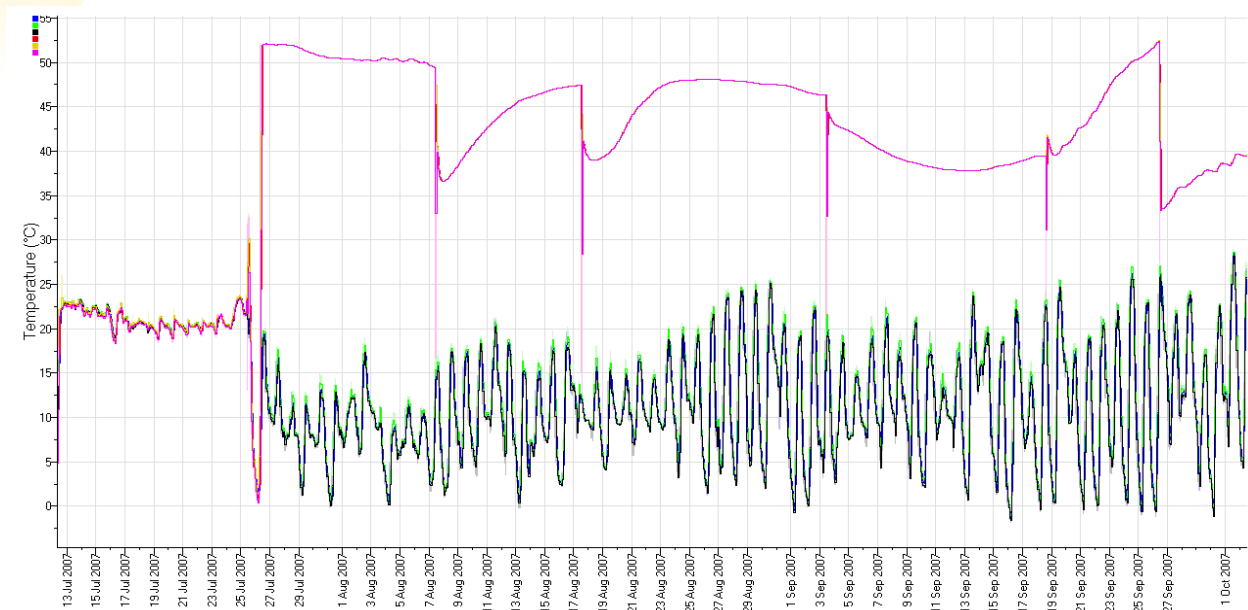


Figure 1. Carcass compost temperature graph showing ambient temperature (bottom) and temperature within the compost pile (top). Sharp drops in temperature observed on 7 August, 17 August, 3 September and 19 September identify when the temperature probe was removed and the compost pile was turned.

1.4. Methods for Composting

Composting of large volumes of material is generally carried out in windrows. This allows for monitoring and turning using machinery. Windrows may be up to 100m long, 3-4m in width and 2-3m high depending on the composting site and the machinery used for composting. This technique is ideal for composting litter, manure or large numbers of spent hens.

However, different methods may be used for daily mortalities and egg waste as these generally involve small quantities of material that are added to on a frequent basis. In this situation it may be convenient to use bins, piles or sealed composters so that the unit can be within walking distance of sheds.

Composting in sealed bins

Composting in sealed, rotary composters can offer a rapid (5-7days), contained way of handling carcasses. Advantages of rotary composters are the rapid breakdown time, the low amount of co-composting material required and the fact that they are a closed container to avoid scavenging. The size and number of units needed depends on the size of the operation and normal levels of bird mortality.

Rotary composters can act as a primary stage for carcass composting, allowing rapid breakdown of carcasses after which the material can be stockpiled prior to land application without significant risk of pathogens.

A disadvantage to the rotary composter is the high initial cost of purchase compared with the relatively simple bin design composting systems. This will need to be weighed against the advantages that come from very rapid breakdown of carcasses from the rotary units. Rotary composters may also be difficult and costly to manage.



Photograph 3. A rotary composting unit used for daily mortality composting

Composting in small bins

Carcass composting can be carried out on a small scale in purpose built bins that can be located within walking distance of the sheds. These bins can be added to daily until they reach capacity, after which time they need to be left for approximately 4 weeks to allow for the last bird to compost. Daily mortalities can also be refrigerated or frozen and composted on a weekly basis (particularly for small enterprises) to reduce the handling time required in managing the process.

After this initial composting phase the material can be removed from bins and composted in a pile for a further 2-6 months to allow further breakdown before spreading or sale. Emptying the bins will redistribute excess moisture and introduces more oxygen. This promotes further composting and decomposition and is an important secondary step in the process to ensure all the carcass material is exposed to the optimum composting conditions.

Careful thought needs to go into handling techniques for loaded bins. Some farmers have successfully used 44 gallon drums for this, however emptying may require the use of a tractor to lift and transport the loaded bins.



Photograph 4. An example of a small bin (constructed out of rubber belt) used for daily mortality composting. 200 litre fuel drums may also be used for this.

Composting in open bays or piles

Composting can be easily carried out in open bays or piles with minimal construction costs. Bays can be formed using large round or square hay bales for the walls and a concrete or compacted clay base to minimise leaching from the site. These bays allow for storage of fresh bulking material and different stages of compost. Each bay may be turned at 1-6 month intervals (after the addition of the last carcass), depending on management aims. Using open bays, it is important to peak the compost piles to ensure that they are able to shed rainfall. The site will require adequate drainage to allow runoff to escape and not pool around the piles. This runoff will then need to be captured to avoid and water contamination.



Photograph 5. Outdoor piles used for spent hen composting.

1.5. Pathogens and Pathogen Survival During Composting

This section provides a general background of the pathogens of significance to poultry waste. These pathogens have the possibility of re-entering the poultry operation because of the composting operation on-site or of being transferred via improperly treated manures or wastes to the animal or human food chain.

Clostridium botulinum is a serious animal and food-borne pathogen, though it is considered a limited risk to human health. The factors associated with cattle botulism and composting are discussed in Chinivasagam & Runge (2008) and a brief overview is included here. *Clostridium botulinum* is responsible for botulism, a fatal illness in both humans and animals (Jay 1978). *Cl. botulinum* is widely distributed in environmental sources such as soil (Smith 1975a; Wobeser et al. 1987) and aquatic environments (Segner et al. 1971a; Huss 1980). *Cl. botulinum* is an anaerobic spore forming organism with spores that are able to survive in the environment for decades (Mitscherlich and Marth, cited in Böhnel et al. (2002) and under most environmental circumstances e.g. dry heat (Critchley 1991). The ingestion of a highly toxic, soluble exotoxin produced by the organism is responsible for the symptoms of the food-borne botulism (Jay 1978). This exotoxin, also known as botulinum neurotoxin, varies depending on the different serotypes. Toxins are formed within the organisms and are released during autolysis. These toxins are among the most toxic substances known to man and contain 30,000,000 mouse LD₅₀/mg. (Jay 1978).

Because of the high degree of toxicity and relative likelihood of contact between cattle and manure or compost (because of on-farm storage or spreading on pastures), contamination with *Cl. botulinum* is considered a serious concern within compost samples and has been one pathogen of focus in the trials.

Food-borne pathogens such as *Campylobacter*, *Clostridium perfringens* and *Salmonella* are all associated with poultry and poultry waste (Shane 1992, Limawongpranee et al. 1999; Chalmers et al. 2008). *Listeria monocytogenes*, commonly linked with the environment, can also be associated with the free range poultry production systems (Esteban et al. 2008). *Arcobacter*, an emerging pathogen, is linked with poultry (Wesley and Baetz 1999) and may be of future significance. These pathogens are of concern for their potential impact on humans, both through direct contact and through the food chain. Contamination with these pathogens may be relatively common, and the risk needs to be assessed with respect to the intended use of the compost. Below is a list of the organisms of importance (primary and secondary) in relation to poultry.

Table 3. Organisms of primary importance in poultry manure and compost

Organism	Reason for consideration
<i>Salmonella</i>	<ul style="list-style-type: none"> • Ability to survive in the environment • Dominant association with poultry • One of the major food-borne pathogens • Key serovars linked with egg related outbreaks in Australia
<i>Cl. botulinum</i> (Cattle)	<ul style="list-style-type: none"> • Good survivor in the environment • Spore former • Cattle mortality – chicken waste, associated with previous outbreaks in Australia • Chicken – chicken waste link
<i>E. coli</i>	<ul style="list-style-type: none"> • A common indicator organism

Table 4. Organisms of secondary importance in poultry manure and compost

Organism	Reason for consideration
<i>Campylobacter</i>	<ul style="list-style-type: none"> • Poor survivor in the environment • Poor survival during composting • Dominant association with poultry • One of the major food-borne pathogens • Prevalent in barn, cage, free range birds
<i>Cl. Perfringens</i>	<ul style="list-style-type: none"> • Good survivor in the environment • Spore former • Chicken – chicken waste link
<i>Listeria monocytogenes</i>	<ul style="list-style-type: none"> • A food-borne pathogen • Present in the environment
<i>Arcobacter</i>	<ul style="list-style-type: none"> • Possible link with free range poultry • A food-borne pathogen • An emerging food borne pathogen

In order to benchmark the performance of the compost trials, pathogen testing was also carried out on fresh layer manure from one farm. Results from this sample (Table 5) are referred to in the case study trials.

Table 5. Pathogen results for sample 9 – fresh layer manure sample from farm A

Pathogen	Units	Result
<i>E. coli</i>	cfu/g	186,000,000
<i>Clostridium perfringens</i> spp	cfu/g	1,290,000
<i>Salmonella</i> spp.	MPN/g	4,600
<i>Campylobacter</i> spp.	MPN/g	24,000
<i>Cl. botulinum</i> toxin (Type C or D)	+ve / -ve	-ve

2. Project Overview and Methodology

The project involved composting trials on nine farms located in NSW, Victoria, Western Australia and Queensland, composting daily mortalities, spent hens and egg waste using a range of bulking materials including municipal green waste, straw and sawdust.

Initially, a workshop was held with participant farmers to discuss the theory of composting and practices, enabling suitable design and management of the on-farm trials. These trials are reported on as case studies in the following section.

The objective of the project was to use composting to produce a product which is microbiologically risk free for low risk applications (pasture, broadacre cropping) on farmer owned land or for sale to other farmers for similar purposes. A second objective was to develop practices that are low cost and require a low management input. Individual producers may have also had specific aims for their trials and these are described in the case studies.

The trial case studies involved a variety of composting practices including closed digesters, static piles and turned windrows allowing for comparison between a range options. The on-farm trial results have been assessed with respect to the quality of end product (see Table 6) and the cost / ease of management.

Table 6. Compost Assessment Criteria

Criteria	Assessment method	Requirement
Adequate pasteurisation (to ensure pathogen and weed seed kill)	Compliance to AS 4454	Windrows must be turned 3 times and achieve a minimum of 3 consecutive days at above 55°C after each turning. The material must be composted for at least 6 weeks.
Moisture	Laboratory	Ideal moisture 30-40%
Carbon availability and C:N ratio	Visual assessment and calculations based on laboratory results	Carbon availability based on particle size. C:N ratio determined from laboratory analysis.
Compost free from contamination	Visual assessment	Sample must be free from obvious bones and undecomposed flesh.
Nutrient content	Laboratory analysis	n/a
Pathogen assessment	Laboratory analysis	Compost samples compared with fresh manure sample to determine relative levels of pathogens (Table 5).

In order to measure these objectives, records of all trial activities were collected, and the trials were assessed during an on-farm visit. The composting process was monitored using temperature loggers which reported ambient and internal compost pile temperatures. The probe from the logger was placed 450- 500mm in the pile and at least 300mm above ground level.

Samples were collected and analysed for pathogens at the Queensland Department of Primary Industries and Fisheries, Brisbane. Fourteen different composts and a poultry faeces sample were examined for the levels of key pathogens *Campylobacter* and *Salmonella*. The levels of the standard indicator organism *Escherichia coli* were also determined. The presence or absence of *Cl. botulinum* toxins C and D was determined by an ELISA. It is noted that this ELISA did not distinguish between toxins C and D, however both toxins are of significance to cattle. As well, levels of *Clostridium perfringens* – an organism known to be commonly capable of surviving the compost process were determined. The percentage moisture content and percentage dry matter were also determined. In addition to results presented here, a comprehensive pathogen report was completed as part of the project (Chinivasagam & Runge 2008). This report is available from the Australian Egg Corporation Ltd on request.

Samples were assessed by FSA Consulting for general consistency (particle size, odour, moisture) by visual observation, and for composition and compost maturity at SGS Agritech Toowoomba, a NATA accredited laboratory.

3. Farmer Case Studies

The nine on-farm trials are reported here as case studies. The farms have been characterised as small (<35,000 hens), medium (<50,000 hens) and large (> 100,000 hens) egg farms. All farms were visited around the time the trials were initiated and in some cases during the trial. Trials were also visited to collect samples. On the first visit the data loggers were placed, the use of the digital thermometer demonstrated and the farmer's aims and compost procedures discussed. A final timeline for sampling was set irrespective of whether the composting was completed on each farm for logistical reasons associated with travelling and processing at the microbiology laboratory. Some sampling was done during the trial to test sample transport and laboratory procedures.

3.1. Case Study 1 - Farm A

Background

Farm A is a medium sized caged layer producer in regional NSW. Composting on this farm focused on daily mortalities and egg waste. The farmer's objective of the composting trial was to produce a partially composted product for reuse on his own land. The composting process aimed to safely dispose of daily mortalities and egg waste with minimal labour requirements. As the compost was to be used on the producer's own broad acre cropping land, the finished product did not need to reach a quality suitable for sale to off farm users or for use in horticulture. Sheep may graze the cropping land while lying fallow.

Table 7 shows the annual average temperatures in the vicinity of farm A, and shows the rainfall during the trial months in 2007 at a nearby weather station (BOM 2008).

Table 7. Annual average climate data for Farm A (local region)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Maximum Temperature (mean C)	31.7	31	27.9	22.7	17.8	13.8	12.9	14.8	18.4	22.5	26.6	29.9	22.5
Minimum Temperature (mean C)	16.2	16.1	13.4	9.3	6.3	4	3.1	4	6.1	8.9	11.7	14.5	9.5
Rainfall													
Mean rainfall (mm)	52.7	47.1	47.2	47	49.9	57.6	56.2	56.6	50.8	55.5	48.7	53.3	622.4

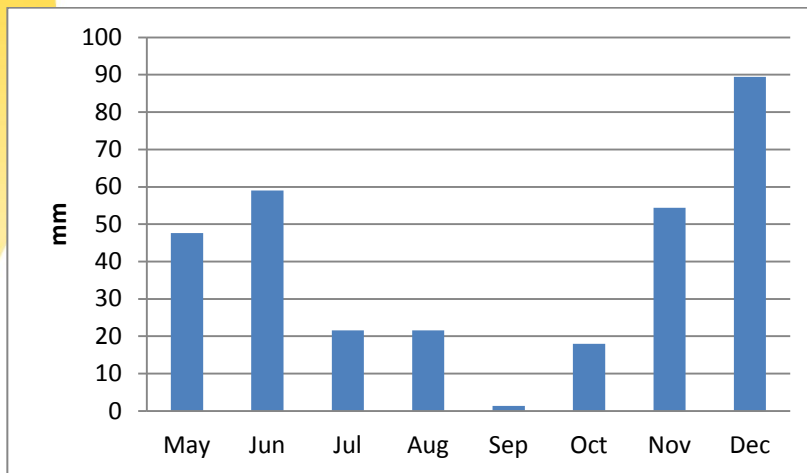


Figure 2. Monthly rainfall from May – December 2007 for Farm A

The composting test windrow was started in May and took six months, during which time the pile was turned eleven times. Composting utilised wheat straw and caged layer manure in a 1:1 ratio by bulk. The windrow was constructed by laying 200mm of caged layer manure in an outdoor pile large enough to take the dead birds for the period, followed by a layer of mortalities, then buckets of egg waste poured on top and a 200mm covering of straw and manure. Two or three layers were made this way. The windrow was then lengthened and the process repeated each time the birds and egg waste were added every few days. The windrow was closed after 10 weeks (22 July) then left to sit for five weeks and then turning commenced (27 August). On the first turn the windrow was formed into a pile and any exposed carcasses covered with manure.

Results and Discussion

The composting process was monitored using a temperature logger to record internal pile temperatures. Temperature results during the final turning phase of the trial are shown in Figure 3 below. The graph shows temperatures in excess of 60°C after each turn (the sharp drops in temperature indicate where the probe was removed for turning).

