STRATEGIES TO REDUCE ODOUR EMISSIONS FROM MEAT CHICKEN FARMS

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The Problem

The recent growth in the Australian meat chicken industry has coincided with rising community interest in environmental issues. To ensure the environmental sustainability of the industry and of individual farms, it is important to carefully manage environmental concerns.

Meat chicken processing plants have traditionally been located in large cities for economic reasons. The meat chicken farms that supply these plants have thus been located in rural residential areas on the outskirts of these cities for economic reasons related to transport costs. Farms in many of these areas have suffered from urban encroachment by people looking for cheaper land and a rural lifestyle. Consequently, interference to community amenity (particularly through odour) is an important issue. Even with very well managed farms, odour will still be generated and may be detected off-site. This off-site impact however, can be minimised with appropriate planning and management.

Principles of Odour Generation and Control

Decomposing waste products such as manure, feathers, dust and bedding causes odours in intensive meat chicken buildings. This degradation takes place under two different conditions in terms of oxygen requirements: aerobic and anaerobic conditions. The breakdown of sulphide containing compounds produces hydrogen sulphide, mercaptans and organic sulphide. The breakdown of nitrogen containing compounds produces ammonia, amines, indole and skatole. At the same time, some odorous compounds such as volatile fatty acids, alcohols and aldehydes might also be produced through the breakdown of other compounds. Aerobic biodegradation can be expected to break nitrogen-containing compounds down into odorous compounds containing nitrogen. Anaerobic biodegradation can be expected to produce sulphide containing odorous compounds that are perceived as odours at very low chemical concentrations (Jiang, 2000).

As biological degradation of organic material progresses, odorous compounds are produced in the liquid and solid phases. The volatilisation rate of these odorous compounds is controlled by the concentration difference between liquid/solid and gas phases. Ventilation rate and temperature significantly influence the concentration in the gas phase. The higher the ventilation rates, the higher the volatilisation rates and vice-versa. Due to the high levels of odorous compounds in the litter, the volatilisation process becomes a dominant factor in the generation of atmospheric odour emissions (Jiang, 2000).

Reducing the moisture content in the litter will inhibit anaerobic bacterial activity, and reduce the formation of other odorous gases. Furthermore, low pH (< 7.5) causes anaerobic conditions, which correspond to an increase in odour emission rates. Jiang (2000) reports that the control of pH and water content in the litter can effectively reduce the odour emission from meat chicken sheds.

The sources and factors affecting the odour generation from a meat chicken shed are summarised in Table 1.

Table 1 Factors affecting odour generation in meat chicken sheds

Process	Affecting factors
Breath, flatus and faeces	Bird number and diet
Degradation of waste	Temperature, pH and water content