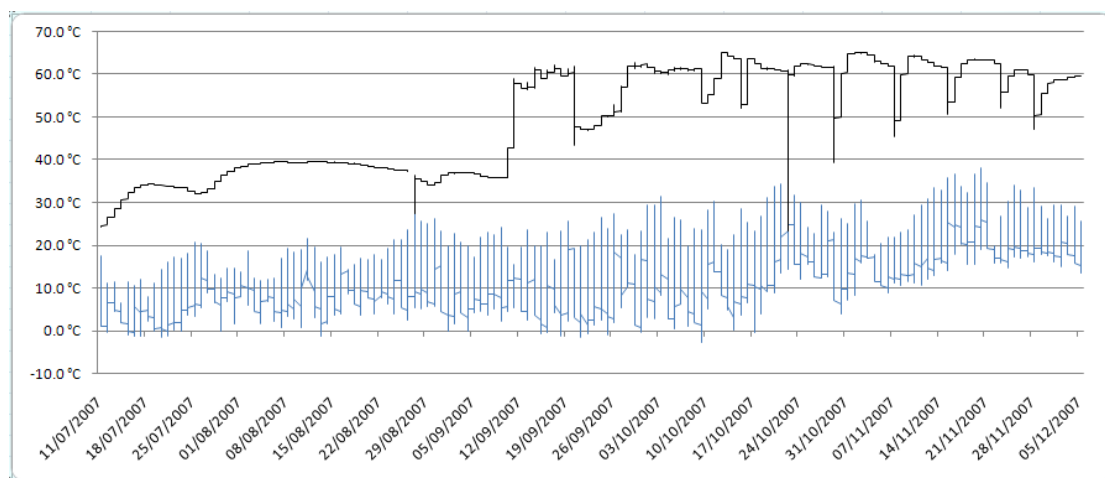


Figure 3. Temperature records for Farm A showing internal temperature within the compost pile (above) and ambient temperature (below)

Temperature records show ambient temperatures from -1 to 29°C during the compost trial. Within the windrow, temperatures ranged from 33-62°C, and exceeded 55°C for several periods of 3+ days after each turning. This meets the temperature requirements for pasteurisation specified in the composting standard AS 4454. Considering the high temperatures at the end of the recording period, it is not likely that the compost had fully reached maturity, however for the purposes of the trial this was not considered a problem. Turning was carried out at a regular interval in this trial (weekly) however the temperature records suggest that this turning interval could have been extended until temperatures began to decline in the compost pile, provided a minimum of three turning events were carried out.



Photograph 6. Outdoor compost pile at Farm A

The compost was sampled for analysis on two occasions (Sample 2 – October and Sample 7 – December). The first sample was collected mid way through the composting process after four turns had been carried out. At this time, the partially composted material had a pungent odour (primarily of ammonia) and this was largely the result of using a high proportion of layer manure in the composting mix and suggested an inadequate supply of carbon to effectively secure the nitrogen. There were a few bones and feathers present in the sample, and the moisture measured 30.6%. The composting process was not considered complete.

The second sample (Sample 7) taken after another seven turns had mild odour, and egg shell was prevalent. Moisture content was 27% and the nutrient analysis showed high levels of phosphorus (1.7%), nitrogen (1.5%) and calcium (10.8%). The sample passed the compost maturity test done at the laboratory. High phosphorus levels in the compost mix are a reflection of the high levels of manure used in the initial composting material. From the analysis results it could be seen that nitrogen declined from 4.3% at the first sampling to 1.5% at the second sampling. The C:N ratio of the mix was approximately 7.5:1 for the first sampling and 11:1 for the second sample. These C:N ratios are below the levels recommended for composting, and are the most likely cause of the high nitrogen loss over the trial. Complete laboratory analysis results for Sample 2 and Sample 7 are presented in **Error! Reference source not found.**

The two sampling periods allowed comparison of pathogen levels at different stages within the compost process. Both samples showed significantly lower levels of the indicator organism *E. coli* than the fresh manure sample. *Salmonella spp.*, *Campylobacter spp.* and *Cl. botulinum* toxin were not detected in either sample. Sample 2, collected early in the process, showed higher counts of *Clostridium spp.* compared to the later sample (pathogen results are presented in Appendix 1). Sample 7 showed the lowest results of all samples collected for all pathogens of interest, indicating the efficacy of the composting process.

Management Considerations and Conclusions

The composting process at farm A was successful in achieving the general and specific aims of the project. The trial used a high ratio of layer manure in the initial compost mix (C:N ratio of approximately 7.5:1). The high ratio of manure resulted in high phosphorus levels in the finished compost; however this also contributed to ammonia release and losses of nitrogen.

The temperature records show consistent high temperatures sufficient to kill harmful pathogens, and this was confirmed by the pathogen analysis. The temperature records suggest that turning frequency could be reduced to minimise labour input. Turning is only required when temperature within the pile begins to decline significantly, provided that the compost is turned at least three times to ensure all material has been adequately heated. As a guide, turning should be undertaken when the temperature drops below approximately 45°C.

This material would be considered safe for use in most agricultural production systems.

3.2 Case Study 2 – Farm B

Background

Case study 2 was conducted on a large, caged layer farm in regional NSW. Composting was carried out in an outdoor windrow and changed to the pile system at the first turn. Daily mortalities and egg waste were composted in this trial. The first composting trial was initiated in early July 2007 and was carried out over twelve weeks. The second trial commenced in early October and was sampled after nine weeks.

Both trials utilised feed mill waste and caged layer manure (40:60) as a substrate. The windrow was constructed by placing a layer of manure (300mm thick) on the ground large enough to take that days mortality, followed by the layer of dead birds + egg waste, then a layer of manure + mill waste. This process was repeated until there were 3 layers of carcasses and then started from the ground up again. The windrow was added to daily for a period of 2 weeks.

At the first turn the windrow was formed into a pile. Trial 1 was turned five times before the first sample was collected. The pile for trial 2 was turned twice before sample collection. Turning was continued after sampling in both trials until the farmer believed it was finished. The composting process aimed to manage daily mortalities and egg waste, which would then be sold off farm with raw manure. Table 7 and (Case Study 1) show the annual average temperatures and rainfall in the vicinity of farm B.

Results and Discussion - Trial 1

Trial 1 utilised a windrow with 3 layers of carcasses and egg waste. Temperature results from this trial show a range in ambient temperatures from -2 – 28°C, while within the piles the temperature range was 35-52°C. There were no days recorded where temperature exceeded 55°C, and temperature records show low and variable overall temperatures across the trial period (Figure 4).

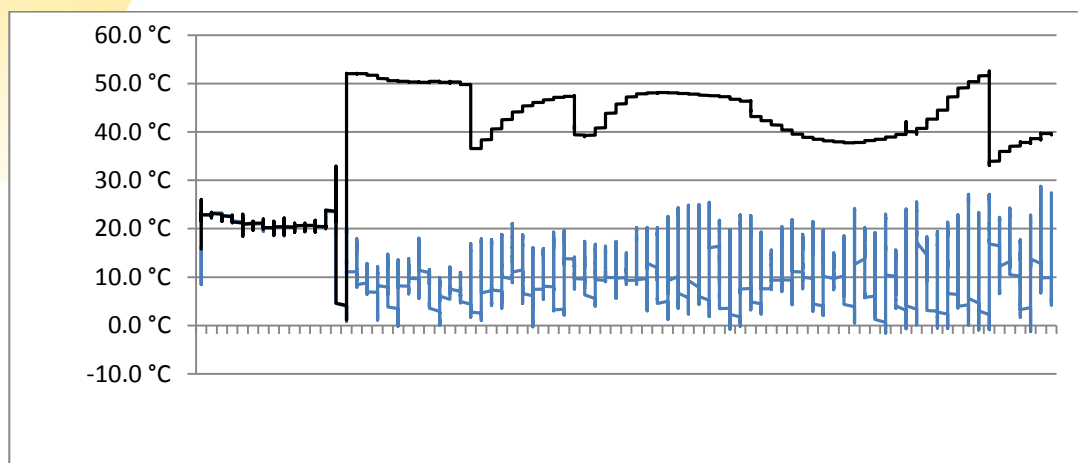


Figure 4. Temperature records for trial 1 at Farm B showing internal temperature within the compost windrow (upper) and ambient temperature (lower)

It could not be determined from these temperature records if the compost was successfully finished at the end of the trial period, and adequate temperatures to meet the AS 4454 compost standard were not met.

Trial 1 was sampled in October (sample 1), 4 days after the last turning event. At this point the compost was not considered complete, and the sample was highly odorous. Sample 1 showed low levels of pathogens compared to raw manure (positive counts for *E. coli* and *Cl. perfringens*) and no recorded *Salmonella spp.*, *Campylobacter spp.* or *Cl. botulinum* toxin was present in the sample (see Appendix 1). However considering the temperature records, adequate pasteurisation could not be assured.

The sample showed high phosphorus levels (1.8%) and relatively low nitrogen levels (1.9%). It is noted that sample 1 had a C:N ratio of approximately 9:1 which is below the ideal range for composting. This may have led to nitrogen losses from the compost, contributing to the low levels measured. Sample 1 also showed a high level of calcium (9.3%) which is the result of egg waste used in the compost. Complete laboratory analysis results are presented in **Error! Reference source not found.**



Photograph 7. Outdoor windrow used for Trial 1 at Farm B

Management Considerations and Conclusions

Trial 1 was able to achieve the goal of producing a material that was relatively safe for reuse, roughly comparable to raw manure. However the trial does not meet the compost standard 4454 with regard to heating. There were several management effects that may have led to reduced composting efficiency. It was observed that the windrows were not peaked adequately to shed rain and in addition, it was discovered that during the trial the pile was compressed using a loader bucket after turning. These factors resulted in reduced porosity and poor aeration and a lumpy consistency. This is likely to have led to the low temperatures observed. Compressing the pile will reduce oxygen supply which will suppress aerobic composting. It is also noted that heavy rain was experienced during the first 4 weeks of the trial, which may have led to some leaching of nitrogen. Considering the very low C:N ratio observed in sample 1, it is recommended that additional bulking material (preferably sawdust or chopped straw) is used to reduce the loss of nitrogen and aid porosity within the windrow.

The compost from this trial would only be suitable for sale off farm with a clear understanding that no guarantee is made regarding the pathogen levels in the material. While the pathogen results show lower levels of pathogens compared with fresh manure, the temperature records do not provide confidence to show the material has been fully pasteurised. As a precaution, the material should not be sold/used on properties where land is to be grazed because of the risk of botulism.

Results and Discussion - Trial 2

The second trial at this farm was a repeat of the first trial, with some alterations to management practices to improve composting conditions (the pile was not compressed). The trial was turned on three occasions before sampling occurred. Temperature results from this trial show a range in ambient temperatures from -3 – 38°C, while the within pile temperature range was 41-76°C, with 9 days continuously exceeding 55°C (see Figure 5). The windrow was formed into a pile on the 19 October. Prior to this the birds were being added until the 15 October. The probe was moved on the 15 October also. The sudden jump in temperature on the 19 October suggests variability in compost activity within the windrow prior to this.

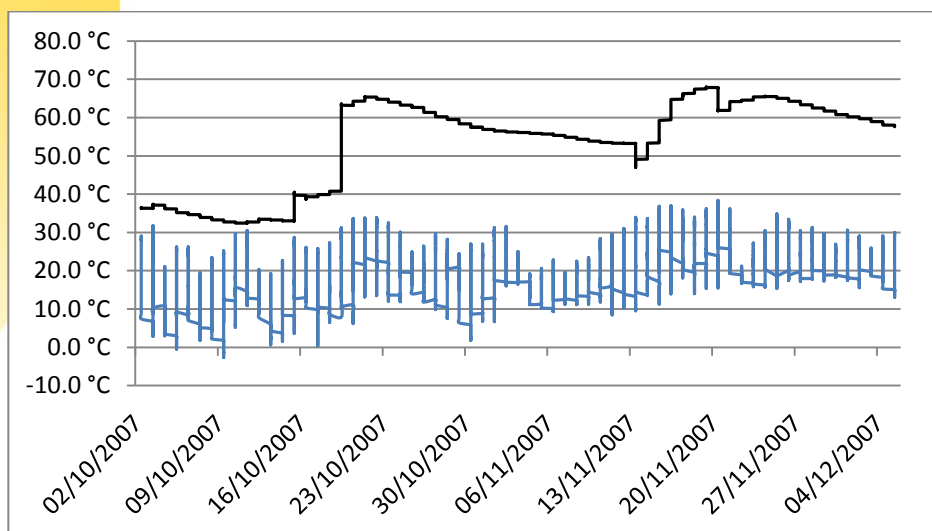


Figure 5. Temperature records for trial 2 at Farm B showing internal temperature within the compost windrow (above) and ambient temperature (below)

It can be seen from the temperature records that the compost was still reaching high temperatures at sampling, suggesting that the compost was still active at this stage. At the time of sampling, the records do not show three cycles of heating, indicating the AS 4454 requirements were not met.

The compost from trial 2 was sampled (sample 8) for pathogen and nutrient analysis in December. The sample was highly odorous and the composting process was incomplete, with obvious feathers and other material in the mixture. There were quantities of egg shell in the compost mix and moisture level was approximately 40%.

Nutrient levels within the compost sample showed moderate levels of phosphorus (1.1%), calcium (3.4%) and nitrogen (2.7%). The C:N ratio in the sample was approximately 16:1 which is in the correct range for effective composting. Complete laboratory analysis results are presented in **Error! Reference source not found.**



Photograph 8. Sample 8 showing lumpy material and undecomposed feathers

Sample 8 recorded relatively low levels of *E. coli* and *Cl. perfringens* and *Salmonella spp.* compared to the fresh manure sample (Table 5). *Campylobacter spp.* and *Cl. botulinum* toxin were not present in the sample. A full summary of pathogen results is available in Appendix 1.



Photograph 9. Outdoor windrow used for Trial 2 at Farm B

Management Considerations and Conclusions

Trial 2 was successful in managing mortalities and egg waste, providing an end product with few bones and relatively low pathogen risk, though the presence of several pathogens indicate the compost is not completely pasteurised. Further turning and maintenance of temperature records would increase the quality of the product by meeting the AS 4454 requirements. The trial produced better results than trial 1, demonstrating the importance of porosity and aeration. The process was not considered complete at the time of sampling, and it is expected the pile would continue to compost after this time resulting in fewer feathers remaining in the final product. The material is considered of similar quality to raw manure, however the presence of bones in the sample may be a concern to users. Screening the end compost and meeting the AS 4454 requirements would improve the quality of the end product.

3.2. Case Study 3 – Farm C

Background

Case Study 3 was conducted on a large caged layer farm in the Sydney basin, NSW. Composting at the facility was used to dispose of daily mortalities, egg waste and cardboard cartons, with all composted material being removed off farm for further composting at a commercial facility. The trials were initiated in July 2007 and ran for approximately nine weeks.

Table 8 shows average climate data in the vicinity of farm C, and Figure 6 shows rainfall measured at a nearby weather station during the trial period of 2007 (BOM 2008).

Table 8. Annual average climate data for Farm C (local region)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Maximum Temperature (mean C)	28.2	27.9	26.2	23.9	20.5	17.8	17.3	19	21.5	23.9	25.3	27.5	23.2
Minimum Temperature (mean C)	17.4	17.6	15.8	12.8	10.1	7.4	6.2	7.1	9.3	11.9	13.9	16.2	12.1
Rainfall													
Mean rainfall (mm)	105	124	108	85.9	73	84.2	45.7	58	53.6	68.8	86.1	70.9	962.6

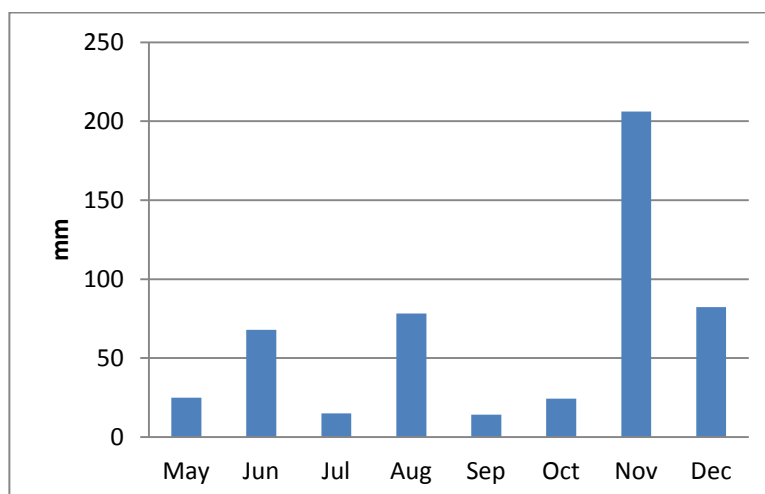


Figure 6. Monthly Rainfall from May – December 2007 in the locality of Farm C

The trial conducted on Farm C included three separate facilities owned by the same operator. These facilities had approximately 12,000, 50,000 and 100,000 birds on site. The composting trial was initiated in July and was carried out over nine weeks. All composting was carried out using the Biobin[®] system, which is a closed, aerated composting bin system. The carbon source and rate of addition varied between facilities, with both sawdust and filler flats (un-shredded) being used.

Table 9. Details of the three composting trials conducted at farm C

Facility capacity hens)	Waste material composted	Bulking material	Ratio added	Comment
12,000	Mortalities & egg waste	Shredded paper, filler flats	1:1	Compost process stalled. Needs more bulking material (sawdust) Slight odour & attracting flies
50,000	Mortalities & egg waste	Pine sawdust, filler flats	1:2	Compost process stalled. Needs more bulking material, odour & ammonia present, attracting flies
100,000	Mortalities & some egg waste	Sawdust & chopped straw	1:1	Anaerobic conditions observed. Significant odour emissions observed and attracting flies.

Composting on this farm was being used to dispose of daily mortalities and egg waste and the material was being removed off farm for further composting by a commercial composter. The Biobin[®] system is designed to operate without turning, relying on a fan system to provide oxygen and remove odorous gases. These gases are filtered before release to the atmosphere, minimising odour.

Facility 1 in this case study (12,000 bird flock) composted daily mortalities + egg waste + shredded paper. Facility 2 (50,000 bird flock) composted daily mortalities + egg waste, egg carton waste and sawdust, while facility 3 (100,000 bird flock) composted daily mortalities + egg waste (small quantities) + sawdust and chopped straw.

Results and Discussion

A data logger was placed in the bin on facility 3. The ambient temperature ranged between 0° and 31 C. Three days after the first mortalities were added the temperature in the bin started to rise. It peaked at 29°C (see Figure 7). After 17 days the temperature fell and fluctuated between 18 and 23 C until the logger was removed when the bin was full 40 days later.

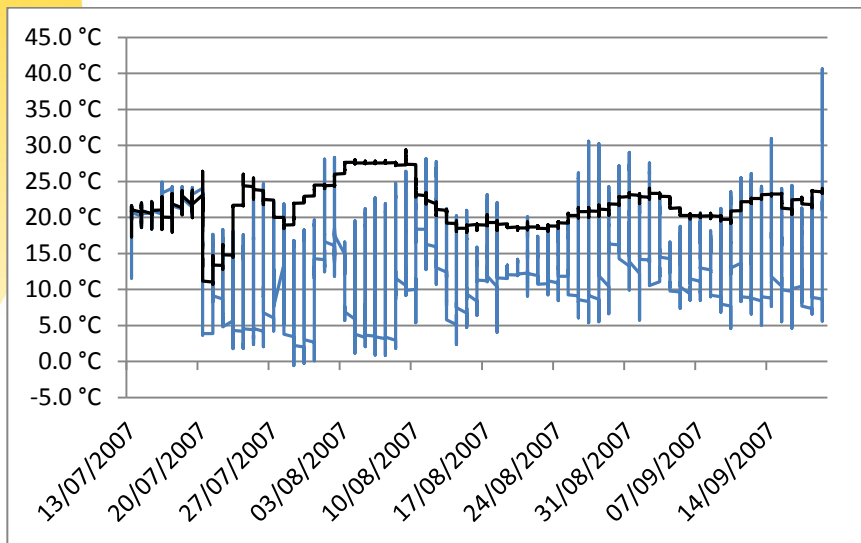


Figure 7. Temperature records for facility 3 at Farm C showing internal temperature within the compost windrow (black line) and ambient temperature (blue line)

No samples were taken of the composted material. The case study was assessed during a site visit where the efficiency of the system was observed. All farms used the same size bin to compost daily mortalities, however the loading rate for each system varied according to the flock size. The mortality rate was about 2.5 percent per annum for all flocks. The bin at facility 1 was relatively successful in disposing of daily mortalities, however the bin was not sealed completely, and some flies were present. Some composting was taking place in the bin, however the compost appeared too dry at the top of the bin and there was a mild odour.

Facility 2 had a significantly higher daily mortality loading, and it appeared the bin was not successfully handling the higher load. The bin was leaking fluid from the bottom and was not able to seal effectively to exclude flies. On opening there was a very strong odour and smell of ammonia which decreased to emitting an odour that was slightly offensive. The mortality loading for the bin at facility 3 was higher again and the bin showed signs of overloading / failure. This included high odour emissions and excess liquid from the carcasses. There were also flies present.



Photograph 10. The Biobin© Sealed Composting Unit used on Farm C

Management Considerations and Conclusions

While composting within the sealed bins was not successful at this farm, the sealed bins do offer a means for containing daily mortalities with low odour emissions in urban areas. This can help reduce biosecurity risks when the bins are operated correctly. It is believed that the sealed bin system would operate more effectively when a correct procedure and loading rate was used. According to the manufacturer's recommendation, the bins have a maximum loading rate of 20-30 birds / day. They recommend one bucket of sawdust be added along with one bucket of mortalities. However, for a desirable carbon to nitrogen ratio, the amount of sawdust should be doubled. In the trial however, it appeared that the bins were not able to handle the number of mortalities produced on farms 2 and 3. It is noted that the manufacturer's recommendations are based on meat chickens which are generally less than 7 weeks of age. It is possible that layer hens have a slower decomposition rate because they are typically much older, leading to lower maximum loading rates.

Several other management concerns were also raised with this system. Firstly, the Biobin© is expensive to purchase and requires electricity to operate. In addition to this, the Biobin© has a limited lifespan, estimated at seven years because of the mild steel construction and the corrosive nature of material they contain. For these reasons, the Biobin© may be a less cost effective option compared to some other alternatives. The Biobin© system was not run to full potential in this trial, however considering the high cost of purchase and management of this system, it is not considered a cost effective option when compared to simple outdoor pile or windrow systems.

In urban situation where neighbours are close by Biobin© offer a managed system (albeit expensive) and would be effective in disposing of mortalities without unsightliness and odours. The bins provided a means of holding the mortalities on site until full when they are removed for further composting at the manufacturers site. Because of the anaerobic conditions observed there is distinct pathogen risk with this material. For this reason, material from this case study would not be suitable for land application without further composting.

3.3. Case Study 4 – Farm D

Background

Case Study 4 was conducted on a large caged layer farm in regional Victoria, composting daily mortalities. Composting on this farm aimed to manage daily mortalities, with the end product to be used on farm or sold with raw manure. Composting was trialed in two systems: a rotary composter constructed from a concrete delivery barrel and an outdoor pile system. Trial 1 was initiated in July 2007 and ran for approximately seven weeks. Trial 2 started in August and samples were collected in December.

Table 10 shows average climate data in the vicinity, and Figure 6 shows monthly rainfall in the vicinity during the period of the trial (BOM 2008).

Table 10. Annual average climate data for Farm D (local region)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Maximum Temperature (mean C)	24.3	24.9	22.9	20.1	17.1	14.4	13.9	15	16.5	18.5	20.4	22.6	19.2
Minimum Temperature (mean C)	12.9	13.5	12	9.5	7.8	6.1	5.4	5.8	6.6	7.6	9.4	11	9
Rainfall													
Mean rainfall (mm)	35.6	31	29.8	48.3	49.5	45.7	52.9	48.6	49.5	55.2	52.4	39.3	534.2

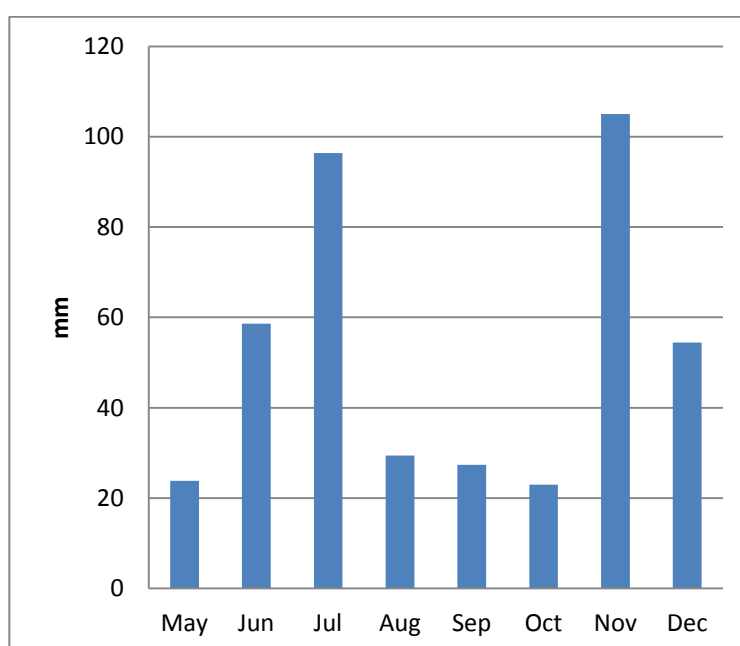


Figure 8. Monthly rainfall from May – December 2007 in the locality of Farm D

Results and Discussion - Trial 1

Trial 1 used a modified, second hand concrete barrel to function as a rotary composter (see Photograph 11). However, it became obvious that removing the compost from the barrel once the process was complete is very difficult. To empty the barrel required adding water to the composted material to form a slurry. This necessitated a second stage of composting to dry the material down prior to use. In addition to this the material tended to form into balls.

It was quite difficult to get the correct mixture in the composter. Straw was added as the carbon source in a ration of 2:1. It took two weeks to fill the barrel. The mixture was left to compost for four weeks and turned weekly before emptying. Temperatures measured with a hand held digital thermometer were 56-60°C. The farm had been trialling the barrel for six months prior to the trial, and for the reasons given earlier the rotary composter was abandoned and a window system was employed. The data logger placed in the barrel was lost and consequently no temperature records were collected during the trial.



Photograph 11. Rotary Composter Built from Cement Mixing Barrel

Results and Discussion - Trial 2

A second trial undertaken at farm D, starting in August. This trial used a windrow system to compost daily mortalities with green waste and caged layer manure. The pile was constructed in the following way; a base of manure was formed, then green waste, birds, then green waste and covered with manure. This was repeated (carcasses, green waste, manure) to give three layers of carcasses. When the windrow was completed it was then formed into a pile and turned several times. From mid-September on, egg waste was added on top of each layer of carcasses to improve the moisture content in the windrow.

Unfortunately, cattle gained access to the composting site early in the process and no useful records of temperature were collected, however manual readings taken were between 55 and 60°C.

The compost pile was sampled in December for nutrient and pathogen analysis, at which time the composting process was not considered complete. The sample had a mild odour, and contained large bones and feather shafts. These bones were quite strong and in some

cases had undecomposed flesh attached, which was infected with maggots. It appeared that there was insufficient available carbon (because of the large particle sizes) and possibly insufficient moisture within the mix to enable complete composting of the birds. The presence of maggots suggested insufficient heating and coverage of carcasses with bulking material.

Pathogen analysis for this sample (Sample 4) showed undetectable levels of *E. coli* and *Campylobacter spp.* while both *Cl. perfringens* and *Salmonella spp.* were detected. The sample tested negative for *Cl. botulinum* toxin. Further pathogen results are presented in Appendix 1. The pathogen results are relatively low compared to the fresh manure sample, however considering the lack of temperature records and the presence of flesh in the sample, the material could not be considered safe for reuse at the time of sampling.

Nutrient analysis of the sample showed low levels of phosphorus (0.1%) and nitrogen (1.3%). The C:N ratio of the sample collected was 1:32 which is high. These results reflect the high levels of green waste which is typically low in nutrients and suggest low levels of layer manure. This compost has a low nutritional value for reuse on crops and pastures and would best be used as a soil conditioner. Complete laboratory analysis results are presented in **Error! Reference source not found.**

Management Considerations and Conclusions

Composting at this farm was initially done using a concrete delivery barrel, however it was discovered that emptying the barrel once the compost process was complete was difficult and required the addition of large amounts of water to form a slurry. Following this, an outdoor windrow was trialled; however this met with a low degree of success in composting the carcasses. There are several possible reasons for this. The green waste used as a substrate for composting was very coarse, with chips up to 20mm thick and 50-75mm long. Wood chips of this size do not compost readily because of their low surface area to volume ratio. It is possible that there was insufficient *available* carbon to adequately compost the birds. In addition to this, the coarse green waste is very porous, allowing the mix to dry out excessively and allowing insects such as flies to access the carcasses. A very porous mix is not able to maintain adequate heat within the pile, leading to poor pathogen kill and the presence of insect larvae in the carcasses.

In order to improve this process, it is advised that further trials use fine grade green waste and or chopped straw or sawdust to ensure an adequate coverage of the carcasses. This will contain heat within the pile, restrict insect access, maintain moisture and provide a supply of carbon to soak up liquid and nutrients from the carcasses.

Maintaining temperature records will allow for monitoring of the process and display pasteurisation of the compost to allow confidence in the product. The compost mix may also benefit from additional layer manure to improve nutrient levels in the final compost mix, however this will depend on the intended end use for the product.

Considering the findings from the trial at the time of sampling, the material should not be sold/used on properties where land is to be grazed because of the risk of botulism.

3.4. Case Study 5 – Farm E

Background

Case Study 5 was conducted on a large layer farm with caged and free range hens in regional Victoria. The trial focussed on disposal of spent hens, in response to a lack of processing capacity in the region and the need for rapid depopulation of layer sheds. The composting process used a windrow system. The intent of the composting operation was to produce a saleable end product to broad acre cropping farmers. Two trials were conducted. The first one using 5,500 spent hens were used to test the procedure from removal from the cages, humane killing and constructing the windrows. This model was used to scale up to doing large number of hens. The second trial was done using 60,000 hens.

Table 11 shows average climate data in the vicinity, while Figure 9 shows rainfall during the trial period for 2007 (BOM 2008).

Table 11. Annual average climate data for Farm E (local region)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Maximum Temperature (mean C)	24.3	24.9	22.9	20.1	17.1	14.4	13.9	15	16.5	18.5	20.4	22.6	19.2
Minimum Temperature (mean C)	12.9	13.5	12	9.5	7.8	6.1	5.4	5.8	6.6	7.6	9.4	11	9
Rainfall													
Mean rainfall (mm)	35.6	31	29.8	48.3	49.5	45.7	52.9	48.6	49.5	55.2	52.4	39.3	534.2

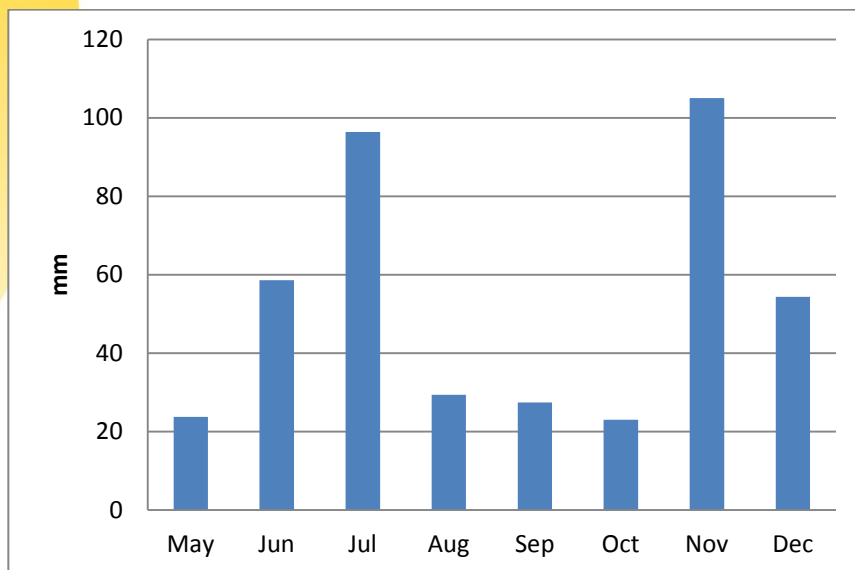


Figure 9. Monthly rainfall from May – December 2007 in the locality of Farm E

Results and Discussion - Trial 1

Trial 1 utilised a windrow to compost 5,500 spent hens, using green waste and barn litter as a carbon source. It was laid down in early June. The first layer of carcasses was placed on a layer of barn litter over green waste and bark chips, this was covered with barn litter, then a layer of carcasses, barn litter again, another layer of carcasses, then barn litter and finally the whole windrow was covered with green waste and bark chips. Some egg waste was also poured over the carcasses. The windrow was not turned during the composting process and did not achieve complete composting of the carcasses within the timeframe of the project. Heavy rain occurred after the windrow was formed.

At sampling observations of the windrow indicated that moisture content varied between wet to dry, a temperature of about 45°C and a strong odour. The failure of the compost to heat sufficiently is likely to be the result of high rainfall during this time which led to anaerobic conditions within the windrow.

The windrow in Trial 1 was sampled (Sample 6) in December and tested for pathogens and nutrient composition. At the time of sampling, the composting windrow emitted a strong manure odour, moisture content varied between wet and dry. The temperature was about 45°C and the composting process was incomplete, with obvious large bones and feather shafts in the sample. These bones were quite strong, and some undecomposed flesh was discovered attached to bones. Egg shell was prevalent in the compost mix, as were large particles of green waste material.



Photograph 12. Sample 6 showing lumpy manure and undecomposed material

Pathogen results (Sample 6) tested negative for *Salmonella spp.* and *Campylobacter spp.* and showed low levels of *E. coli*. However, the sample showed high counts of *Cl. perfringens* and measured positive for *Cl. botulinum* (type C or D) toxins which is highly toxic to cattle. Further pathogen results are presented in Appendix 1.

The nutrients analysis for Sample 6 showed low levels of phosphorus (0.4%) and nitrogen (1.5%), and the C:N ratio was ideal (21:1). This suggests the manure content in the mix was relatively low. Complete laboratory analysis results are presented in **Error! Reference source not found.**

Management Considerations and Conclusions

Trial 1 was done as a test run to compost spent hens, and the trial identified a number of problems with the system. Farm E is located in a winter dominant rainfall area, and during the trial significant rainfall was experienced. This led to anaerobic conditions within the compost windrow, poor heating and propagation of harmful bacteria including *Cl. botulinum*. The presence of this toxin makes the material unsuitable for sale and lethal to livestock. It must be noted that sampling occurred before the end of the composting cycle and subsequent composting may improve the quality of the end product. In subsequent trials it is recommended that observations are made on a weekly basis to assess the progress of the composting process. This can be done by digging into the windrow to assess heat generation and checking moisture levels using the squeeze test. The piles may be turned to reduce moisture levels or additional dry bulking material may be added. Composting at this site was also complicated by the lack of a properly compacted pad with adequate drainage, which made machinery operation difficult and led to moisture seeping into the compost. A compacted pad is essential for successful composting operations.

Considering the presence of *Cl. botulinum* toxin in this sample, extreme caution should be taken in handling the material, and access to livestock must be strictly avoided. The material is not considered safe for use from these sample results.

Results and Discussion - Trial 2

Trial 2 was started in early July, using an outdoor windrow to compost 60,000 spent hens with caged layer manure, barn litter and a bark green waste. The windrow was constructed

in the following way; firstly a layer of carcasses was placed on a layer of bark green waste, these were covered with a thin layer of bark green waste and then cage manure/barn litter. Another three layers of carcasses were added, each being covered with the same material. A final cover of the bark green waste was placed over the windrow. Heavy rain occurred whilst the windrow was formed and the birds added and continued afterwards. The final cover of bark green waste was not placed on until the area had dried out enough to allow machinery back in. The windrow was 80m long, 4m wide and 2m high. This windrow was turned twice during the composting process and achieved an incomplete degree of carcass decomposition (bones and some feathers still evident).

In the seven weeks before the first turn in late August, the ambient temperature ranged between -1 and 23°C whilst the temperature in the pile gradually decreased from a peak of 27°C shortly after the start to 21°C. Upon turning the temperature increased from 21 to 39°C in three days and then gradually rose to 52°C over 24 days whilst the ambient varied between -1 and 23°C (Figure 10). After the second turn in late September until sampling in early December the ambient temperature varied between 1 and 37°C whilst the windrow varied between 50 and 65°C. For 14 days continuously it was over 55°C (see Figure 10).

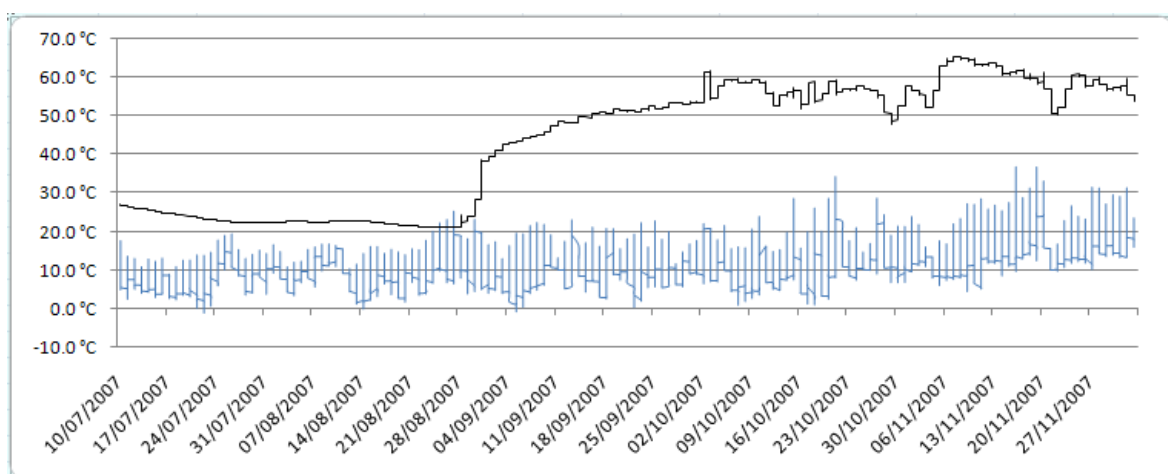


Figure 10. Temperature records for trial 2 at Farm E showing internal temperature within the compost windrow (above) and ambient temperature (below)

Temperature records show a successful heating phase, with temperatures from 50-60°C for two months without turning. The high temperatures through to the end of the composting trial period suggest that the compost had not reached maturity. Because of insufficient turning frequency, the compost does not meet the AS 4454 requirements.

The sample (Sample 5) was moderately odorous; with obvious small bones and feather shafts in the sample along with moulding lumps of manure. These bones were quite strong and this is likely to be the result of exposure to the atmosphere. The sample was quite wet (41%) and it is likely that the mix would compost further without drying by turning or adding more dry bulking material.

Pathogen results showed no detectable *Campylobacter spp.*, however relatively high levels of *Cl. perfringens* were observed as compared to other compost samples in this trial (levels are still lower than the fresh manure sample). *Salmonella spp.* was present and the sample tested negative for *Cl. botulinum* toxin. Further pathogen results are presented in Appendix 1.

Nutrient analysis of sample 5 showed relatively high levels of phosphorus (1.6%) and nitrogen (2.7%). The sample had a C:N ratio of 8.5:1 which is very low and suggests high levels of manure within the compost mix. Complete laboratory analysis results are presented in **Error! Reference source not found.**



Photograph 13. Windrow used to compost spent hens

Management Considerations and Conclusions

Trial 2 showed the possibility of composting large numbers of spent hens for rapid disposal and ease of management. The composting process showed that high temperatures can be achieved and maintained with low management input, providing a reasonable degree of pathogen kill. The composting process had not been completed at the time of sampling, as evidenced by the presence of bones and feathers within the compost and the high temperatures recorded to the point of sampling. It is likely that this pile would continue to compost provided ideal conditions were maintained. This may result in lower levels of pathogens and a more consistent product with lower moisture and few lumps. It is also essential that carcasses are adequately covered as bones will harden when exposed to the atmosphere. Ensuring adequate coverage may reduce the number of bones in the final sample. Considering that temperature records do not show sufficient heating cycles to ensure pasteurisation this material would not be considered safe to be sold or used on properties where land is to be grazed because of the risk of botulism.

With respect to management, the composting process required machinery to enable handling and turning of large volumes of material, and handling was made difficult because of wet conditions and the lack of a compacted pad. Composting of spent hens is being trialled further at this farm. The farmer reported that the total time taken to establish the compost windrow was 22 hours, while each turning took 5-6 hours.

3.5. Case Study 6 – Farm F

Background

Case Study 6 was conducted on a large caged layer farm in WA. Composting at this farm focussed on disposal of spent hens and daily mortalities in covered windrows. This system utilised wheat straw, lawn clippings, sawdust and feed mill dust as carbon sources, and

aimed produce a material that could be sold off farm with raw manure. The spent hen trial was initiated in late June 2007 and ran for approximately 14 weeks. The daily mortality trial started in late September.

Table 12 shows average climate data in the vicinity of Farm F and Figure 11 shows monthly rainfall in the vicinity during the trial period (BOM 2008).

Table 12. Annual average climate data for Farm F (local region)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Maximum Temperature (mean C)	31.6	32.5	30.9	27.6	24	20.9	19.5	20	22	24.4	27.1	29.4	25.8
Minimum Temperature (mean C)	18.3	19.1	17.9	15.4	12.9	11	9.5	8.9	9.3	10.9	13.8	16.3	13.6
Rainfall													
Mean rainfall (mm)	5.7	11.2	16.2	24	71.2	100.7	92.1	65.4	32.4	19.3	9.3	5.5	450.2

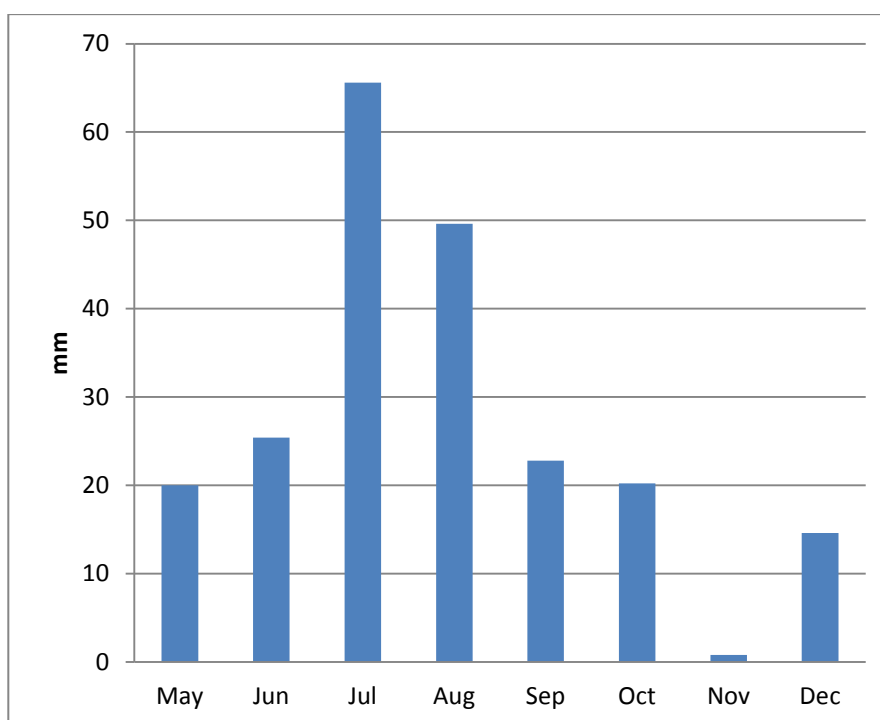


Figure 11. Monthly rainfall from May – December 2007 in the locality of Farm F

Results and Discussion – Trial 1

Trial 1 utilised an indoor windrow to compost 1200 spent hens. Two windrows formed by using rectangular straw bales. Six hundred hens were placed in each side. The hens in one bay were wet before placement in the compost. Aeration tubes were placed in one bay. There was no observable difference between bays during the turns. The windrows were turned three times during the composting process. Temperature results from this trial show a range in ambient temperatures from 8 – 31°C, while within the windrow the temperature range was 29-76°C. Temperature exceeded 55°C for 2 periods exceeding three continuous days during the composting process (see Figure 12).

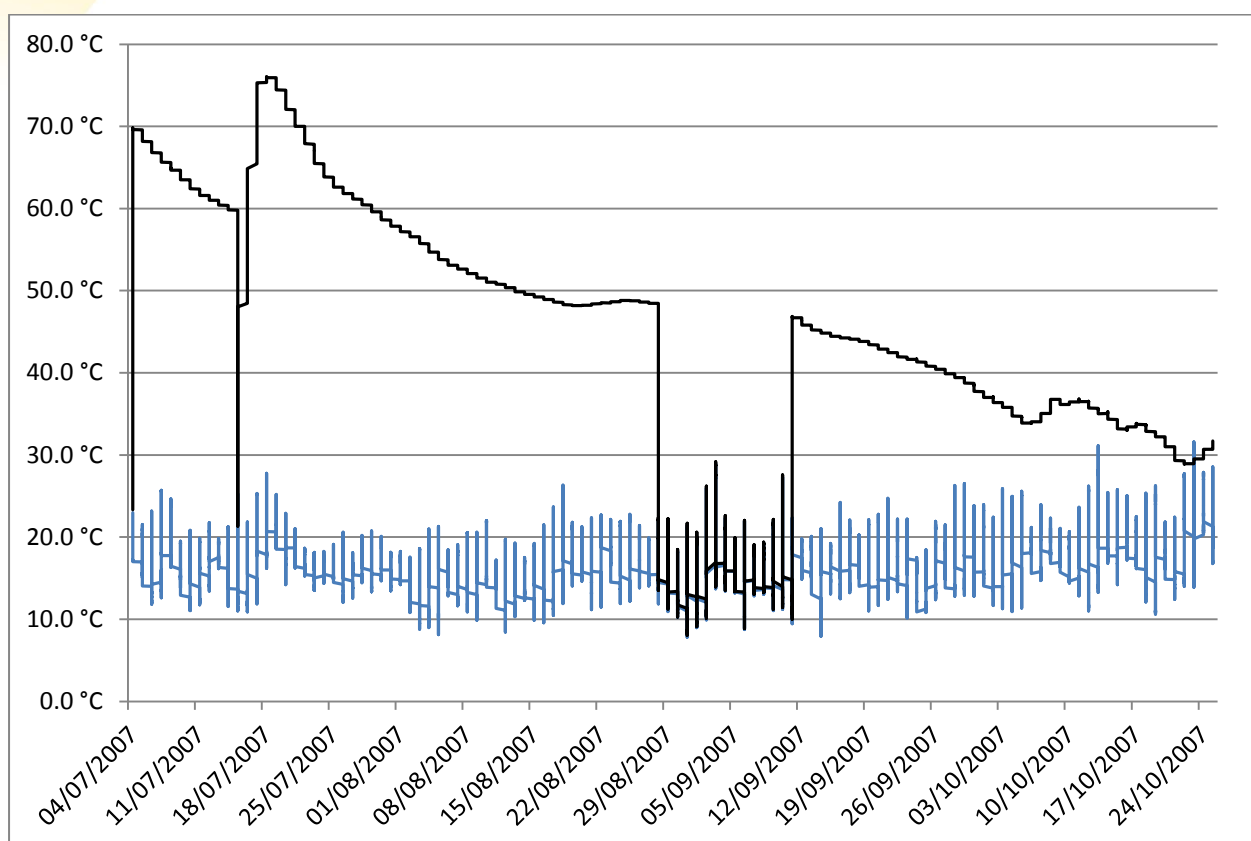


Figure 12. Temperature records for trial 1 at Farm F showing internal temperature within the compost windrow (above) and ambient temperature (below)

Figure 12 shows high temperatures initially within the compost windrow in the second bay, and a strong response to turning the windrow after two weeks. In the first two weeks of September the probe was accidentally left out of the pile. The steady decline in temperatures from mid August onwards may be the result of a lack of moisture in the windrow. These temperature records are not sufficient to ensure pasteurisation and do not meet the requirements of the AS 4454. At the end of September the composted material was removed from both bays and placed in a pile elsewhere under cover. It was sampled in December. Observations at sampling were; the compost was dry, rough in texture, low in uniformity, had moderate odour and was cool to touch.

Results and Discussion – Trial 2

Trial 2 utilised the indoor windrows bays used previously for the spent hens. The daily farm mortality was layered in one bay with lawn clippings and straw. When the bay was full (450 hens) the daily mortalities were placed in the second bay and the material in the first bay left to compost. The first bay had been down for nine weeks when sampled in December. It had been turned once.

The compost windrow was sampled in December, at which time the composting process was considered complete by the farmer. The samples from both trials were combined on the farm. However, observations at the time of sampling of Trial 2 suggest the windrow was too dry (moisture measured 21.4%) and this may have been limiting the process and leading to a lack of temperature generation and breakdown of organic matter. The sample (Sample 10) had low odour, however the composting process was not considered complete, with obvious large bones (brittle), feather shafts and undecomposed flesh in the sample. The sample suggested a very porous mix with large particles of straw bulking material which may have contributed to the low moisture and low temperatures late in the process. It appeared that there was insufficient available carbon (because of the large particle sizes) and possibly insufficient moisture within the mix to enable complete composting of the birds.

Pathogen results from the sample (Sample 10) showed low levels of *E. coli*, *Cl. perfringens*, and *Salmonella spp.* present in the sample. These pathogens were present at much lower levels than those observed in the fresh manure sample. The compost sample tested negative for *Cl. botulinum* toxin. Further pathogen results can be found in Appendix 1.

The nutrient composition for the compost sampled showed relatively high levels of phosphorus (1.6%) and calcium (10.2%). These are most likely sourced from the manure component and from the egg waste present. Nitrogen was moderate (2.6%) and the C:N ratio of the mix was relatively low (9:1). However the laboratory may have sieved out larger particles of straw, reducing the recorded carbon percentage in the mix. Complete laboratory analysis results are presented in **Error! Reference source not found.**

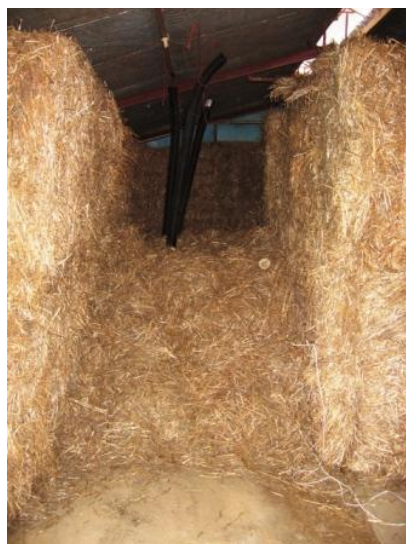
Management Considerations and Conclusions

The trials achieved an incomplete level of carcass breakdown as seen by the presence of bones, feathers and undecomposed flesh in the compost mix sampled. It is likely that the composting process was limited by the lack of small particles of carbon, as well as too little moisture. It is suggested that chopped straw be used to form a denser layer around the carcasses which will maintain heat and liquid more effectively, improving the efficacy of the carcass composting process.

Considering the presence of bones and undecomposed flesh in the sample taken, it is advised the material is re-used for further composting and is not spread where exposure to livestock is expected because of the risk of botulism. Additional turning, watering and maintenance of temperature records that show the minimum standards are met will provide greater confidence in these results in the future.



Photograph 14. Sample from Farm F showing large particle size of the carbon material



Photograph 15. Indoor composting at Farm F showing hay bales used as walls and black hosing used to aerate the windrow.

3.6. Case Study 7 – Farm G

Background

Case Study 7 was conducted on a small free range farm in regional WA, composting spent hens using a turned windrow and a static pile. The trials were initiated in late June 2007 and ran for approximately 23 weeks. This system utilised free range barn litter (25%), sawdust (50%) and hardwood timber chip waste 25% as a carbon source in both systems and aimed to provide a rapid disposal method for managing spent hens. The end product was intended for sale off farm with free range barn litter. A clay base was laid down at the composting site, however following heavy rain the base became puggy when worked on with machinery.

Climate data for the region is presented in Table 13, and Figure 13 shows rainfall during the trial period for the local region (BOM 2008).

Table 13. Annual average climate data for Farm G (local region)

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Maximum Temperature (mean C)	28.5	28.4	26.1	22.8	19.3	17.3	16.3	16.7	18.1	20.1	23.6	26.5	22
Minimum Temperature (mean C)	13.8	14	12.7	10.7	9.2	8.3	7.5	7.5	8.4	9.3	10.9	12.5	10.4
Rainfall													
Mean rainfall (mm)	9.7	10.6	20.7	41	116.2	172.3	165.6	116.8	74.5	51.3	24.3	13	812.2

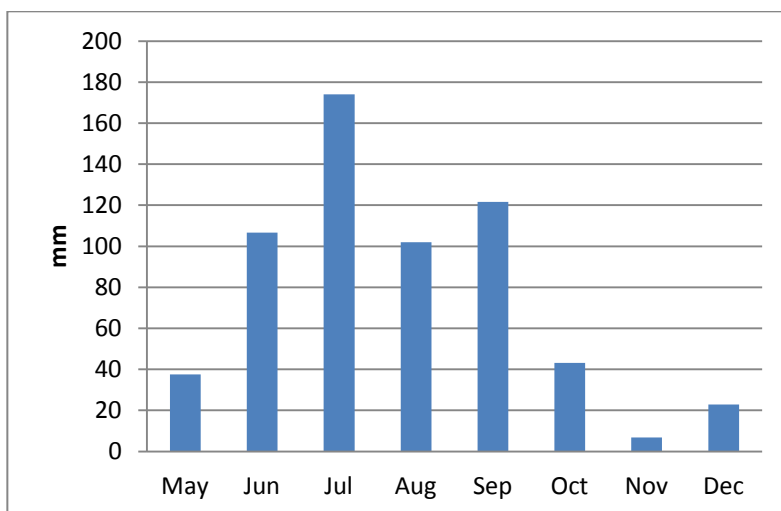


Figure 13. Monthly rainfall from May – December 2007 in the locality of Farm G

Results and Discussion - Trial 1

Trial 1 utilised an outdoor windrow to compost 3,000 spent hens. A layer of coarse woodchip, free range barn litter, sawdust mix then green waste was laid, followed by the carcasses. This was then repeated with another layer of carcasses. Finally, the windrow was covered with sawdust. Each layer of carcasses was sprayed with about 250 litres of compost tea containing aerobic bacteria. There were some concerns regarding the tea mix, as it was left over from mix made up five days earlier for another application. This windrow was turned after two weeks and again 17 days later during the composting process. It was turned again about two weeks before sampling occurred and achieved an incomplete degree of carcass decomposition at the time of sampling. Temperature records from this trial show a range in ambient temperatures from 1 – 25°C, while within the windrow the temperature range was 25-68°C. Temperature exceeded 60°C for eight continuous days during the composting process and exceeded 55 °C for 3 days during two periods (see Figure 14).

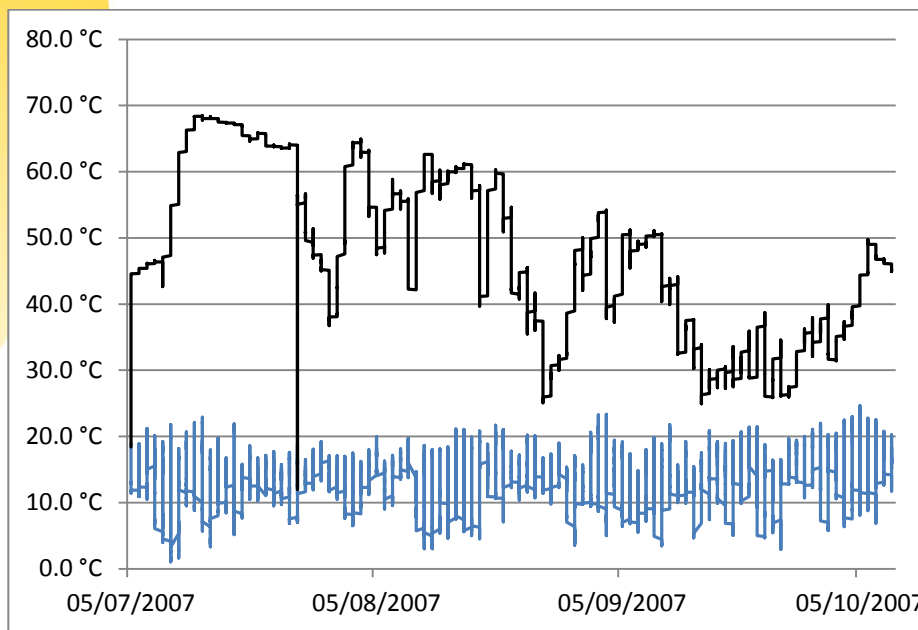


Figure 14. Temperature records for Trial 1 at Farm G showing internal temperature within the compost pile (above) and ambient temperature (below)

Error! Reference source not found. Figure 14 shows variable temperature records following an initial period of consistent heating. The pile successfully maintained high temperatures in the range of 50-60°C over a six week period, and temperatures were still relatively high at the time of sampling suggesting the compost process was not complete. The pile was turned three times, however there are no temperature records following the third turn. Because of this, the AS 4454 requirements could not be ensured from the recorded data.

Water was added (1000 L) to this windrow at each turning, however carcasses were not adequately covered after the windrow was turned and this may have led to poor decomposition of some bones and feathers.

The sample (sample 12) emitted little odour, however the composting process was clearly not complete, with many bones (mostly strong) some feathers and undecomposed flesh in the sample. Pathogen analysis of this sample showed *Salmonella spp.*, *E. coli* and *Campylobacter spp.* were all below the detection limit, while *Cl. perfringens* was at relatively low levels. *Cl. botulinum* toxin was not present in the sample. Further analysis results are presented in Appendix 1.

The nutrient analysis showed moderate levels of phosphorus (1.2%) and low levels of nitrogen (1.5%). The C:N ratio of the sample mix was 1:10 which is quite low. This may be because larger particles of wood chip were screened out of the sample at the laboratory. Complete laboratory analysis results are presented in **Error! Reference source not found.**



Photograph 16. Sample taken from the windrow at Farm G – note the large particles of carbon material

Management Considerations and Conclusions

At the time of sampling, the compost was not suitable for sale or reuse, because of the presence of bones, feathers and undecomposed flesh within the compost. This should be monitored to improve the level of breakdown within the compost prior to sale or reuse. It is likely this material would continue to compost if the right conditions were provided, and further observations will determine the success of the process. It is suggested that a higher volume of spent litter be used, that coverage of birds is maintained at all times and that temperature records be maintained and used to monitor the success of the process. Turning should be carried out when temperatures decline below approximately 45°C, and water should be added if the moisture level drops below about 40%. Ensuring the compost pile is turned a minimum of three times with adequate heating to meet the AS 4454 requirements will improve the quality of the product. As a precaution, the material should not be sold or used on properties where land is to be grazed because of the risk of botulism.

Trial 2 Results

Trial 2 utilised 1,000 spent hens in a static pile, and was supplemented with a biological compost starter formulation. A base was constructed using logs (blue gum left over from plantation harvesting) over which was placed the sawdust/wood chip mix. The carcasses were piled down the middle of the windrow and then soaked with 1,000 litres of Effective Micro-organism (EM) tea. It was then covered with half a metre of sawdust. This windrow was turned twice during the composting process and had achieved an incomplete degree of carcass decomposition at the time of sampling. Temperature results from this trial show a range in ambient temperatures ranging from 1 – 28°C, while within the windrow the temperature range was 40-53°C (see Figure 15). The farmer had understood that the EM tea was a selection of anaerobic micro organisms that will compost at low temperatures under anaerobic conditions. Later he discovered that the EM does not break down the organic matter but preserves it and was designed to reduce odour, however after 3 months odour levels began to increase. Once he discovered the error he decided to turn the pile so that it would break down aerobically. The farmer chose to try the anaerobic process because no turning is needed for 6 to 12 months. The compost was not considered

complete by the farmer at the time of sampling as the pile was still heating where sufficient moisture was present.

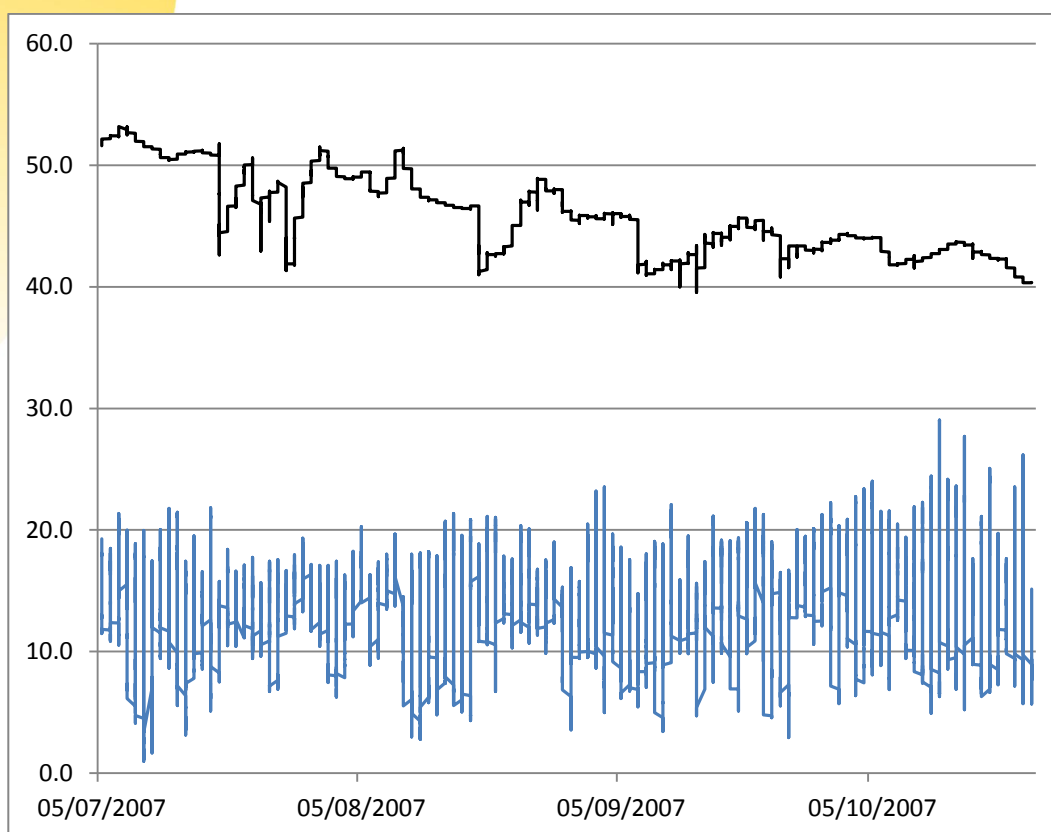


Figure 15. Temperature records for Trial 2 at Farm G showing internal temperature within the compost pile (above) and ambient temperature (below)

The sample collected from Trial 2 (Sample 11) emitted little odour, however the composting process was clearly not complete, with many bones (some brittle) some feathers and undecomposed flesh in the sample. Pathogen analysis showed low counts of *E. coli* and *Campylobacter spp.*, and *Salmonella spp.* levels were below detection limit. *Cl. perfringens* was present and the sample tested negative for *Cl. botulinum* toxin. For further results see Appendix 1.

The nutrient analysis for sample 11 showed moderate levels of phosphorus (0.56%) and low levels of nitrogen (1.6%), however there were relatively high levels of calcium present in the sample (6%). The C:N ratio for the sample collected was approximately 12:1 which is relatively low. This is likely to be because the woodchips were sieved and not included in the analysis. Complete laboratory analysis results are presented in **Error! Reference source not found.**



Photograph 17. Compost sample from Trial 2 at farm G showing large particle size of the carbon material and bones

Management Considerations and Conclusions

The compost in Trial 2 had not been fully composted during the trial period, and the sampled material was not considered fit for sale as in trial 1. The compost pile failed to heat adequately during the monitored phase, raising concerns over the ability of the compost to pasteurise the material. While the pathogen results were positive, it cannot be guaranteed that populations of bacteria would not increase following the end of composting process.

Other observed problems included the use of coarse wood chips within the compost mix. These woodchips are not likely to take part in the composting process as they have a very high surface area to volume ratio. For this reason there was relatively little carbon available to co-compost with the spent hens and this is likely to have limited the process.

Trials 1 and 2 provide a useful starting point for composting on this farm, further work should focus on developing appropriate procedures for developing the compost mix (ensuring adequate carbon supply) turning, watering and monitoring of the process using temperature records. As a precaution, the material should not be used or sold to properties where land is to be grazed because of the risk of botulism.

3.7. Case Study 8 – Farm H

Background

Case Study 8 was conducted on a large, caged and free range egg farm in regional Queensland. Composting on this farm started with tumblers and windrow system and then changed to a windrow system. The system aimed to dispose of daily mortalities, with the end product intended for sale off farm with raw manure. The trial commenced in May 2007.

Regional climate data for the locality of farm H are presented in Table 14. Annual average climate data for Farm H (local region) and rainfall during the trial period is shown in (BOM 2008).

Table 14. Annual average climate data for Farm H (local region)

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Maximum Temperature (mean C)	27.6	26.6	25.5	22.9	19.6	16.9	16.3	17.9	20.9	23.7	26	27.5	22.6
Minimum Temperature (mean C)	16.7	16.6	15.4	12.3	9.1	6.3	5.3	6	8.5	11.5	13.8	15.7	11.4
Rainfall													
Mean rainfall (mm)	132.1	121.1	94.6	61.9	58.4	56.8	52	39.5	46.7	72.2	89.5	120	944

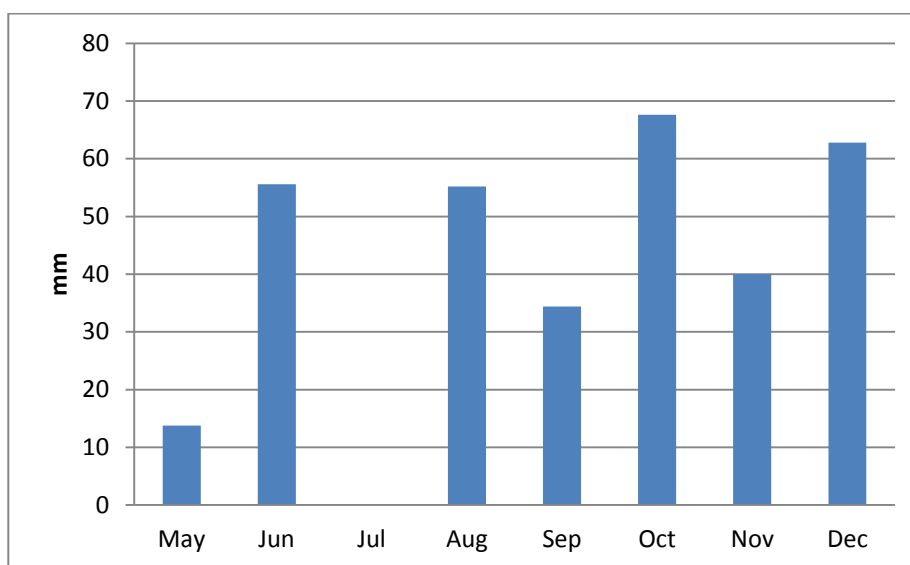


Figure 16. Monthly rainfall from May – December 2007 in the locality of Farm H

Results and Discussion

Composting at this farm utilised a tumbler for initial composting (28 days) after which the material was placed into a windrow to complete the process. There were four tumblers. Each was filled in seven days with carcasses and wood shavings in a ratio of 1:1 and then left to compost for three weeks. The tumbler was then emptied and the partly composted material placed in a windrow on a bed of barn litter and covered with barn litter. In the tumblers it was observed that the composting material was forming into balls, reducing the efficacy of the process. In order to rectify this, the carbon material was changed to barn litter and the ratio of carcasses to litter decreased to 1:2.

Difficulties were also experienced in trying to maintain cover over the carcasses within the tumbler. This was because on turning, the vanes in the tumbler separated the carcasses from the litter leaving the carcasses on top. In addition to this, filling the tumblers was difficult because both carcasses and litter had to be bagged and carried up a ladder to reach the tumblers. Because of these difficulties in management, composting with the tumblers was terminated during the trial and the use of an elevator to carry the material to the tumbler is being investigated. Unfortunately, the tumbler instrumented to collect temperature data malfunctioned during the trial, and consequently no temperature records were obtained. Manual readings taken by the operator showed that the temperature did not reach 60°C. Temperatures were lower during winter.

The partially composted material from the tumblers was finished off by composting in a windrow. The birds were covered with layers of free range barn shed litter. The windrow was sampled during the site visit in October and the sample was analysed for pathogens and nutrient composition. The windrow had been composting for about eight weeks and had not been turned. The compost was not considered complete at the time of sampling. No temperature records were collected for the windrow.

The sample (Sample 3) had a mild odour, and contained particles of sawdust that were obviously not composted, suggesting the carbon supply was in excess. There were obvious large bones and feather shafts in the sample; however the bones were relatively brittle.

The pathogen analysis (Sample 3) tested negative for *Salmonella spp.* and *Campylobacter spp.* however *E. coli* and *Cl. perfringens* were both present. These levels were not high compared to fresh manure. No *Cl. botulinum* toxin was present in the sample. For further results see Appendix 1.

The nutrient analyses for sample three showed moderate to low levels of nitrogen (1.1%) and phosphorus (0.5%). The carbon in the sample measured 10.9% which was lower than expected considering the sample composition, and the C:N ratio for this sample was 1:10 which was considered low. Considering the amount of free range barn litter used in the compost mix it is not known why the carbon levels in the sample were so low. Complete laboratory analysis results are presented in **Error! Reference source not found.**



Photograph 18. Sample 3 showing undecomposed bones

Management Considerations and Conclusions

The tumbler and windrow composting at Farm H appeared to be successful in composting carcasses and producing a product that can be sold with raw manure, however considering the presence of bones within the product screening would be required. As a precaution, the material should not be sold to properties where land is to be grazed because of the risk of botulism.

The tumbler used at farm H showed mixed success in composting carcasses. Problems encountered include the ability to maintain carcass coverage within the tumblers and general handling (loading) of the equipment. During the trial the carbon source was changed from shavings to barn litter. As the farm has an adequate supply of barn litter mortalities are now being composted using this material.

The trials on this farm were successful as a learning exercise. The composting system is currently using windrows because it is quicker, requires less labour and is easier to manage; however the option to use the tumblers again is still available, provided some solutions can be discovered to the problems observed. The number of carcasses that the tumbler can handle per day was also a concern.

3.8. Case Study 9 – Farm I

Background

Case Study 9 was conducted on a small caged layer farm in regional Queensland, composting daily mortalities, spent hens and egg waste in a small bins and open piles. The farm had been trialling composting with success prior to becoming involved in the project. Three trials were conducted and these were initiated in August 2007. The compost mix utilised green waste as a carbon source, and composted material was recycled within the composting system. The aim of the trial was to develop a process for disposing of mortalities, spent hens and egg waste and providing an end material for reuse on the farmer's own land.

Regional climate data for the locality of Farm I are presented in Table 15 and rainfall during the trial (for the locality of farm I) is presented in Figure 17 (BOM 2008).

Table 15. Annual average climate data for Farm I (local region)

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Temperature													
Maximum Temperature (mean C)	30.1	29.6	28.6	26.7	24.2	21.9	21.2	22.5	25.2	27.5	29.2	30	26.4
Minimum Temperature (mean C)	23.5	23.3	22.3	20.2	17.2	14	12.8	14	16.6	19.7	21.7	22.9	19
Rainfall													
Mean rainfall (mm)	278.1	319.8	250.7	146.5	109.3	65.2	38.6	31.5	16.6	37.2	89.9	180	1573.7

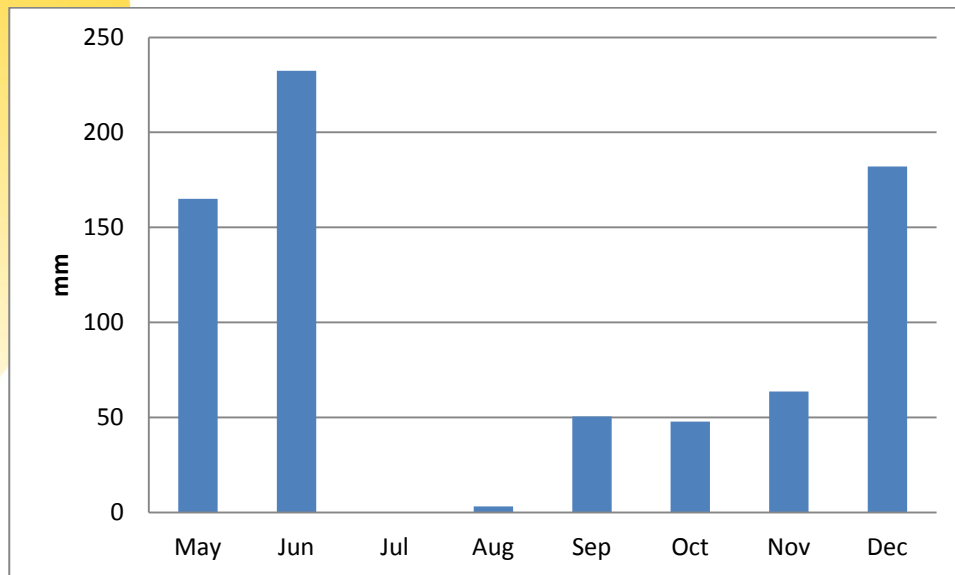


Figure 17. Monthly rainfall from May – December 2007 in the locality of Farm I

Results and Discussion Trial 1

Composting in Trial 1 used small bins (200 litre drums) to compost everyday mortalities. This was carried out near the layer sheds for easy access, and utilised green waste as a carbon source. Mortalities were placed in the bins on a daily basis. A base layer of 300mm of green waste was laid in the bottom of the bin, then carcasses which were covered with another 300mm layer of green waste. This was repeated twice more. After each layer of green waste was placed over the carcasses it was watered. When filled, the bin was left to compost for six weeks. The compost was not turned during the initial composting phase. After this point the material was added to an outdoor pile for further composting.

Temperature records from this trial show an ambient temperature range of 9-36°C, and temperatures within the bins of 52-64°C. The compost achieved temperatures above 55°C for over 14 consecutive days before the probe was damaged (see Figure 18).

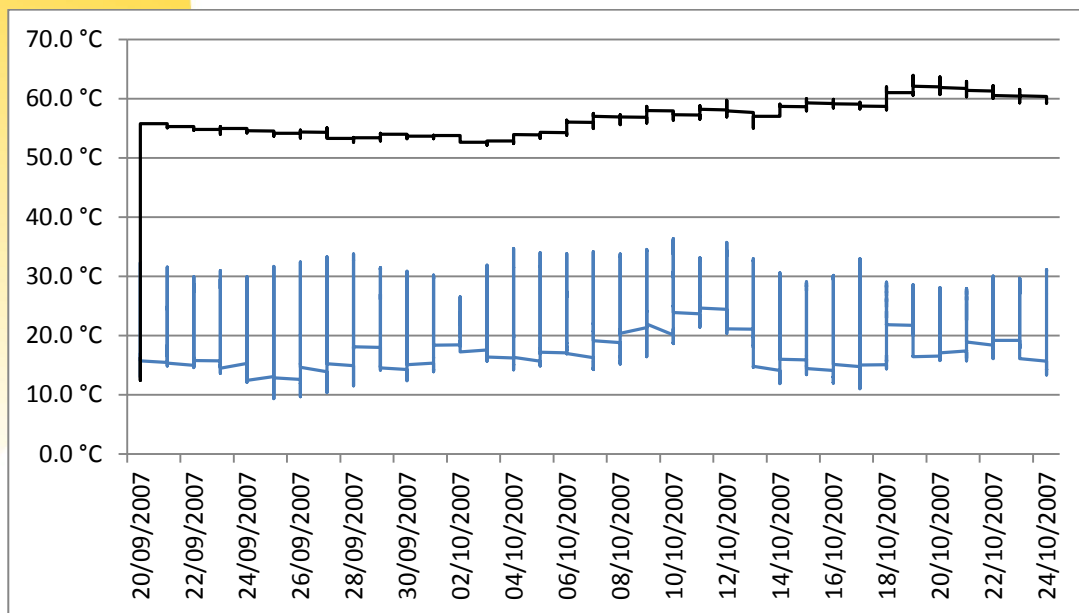


Figure 18. Temperature records for Trial 1 at Farm I showing internal temperature within the compost bin (above) and ambient temperature (below)

It can be seen from the initial temperature that composting was already taking place when the probe was inserted into the composting material, from which point the temperature rose to above 60°C. The probe was damaged on the 24 October, explaining the lack of results for the compost after this time. No sample was collected from this trial, however these temperature results suggest that effective composting was occurring during the time that temperature records were obtained. Considering the bins are not turned, compliance with AS 4454 would require further composting after the bins are emptied to ensure pasteurisation.

Results and Discussion – Trial 2

Trial 2 was established to compost egg waste using partially composted material from other composting trials. The egg waste was poured over 300mm of the partially composted material. The composting was carried out in an outdoor pile system, and was initiated in September 2007. The egg waste is stored in buckets in a cool room until there is sufficient quantity to compost. Three layers of egg waste were added at intervals of 3 to 4 weeks, the last being added at the start of December. Figure 19 shows the temperatures recorded during this trial.

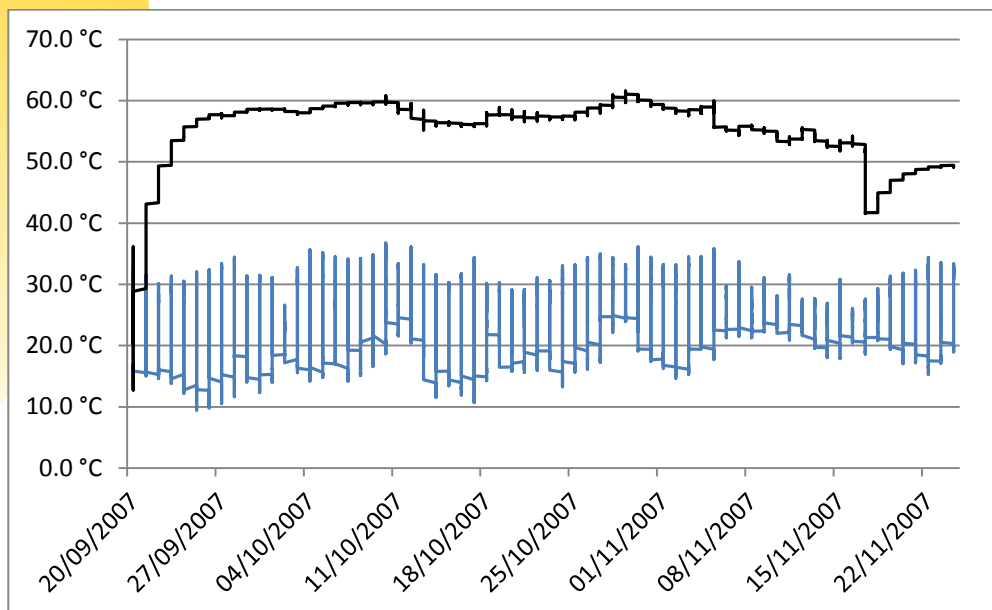


Figure 19. Temperature records for Trial 2 at Farm I showing internal temperature within the compost bin (above) and ambient temperature (below)

Temperature records cease in November when the logger ran out of memory. In mid November there was a significant fall in temperature when the third layer of waste was added to the pile. The temperature in this pile exceeded 55°C for a significant period of time, however the pile was not turned enough times to ensure the whole pile was successfully pasteurised.

The compost in Trial 2 was sampled (Sample 15) in early January, approximately 35 days after the last egg waste was added. Sample 15 was very odorous at the time of sampling and had not completed the composting process. The sample contained egg shell and undecomposed egg waste. The sample contained green waste material and had previously been used for composting spent hens.

The pathogen analysis for sample 15 did not detect *E. coli* or *Campylobacter spp.*, however the sample tested positive for *Salmonella spp.* and *Cl. perfringens*. The sample tested negative for *Cl. botulinum* toxin. Further pathogen results are presented in Appendix 1.

Nutrient analysis for sample 15 showed very high levels of phosphorus (2.54%) which is higher than typical caged layer manure. Nitrogen measured 2%, which is moderate, and the C:N ratio was 1:24 which is ideal provided adequate carbon is present in an available form. Complete laboratory analysis results are presented in **Error! Reference source not found.**

Management Considerations and Conclusions

The composting process in trial 2 was not complete at the time of sampling, and it is likely the process would continue provided the correct conditions are maintained. Further composting would be required to decompose the egg waste present and reduce moisture levels before reuse. The high phosphorus levels in this compost material will provide a valuable resource for use on crops or pastures provided a safe product can be produced.

Previously the farmer had used green waste as the carbon source for composting egg waste, however in this trial partially composted material from spent hen composting was used to assess this material during a second composting phase. According to the farmer, this did not compost as well as earlier trials with green waste. It was decided that new green waste should be used for future composting, as it absorbs more of the egg waste and gives better results. The farmer also commented that a coarse material is best for composting egg waste, as the liquid egg can move into the material without sealing. Sawdust or partially composted material tends to seal and not let the liquid egg into it, leaving a mass of undecomposed egg and shell.

Temperatures achieved within the pile were not adequate to ensure pasteurisation of the compost. As a precaution, the material should not be sold to properties where land is to be grazed because of the risk of botulism.

Results and Discussion – Trial 3

Trial 3 conducted on this property aimed to utilise composting for the disposal of spent hens, using green waste and compost from other trials as a bulking material. Two sub trials with 3000 hens in each were constructed, one in mid September and the second in late October 2007. The composting process was maintained until sampling in early January 2008. The first pile was turned twice and the second pile turned once.

The composting process in trial 3 (September pile) was successful in developing sufficient temperatures (above 55°C) as can be seen in Figure 20.

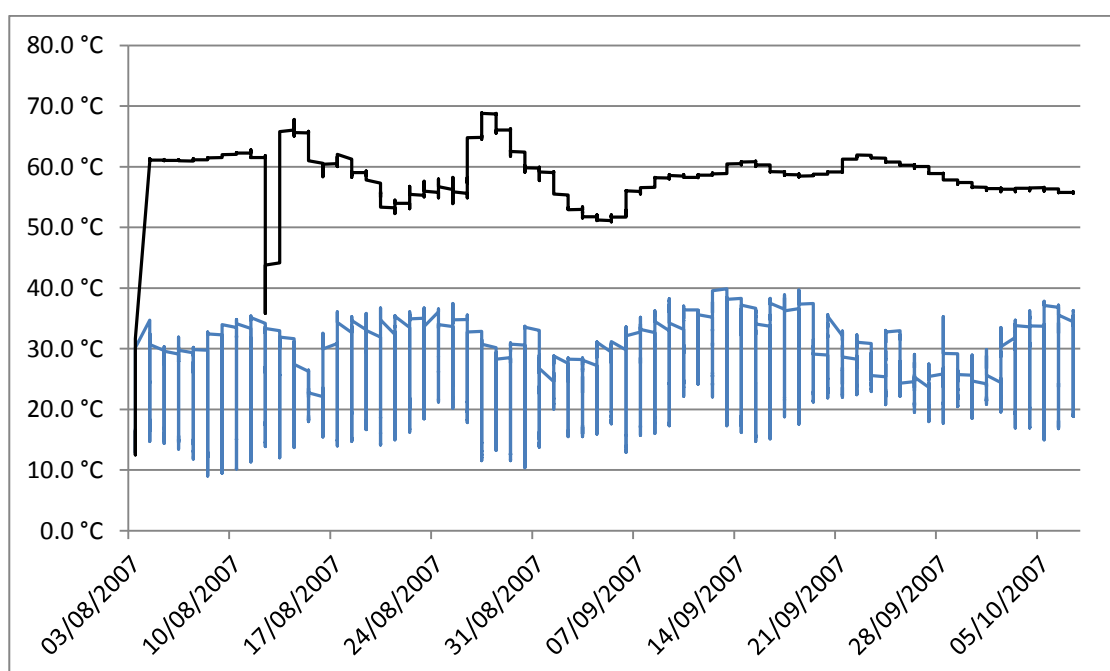


Figure 20. Temperature records for Trial 3 at Farm I showing internal temperature within the compost pile (above) and ambient temperature (below)

Records were maintained through to November when the logger ran out of memory. Temperatures of above 55°C were maintained for several periods greater than 3 days,

however the pile was not turned often enough to meet the compost standard. The pile was turned on the 29 September as seen on the graph.

The compost piles were sampled (Sample 13, second pile and Sample 14, first pile) in early January, at which time the composting process was incomplete. Observations at the time of sampling suggest that the compost mix had dried considerably (23-24% moisture at time of sampling). The samples contained some bones, however these were mostly weak.

Pathogen testing for samples 13 and 14 did not detect *E. coli*, *Salmonella spp.* or *Campylobacter spp.* in the sample, however both samples tested positive for *Cl. Perfringens*. The samples tested negative for *Cl. botulinum* toxin. Further pathogen results are presented in Appendix 1.

Nutrient analysis showed moderate levels of phosphorus (1.4-1.7%) and moderate levels of nitrogen (2.3%). The C:N ratio was 19:1 which is ideal provided the carbon is physically available for composting. Complete laboratory analysis results are presented in **Error! Reference source not found.**

Management Considerations and Conclusions

Spent hen composting in this trial was considered successful in producing adequate decomposition of carcasses and low levels of pathogens within the sample. Temperature records showed consistently high temperatures, however without adequate turning it cannot be assumed that all material was pasteurised. The compost material has moderate to high levels of nitrogen and phosphorus and will be a valuable resource provided it can be considered safe. As a precaution, the compost should not be spread on areas where direct access to livestock will occur because of the risk of botulism.

Overall Conclusions for Farm I

Composting on Farm I was successful as a means of disposing of daily mortalities, egg waste and spent hens. Although samples were collected prior to completion of the composting process, temperature records and pathogen analyses indicate the samples were pasteurised, though without additional turning and temperature records the compost cannot meet the AS 4454 standard, and a final assessment could not be made until the composting process was complete. Management practices at this property should focus on supplying sufficient turning and watering to maintain ideal composting conditions through to completion of the process.

4. Workshop Outcomes

4.1. Participants and Content

A final workshop for the project was held at the Novotel - Brighton Beach (Sydney). The workshop was attended by:

- David Witcombe – Australian Egg Corporation Limited.
- Heather Palmer - Australian Egg Corporation Limited
- Geof Runge – Poultry Cooperative Research Centre
- Eugene McGahan – FSA Consulting
- Chis Holland and Jim Curry – Koolpari Enterprises
- Brett Langfield and Joe Downton - LPC Trading
- Peter Bell - AAA Egg Company Pty Ltd (representing two other participants)

A number of participants from the project were not able to attend the final workshop due to staff issues and the fact that a number of companies are constructing new facilities. The agenda for the workshop was:

1. Welcome and Introduction - Geof Runge
2. Overview of the composting project, what happened - Geof Runge
3. Revision on the principles of composting - Eugene McGahan
4. Discussion using summary sheets of what each farm did and results - Geof and Eugene
5. Sum up the farm results - Eugene McGahan
6. Guidelines for producing a safe product using on farm composting - Eugene McGahan
7. Discussion based on participant perspective on project - Geof Runge

4.2. Conclusions – the farmer perspective

A number of questions were posed to participants during the workshop and in follow-up interviews. A summary of this feedback is included below:

What did you achieve and what did you learn from trying composting on your farm?

1. Using the information provided in the initial workshop and follow-up visits we were able to successfully compost birds.
2. We managed to significantly reduce the time to complete composting from 6 months initially down to about 2 months.
3. Now able to manipulate the system to make it go faster or slower as required.
4. Learnt that we could easily leave the pile not composting and get it to start-up again when time permitted by ensuring air and moisture were correct.
5. Found that it really took at least two good heating periods to get the carcasses to compost properly.
6. Project has focussed attention on what needed fixing.
7. Project has shown that you can relatively easily compost daily mortalities and all spent hens.

8. Able to solve a previous feral cat problem on-farm. As long as 300 mm substrate added then cats no longer a problem. Once had a feral cat problem on-farm with burial.
9. With composting now doing a job quicker and better than before.
10. Needed to be able to get rid of mortalities quickly – this is now achieved. Also once burnt mill waste – which was a problem – this is now composted. Farm has implemented a complete recycling process that has significantly reduced the volume of general waste to landfill.
11. Once bones were exposed to the sun, they would not be able to be composted – wouldn't break-down.
12. Bale fillers were trialled – these didn't really work – wouldn't break-down.
13. Have come up with a good system for the farm and do not know how they would be able to dispose of mortalities more cheaply than the process they now have.
14. Believe that there would be a biosecurity risk if they tried to compost all spent hens on-farm.
15. I trialled two different types of composting style with reasonable success which has stimulated other ideas and refinements.
16. Produced a useable farm soil amendment and eliminated a waste disposal problem in a manner compliant with EMS.
17. Better management of labour and machinery, monitoring and correct timing of turning the compost will result in a much better compost.
18. The piles need more frequent turning because of dry patches and unevenness in initial pile.
19. Have been composting for two years - need to maintain motivation to stay focused on outcomes and must put time into it. Other demands on labour at times on the farm make it difficult to maintain a regular process. Composting has the benefit that if you do not have time to turn it will sit and then pick up again when turned.
20. Have overused carbon source at times through recycling.
21. Must have the right facilities; compacted site and equipment.
22. Developed an alternative disposal method for spent hens.
23. Composting spent hens is not as easy as I thought; required more work and time and did not anticipate the weather issues. It is still the best alternative to previous disposal method.
24. Able to double the value of manure by composting spent hens which covers the cost of the extra labour and shortens the shed downtime between batches of hens.
25. The need to improve the system that we are using. Project made us think about and evaluate what we were doing. We learnt more, discovered the weaknesses in our system and where we could improve.
26. Made us and management aware of problems with the system that we were using and looked at what we were doing. From this we developed a integrated collection and composting process (windrow/pile) for the whole farm that composts daily mortalities, shed dust and egg waste, eliminated plastic bags for collecting mortalities in, reduced environmental issues and labour costs.

Did you achieve your goals?

All participants believed they were able to achieve the goals they set out with at the start of the project.

How will you improve the composting procedure to make it work better?

All participants believed they this had occurred throughout the project where they were able to learn from trial and error. What helped most when things went wrong was going back to the principles of correct moisture content and oxygen and then see what was happening with temperature monitoring.

We will invest in a decent temperature probe.

How do we make the best use of labour?

This has come about from trial and error during the project.

Will you continue composting - why?

All participants believed they would continue composting because it was the best method environmentally and reduced biosecurity risks. Participants also believed it was the most economic method of disposal for their enterprises. One is now starting to compost daily mortality also and another have now developed a process that will work for them.

What will composting mean to your business in the future?

There has been a large cost saving with composting spent hens. Now a shed can be cleaned in two days, instead of 3 weeks and thus reducing the down-time on a shed – this can save a significant amount of money.

We will continue composting for economic and environmental reasons. A good end product can be used on farm to grow better pasture and fruit trees.

It provides an economic and environmentally acceptable means of disposing of birds and egg waste.

Could we have done things better?

Perhaps some more initial input to participants of work that has been done would have elevated the level of results. Whilst there were examples of some of the work that other Australian farmers have done, there is a lot more information available.

A more robust temperature probe with a 1m steel shaft would have made monitoring the pile temperature for the operator a lot easier.

Glad to have been involved, even though we had a number of major setbacks during our trial. I would be happy to continue to be involved if there are future composting trials.

5. General Results and Discussion

5.1. Practical Management of Composting Systems

Composting of carcasses and other wastes produced on egg farms is a relatively simple process provided the correct materials for composting are available and a set procedure is observed. Composting is a forgiving process, allowing farmers to carry out successful composting under difficult conditions with long periods of low management. While composting of hens and egg waste can be carried out under ideal conditions in 12 weeks or less, all trials in this project were carried out over longer time periods than this. In keeping with the goals of the project, composting needs to be a minimum input method for waste management on an egg farm. However, it was observed in the project that some 'time saving' practices actually led to the process needing to be redone at a later stage using considerable time. In general, the following conclusions can be drawn from the project trials:

- Materials including egg waste, daily mortalities and spent hens (up to 70,000 per batch) can be successfully composted.
- Composting in sealed bins or tumblers is more difficult to manage and generally more expensive than windrow composting.
- Selection of the correct bulking material is highly important for successful composting – it is recommended that sawdust be used for initial trials to ensure good results before experimenting with other substrates.
- Avoid using straight manure as the base layer in a pile or windrow for carcass composting, instead blend it with a high carbon and absorbent bulking agent.
- Where green waste is used, finer grades are required to ensure adequate supplies of carbon.
- Where straw is used, high amounts of air movement resulted in dry compost and insufficient breakdown of carcasses. It is recommended that straw is chaffed or alternate materials such as sawdust are blended into the mix.
- Correct design of outdoor compost pads is necessary to allow composting when rainfall is experienced. This needs to include a compacted pad for machinery operation and drainage control as a minimum.
- Carcasses in windrows need to be covered with adequate amounts of bulking material (300mm) to avoid problems with vermin.
- After turning, carcass compost windrows need to be re-covered to ensure all carcass material and bones are covered to ensure composting. (Particularly for the first two turns)
- Properly composted carcasses can provide a valuable nutrient source, particularly where manure has been added to the composting mix.

5.2. Composition of the End Product

As seen for the individual case studies, the composition of the finished compost is highly variable depending on the initial materials used. The composting process can break down carbonaceous organic materials into a fine, humus like product, however this generally depends on the particle size and type of initial materials used and the degree of composting. In addition to this, compost is generally screened after completion to remove any large, resistant particles or non carbon contaminants. Within this project, the goal of

composting was to provide a low input management practice for safe disposal of wastes. In many cases a 'low grade' compost was the result. This was evidenced by large particles of green waste or straw, some bones and in some cases undecomposed mortality. This showed that some of the composting processes were not complete and the material would not be considered appropriate for spreading or sale. This material could be used for further composting processes on farm however. Where the goal is to produce quality compost for sale, there needs to be a more carefully managed composting process with turning, addition of water, mechanical breakdown of large carbon material particles and screening of the end product. This would greatly increase the quality of the end product. However, for small quantities of compost (less than 500-1000 tonnes) the expense of machinery required for windrow turning and screening is not likely to be cost effective. In these cases, provided the compost has been adequately pasteurised and all parts of the carcass is broken down, this material may be used on site or sold to farmers for use on broad-acre crops. It is not recommended that this material be used on horticultural crops or pasture for grazing. Alternatively, compost may be stockpiled for a period of time until adequate quantities are available to make contract screening cost effective. In situations where minimum turning and screening facilities are available, it is recommended that fine particle carbon sources such as sawdust or fine grade green waste are used to achieve the highest quality end product with minimal input.

The nutrient composition of the end product compost will depend on the composition starting materials. Generally, green waste and straw based carcass low analysis for nitrogen (<1.5%) and phosphorus (0.1-0.4%). amounts of manure are included in the compost mix, levels may reach 1.8% for phosphorus. Average and ranges of nutrients in carcass compost are shown in

Table 16. Nutrient Analysis Results for 11 Samples of Partially Composted Poultry Mortalities, Including Manure and Egg Waste

Table 16. Note that these samples vary in the amount manure and other egg waste added.

Table 16. Nutrient Analysis Results for 11 Samples of Partially Composted Poultry Mortalities, Including Manure and Egg Waste

Parameter	Units	Range		Average
Ammonium Nitrogen	mg/kg	36.9	1245.8	419.9
Boron	mg/kg	2.4	28	11.3
Calcium	%	0.5	10.8	5.9
Copper	mg/kg	3	99.0	35.2
Electrical Conductivity	dS/m	1.3	9.5	5.4
Iron	mg/kg	2100.0	28000.0	10000.0
Magnesium	%	0.1	0.7	0.4
Manganese	mg/kg	42	620.0	348.5

Moisture	%	21.4	42.2	31.6
Molybdenum	mg/kg	0.8	4.6	3.1

Table 16. Nutrient Analysis Results for 11 Samples of Partially Composted Poultry Mortalities, Including Manure and Egg Waste (cont).

Parameter	Units	Range		Average
Nitrogen	%	1.1	4.3	2.1
Organic Carbon	%	10.9	42.6	24.9
Orthophosphate	mg/L	25.6	82.3	51.1
pH – Water		6.9	8.7	7.9
Phosphorus	%	0.1	1.8	1.1
Potassium	%	0.3	2.3	1.3
Sodium	%	0.1	0.5	0.3
Sodium Absorbtion Ratio		1.4	6.4	3.7
Sulphur	%	0.2	0.6	0.4
Zinc	mg/kg	23	430	222.4

It can be seen from these results that there is a large variation in some parameters, for example calcium and iron. With respect to calcium, this variation is driven primarily by the presence of egg waste in the compost mix. Compost incorporating egg waste had noticeable levels of egg shell particles in the finished product, contributing to higher calcium levels in these samples compared to mortality compost with no egg waste. The high iron levels in some samples is likely to be the result of contamination with soil high iron levels are not a concern however. Metals such as copper, boron and zinc are generally low and do not pose a threat for reuse on agricultural soils. Based on these averages, the nitrogen, phosphorus, potassium content in 1 tonne of carcass compost (as spread with 31.6% moisture) is approximately 14kg N, 7.5kg P and 9kg K. However, for phosphorus (the most valuable nutrient) this could vary from 1kg – 12kg per tonne.

5.3. Pathogens in Carcass Compost

A detailed study titled “*Food-borne pathogens and animal botulism issues surrounding the on-farm composting of layer chicken waste and mortalities – a review*” (Chinivasagam and Runge 2008) was conducted as part of this project. A summary of the pathogen results as reported in the above report are summarised here, and the results of the pathogen analysis are included in the in Appendix 1. *It is noted that all pathogens tested for are common in poultry systems.*

Samples from 14 different composts and chicken faeces were examined for the levels of key pathogens – *Campylobacter* and *Salmonella* and the standard indicator organism – *Escherichia coli*. The presence or absence of *Cl. botulinum* toxins C and D was also determined. As well, levels of *Clostridium perfringens* – an organism known to be commonly capable of surviving the compost process (Pourcher et al. 2005) – were

determined. The percentage moisture content and percentage dry matter were also determined.

The levels of *E. coli* ranged from a minimum of <3 MPN /g to 9400 cfu /g. The highest levels around 10^4 organisms per gram, were associated with three windrow samples and one pile. However the composts that had low *E. coli* counts (4 or <3 MPN/g) were also derived from a mixture of piles and windrows. This suggests that the process used (windrow or pile) may not have an impact on the levels of *E. coli*. It may be that the more important factor is how the composts (be it windrow or pile) are managed that helps pathogen die-off.

A finding of interest was that compost number 15 had the highest levels of *Salmonella* but had an *E. coli* level of <3 MPN/g (below detection limit). Thus *E. coli*, the common indicator organism, failed to indicate the presence of the pathogen *Salmonella*. It is worth noting that this compost consisted of cracked and broken eggs which may have contributed to this observation.

The fact that *E. coli* levels for some composts ranged from levels below the detection limit (i.e. <3 MPN/g to around 10^4 cfu/ g may be as a result of some piles either not reaching sufficient temperatures or showing an unequal heat distribution pattern. The higher temperatures of the windrows (and piles) should have been achieved at the early stage of the composting process resulting in reduction of *E. coli* levels in a comparable manner in all samples of compost regardless of compost age. Hence compost age should not be a factor in the varying levels of *E. coli* detected in this study.

The levels of *Cl. perfringens* from composts ranged from levels below detection (<100 cfu/g - one sample) to a highest level of 5.1×10^5 cfu/g. In general the *Cl. perfringens* levels were high. This result suggests that *Cl. perfringens*, which is a spore former, probably had a better survival potential in the composted product than non spore forming organisms.

Cl. botulinum is also a spore forming organism like *Cl. perfringens*. Hence the *Cl. perfringens* results may be some indication of the levels of *Cl. botulinum*, if present in these composts. Control of *Cl. botulinum* by composting is a challenge. If the compost temperatures reached were high enough to kill the vegetative cells, the spores could have survived the composting process. Subsequently sporulation under suitable conditions within the compost may result in an increase in number of the organism.

One of the samples was positive *Cl. botulinum* toxins C or D. This sample was mushy and contained a decomposing chicken carcass with maggots and a strong putrefying odour – this sample had clearly not been adequately composted.

No sample, other than the manure sample, yielded *Campylobacter*. This is an expected result given the well recognised poor ability of this organism to survive in the environment. The manure sample was a composite sample – containing both fresh and aged (14 day) layer manure. Hence, it should not be assumed that the level of *Campylobacter* we established (24,000 MPN / g) is typical of fresh layer manure. More extensive studies would be needed to address this issue.

Salmonella was present (in 25 grams) in six of the 14 compost samples, with one of these positives originating from a source material of cracked and broken eggs. In these six presence / absence positive samples the level was shown to be <3 MPN/g for three samples with another sample being 4 MPN/g. Of the remaining two samples one had a

level of 15 and the other 4300 MPN/g the latter being a cracked and broken egg compost (no carcasses). Overall, 12 of the 14 compost samples had a *Salmonella* level of 4 or less MPN/g (with 11 being <3 MPN/g). Hence, despite the fact that most of the samples were only partially completed composts, we found little evidence of high levels of *Salmonella*. This may be due to a good killing of *Salmonella* in the early compost stages or simply the absence of *Salmonella* in the source material. Issues on the possible re-growth potential of the organism or re-colonisation due to external factors (vectors) also needs to be considered during the extended periods of exposure of composts heaps to the outer environment.

The single manure sample examined was a composite of fresh and older (14 day) manure. This composite manure had a level of *Salmonella* of 4600 MPN per g. More extensive studies of manure samples are needed before concluding if this result is typical of *Salmonella* levels in layers in general, however it is interesting to note that most of the compost samples had considerably lower pathogen levels than the manure sample.

Clearly, two major factors play a role in the presence of pathogens in compost - the presence of these pathogens in the source material and the ability of the composting process to reach conditions suitable to eliminate the pathogens (if present).

Only one compost sample in this study had completed the composting process. This sample (sample 7) contained daily bird mortalities, along with cracked and broken eggs, and the carbon source was cage manure and straw. Thus, though having the all the components (i.e. chickens, broken eggs and layer manure, common to most layer operation) the product was composted to a stage where the *E. coli* levels were low at 93 MPN/g. Importantly, however the *Cl. perfringens* level was below detection (<100 cfu/g), a result not observed in any other samples. Furthermore, the *Salmonella* level was <3 MPN/g (below detection) and absent in 25 g. No botulinum toxin was detected and the compost had good physical attributes. These findings mean that safe compost can be produced, with minimum pathogen risk based on good composting practices.

In summary:

- Of the possible food-borne pathogens potentially present in layer waste based composts, the results indicate that only *Salmonella* needs to be considered.
- As one sample was positive for botulinum toxin (type C/D), the results indicate the need to consider the risks of botulism if cattle are exposed to layer waste compost.
- The sole completed compost examined in this study was sourced from a full range of potential layer waste input – daily mortalities, cracked and broken eggs and cage manure. This compost, produced as a heap with active turning, had good physical parameters, an absence of food-borne pathogens, an absence of the spore-forming *Cl. perfringens* and no botulinum toxin. This is evidence that a well managed composting process can deliver a good quality, safe compost under practical on-farm conditions.

6. Conclusions

Composting is a viable alternative method for disposing of daily mortalities, spent hens, egg waste and other waste produced on egg farms. Under controlled systems with the correct management, good results can be achieved and a safe, nutrient rich soil amendment produced for reuse on-farm or sale to other farmers. However, if the correct management practices are not followed, unsatisfactory results are likely to follow. In most case study trials, the material produced would be considered 'partially composted' as it does not meet the Australian composting standards.

With respect to the assessment criteria used in this project, very few of the samples could be considered safe for reuse in a grazing context because of the risk of botulism. In general there were insufficient temperature records to ensure pasteurisation and presence of bones and at some times undecomposed flesh in the samples collected. This being said, many of the trials may have shown significantly better results 1-2 months after the sampling was carried out, provided ideal composting conditions were maintained. It must be noted that pathogens are naturally present in poultry systems, and poultry layer manure is commonly used in agricultural systems without any treatment. Hence, provided composting is managed to avoid conditions favourable to botulism, low levels of other pathogens are not likely to be a concern for reuse in a broad acre context or for grazing pastures where special precautions are adhered to. It is recommended that grazing animals are held off pasture where compost has been applied for a minimum of 3 weeks, and that all livestock are vaccinated for botulism.

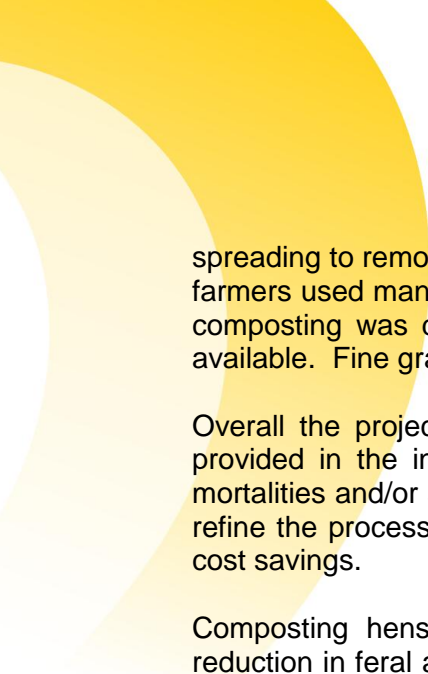
Minimising pathogen risk may be done by following recommended composting and reuse practices, and the following practices should be strictly adhered to:

- Ensure carcasses are not subjected to anaerobic conditions before the compost process has started and during the compost process.
- Ensure livestock do not have access to compost piles or windrows.
- Ensure all material, particularly carcasses, are aerobically composted prior to spreading and that the composting process is complete.
- Follow all composting guidelines provided in Appendix 2 of this document.

Producers interested in composting are directed to read the composting fact sheet available from AECL and the guidelines provided in the appendix of this report.

Many different arrangements were used for composting, but in general the turned piles or windrows offered the best system for minimum set-up and ideal composting conditions. One downside to outdoor piles and windrows was the lack of control over moisture however. It was clear from trials in wet regions that a compacted, clay pad is needed for effective composting to reduce moisture being drawn into the compost and to allow for machinery operation on the compost site. Small bins were used successfully at some sites and offer a good solution for composting near to poultry sheds.

Nutrient analysis results show that compost is a valuable by-product that can be valuable for re-use on agricultural crops and pastures, provided pathogen levels are controlled. Observation of compost samples suggested that most would benefit from screening prior to

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spreading to remove large particles of compost materials and undecomposed bones. Many farmers used manure as a primary material for composting, however, the most successful composting was done using sawdust or barn litter and this material is recommended if available. Fine grade green waste can also be used.

Overall the project proved successful, with the participants able to use the information provided in the initial workshop and follow-up visits to successfully compost their daily mortalities and/or spent hens. With continued experience the producers have been able to refine the process to best suit their operation and this has resulted in significant time and cost savings.

Composting hens has addressed a range of problems for producers ranging from a reduction in feral animal numbers through to being able to now being able to clean a shed in two days, where it once took up to three weeks, thus reducing down-time on a shed.

All project participants believed they would continue composting because it was the best method environmentally and reduced biosecurity risks. Participants also believed it was the most economic method of disposal for their enterprises.

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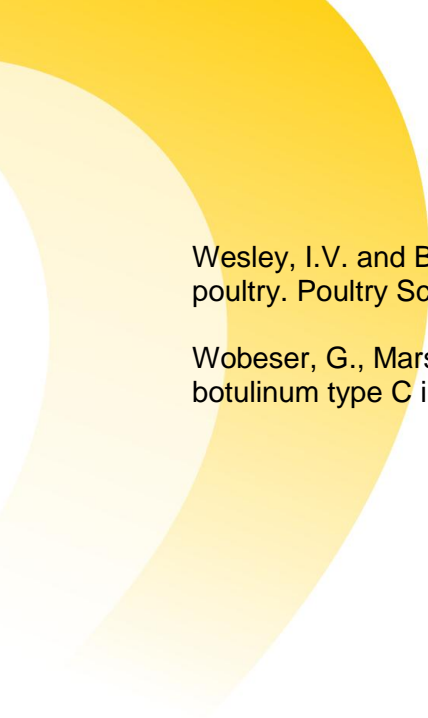
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Appendix 1

Table 17. Microbiological Results from Compost Samples

Samples	<i>E. coli</i> (cfu/g)	<i>E. coli</i> (MPN/g)	<i>Clostridium perfringens</i> (cfu/g)	<i>Salmonella</i> (MPN/g)	<i>Salmonella</i> present in 25 g	<i>Salmonella</i> serotyping	<i>Campylobacter</i> (MPN/g)	<i>Cl. botulinum</i> toxin (Type C & D)	% Moisture
1	9400	n/a	24600	<3	-ve	NA	<3	-ve	35.2
2	1600	n/a	10100	<3	-ve	NA	<3	-ve	28.7
3	n/a	4	600	<3	-ve	NA	<3	-ve	42.0
4	n/a	<3	17100	<3	+ve	1 culture <i>S. Montevideo</i>	<3	-ve	24.4
5	2200	n/a	510000	4	+ve	2 cultures Both <i>S. Mbandaka</i>	<3	-ve	38.7
6	200	1100	130000	<3	-ve	NA	<3	+ve for C or D	n/a
7	n/a	93	<100	<3	-ve	NA	<3	-ve	20.9
8	4600	n/a	7200	<3	+ve	1 culture <i>S. Singapore</i>	<3	-ve	32.5

Table 17. Microbiological Results from Compost Samples (cont).

Samples	<i>E. coli</i> (cfu/g)	<i>E. coli</i> (MPN/g)	<i>Clostridium</i> <i>perfringens</i> (cfu/g)	<i>Salmonella</i> <i>a</i> (MPN/g)	<i>Salmonella</i> present in 25 g	<i>Salmonella</i> serotyping	<i>Campylobacter</i> (MPN/g)	<i>Cl. botulinum</i> toxin (Type C & D)	% Moisture
9	186000000	n/a	5000	15	+ve	9 cultures 8 being <i>S. Singapore</i> 1 being <i>S. Montevideo</i>	24000	-ve	54.4
10	2700	240	2900	<3	-ve	4 cultures All <i>S. Infantis</i>	<3	-ve	11.6
11	n/a	240	2900	<3	-ve	NA	<3	-ve	37.1
12	n/a	<3	3100	<3	-ve	NA	<3	-ve	37.6
13	n/a	<3	100	<3	+ve	1 culture <i>S. Amsterdam</i> <i>var 15+</i>	<3	-ve	21.1
14	n/a	43	400	<3	-ve	NA	<3	-ve	25.4
15	n/a	<3	500	4300	+ve	12 cultures 3 being <i>S. Mbandaka</i> 9 being <i>S. Senftenberg</i>	<3	-ve	44.3

Appendix 2

Carcass Composting Guidelines

In general, carcass composting follows the same principles as manure composting, however some differences are apparent. Poultry carcasses have a high moisture and nitrogen content compared to many organic materials. For successful composting, it is necessary to add a carbon source (such as sawdust or chopped straw) to soak up moisture and feed the composting process.

The first step to setting up the compost is calculating the number of mortalities or spent hens for composting. For daily mortalities, this will equal the total number of birds multiplied by the mortality rate and divided by the days of occupancy, i.e.

10,000 birds x 3% mortality = 300 birds

300 / 365 = 0.8 birds per day, or
= 6 birds per week.

This gives a total mass of about 12 kg of carcass per week, which will require about 25 kg of bulking material (i.e. 0.1 m³ of sawdust). Annually, this amounts to about 5m³ of sawdust to compost the 300 birds. This amount of sawdust may be reused to compost multiple batches of carcasses to reduce expenditure.

Because of the odour and pest potential with carcass composting, it is important that all carcasses are adequately covered with bulking material. This requires coverage with approximately 300mm of carbon bulking material (i.e. sawdust) to ensure that odours do not escape and scavengers do not discover the carcasses.

The key management principle is to always cover the pile with a minimum of 300mm of carbon bulking material.

One very important consideration with carcass composting is to ensure the process has adequate oxygen at all times during the process. This will reduce the risk of botulism, which is caused by the *Clostridium botulinum* organism. Another essential step to reduce the risk of botulism is to ensure that mortalities are well managed before the composting process begins. This can be done by composting mortalities every day, or storing mortalities in a fridge/freezer if daily composting cannot be done.

The key management principle is to never allow carcasses to decompose in an anaerobic environment (such as a pile left in a wheel barrow) for more than a few hours.

Carcass composting can be done successfully with 3 turns of the compost pile. It is advisable to leave a carcass compost pile for a minimum of 4 weeks before first turning the pile to allow time for breakdown of the carcasses. After this time the pile can be turned, but it must be re-covered with about 300mm of an inert material to ensure carcasses are not exposed on the outside of the pile. An ideal material to use for this is 'finished' compost that has been through the cycle once already.

The key management principle is to always ensure carcasses are covered by a minimum of 300mm of material.

Carcass composting can be done in many ways, however the simplest option is to construct bays or a windrow with a compacted base, and turn piles on a monthly basis after the last carcass is added. An impermeable base will avoid nutrient leaching from the compost and will improve machinery access. Site drainage is also important to avoid muddy conditions

and excessive moisture in the compost. Site may also require bunding to reduce runoff from the site, and if this is done the nutrient rich runoff should be collected in a sump / dam. For large scale composting, it is recommended that you check licence requirements as some states require a separate licence for composting.

*The key management principle is; construct a dedicated compost area if using outdoor windrows, including a **compacted, clay** pad and system for the collection and/or reuse of effluent from the site.*

If an expensive carbon source such as sawdust is being used, this material can be recycled to compost many birds to reduce cost. It should be noted that successful carcass composting needs a good source of carbon. The ideal materials are sawdust/shavings, barn litter or chopped straw. Finely mulched green waste may also be used but wood chips or coarse green waste are not ideal. Manure may also be used, but this should only be used as less than 25% of the total mix as it does not contain adequate amounts of carbon for effective carcass composting.

The key management principle is; use a good quality carbon source (sawdust, shavings, litter, fine grade green waste) to ensure adequate carbon is available for composting.

To minimise pathogen levels in carcass compost, the compost should be turned three times and reach temperatures of 55°C for three consecutive days after each turning. These temperatures should be monitored and records maintained. The following criteria (repeated from the methodology section of this report) may be used.

Table 18. Compost Assessment Criteria

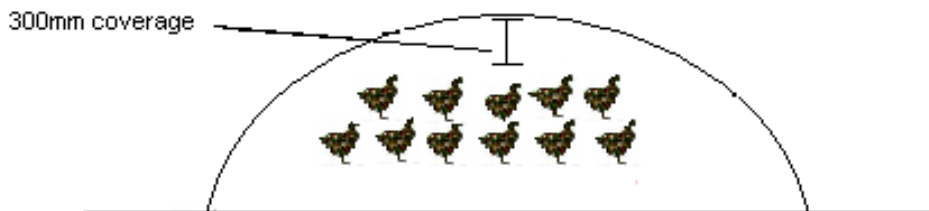
Facility capacity (hens)	Waste material composted	Bulking material
Pasteurisation (to ensure pathogen and weed seed kill)	Compliance to AS 4454 Laboratory analysis	Windrows must be turned 3 times and achieve a minimum of 3 consecutive days at > 55°C after each turning. The material must be composted for at least 6 weeks. Carcasses do not decompose anaerobically before and during composting. For horticultural use (vegetables) undergoing minimal processing, Salmonella should be absent in 50 g (dry weight). For pasture, < 10 Salmonella per 50 g (dry weight), plus with-holding period of 30 – 60 days based on pasture re-establishment and soil incorporation.
Moisture	Laboratory	Ideal moisture 30-40%
Carbon availability and C:N ratio	Visual assessment and calculations based on laboratory results	Carbon availability based on particle size. C:N ratio determined from laboratory analysis.
Compost free from contamination	Visual assessment	Sample must be free from obvious bones and undecomposed flesh.
Nutrient content	Laboratory analysis	n/a

Carcass compost pile construction

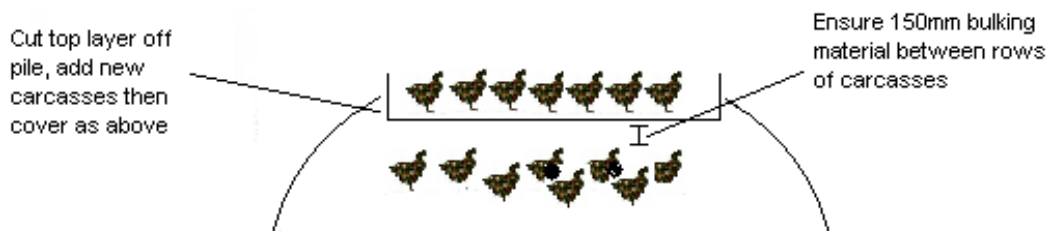
Step 1.



Step 2.



Step 3.



Common Composting Problems

My windrow does not heat up

Possible problems

1. Incorrect moisture – too much, too little? Aim for 40-65% - enough to feel wet without it dripping in your hand.
2. Insufficient mixing / oxygen. Turn windrow and observe again after 6-12hrs.
3. Incorrect C:N ratio – is there enough nitrogen for biological activity? This should not be a problem unless too much bulking material is added - aim for a C:N ratio of between 15:1 and 40:1. To increase nitrogen, add manure.
4. Is the carbon in an accessible form for breakdown? If woodchips or other coarse material is used, the low surface area and low degradability can inhibit composting. Try using straw or sawdust to provide adequate carbon.
5. The composting process is finished – If all other conditions are met and the windrow has been composting for some time, failure to heat after turning is a good indication of completion of the active phase of the composting process.

My windrow is creating excessive odour

Possible problems

1. Is the moisture level too high? This may be caused by rainfall if piles absorb this water. If this is the case turn the pile and form it to shed water – add more bulking material if required.

2. Is the C:N ratio too low (too much nitrogen)? This can cause ammonia loss and odour production – solve by adding more bulking material.

Carcass composting check list

1. Construct bin or bay for composting operations ensuring the base is impermeable to control drainage and ensuring that runoff is contained.
2. Put down a 300mm layer of bulking material (sawdust, straw or other carbon source – not manure) on the bottom of the compost pile.
3. Add mortalities (1.5 birds per layer).
4. Birds must be composted fresh (daily) or stored in a fridge/freezer prior to composting to avoid a build-up of pathogens.
5. Ensure aerobic conditions are maintained throughout the whole process to minimise risk of botulism.
6. Add water if desired, approximately 1 L per 3 carcasses* (optional).
7. Add further bulking material (sawdust, straw or manure mix) at approximately 2:1 ratio of bulking material to carcass mass.
8. Ensure that carcasses are covered with 300mm of bulking material to protect from rodents/pests - use additional bulking material if required.
9. Ensure the pile is peaked so that rainfall will shed from the pile.
10. Ensure carcass compost and runoff from compost is not accessible to livestock and that material is not spread on grazing land unless livestock are vaccinated. This will reduce the risk of botulism.
11. Collect runoff from compost site to avoid surface water contamination with nutrients, organic matter and pathogens. This collected runoff can be reused in the composting operation.

For adding additional carcasses

1. Remove the top layer of bulking material, ensuring 100 to 150mm of bulking material remains to cover the previous carcasses.
2. Add new carcasses and follow steps 3 – 7 above.
3. Ensure that the overall pile height is no greater than 3 meters.

** Water is not essential for carcass composting.*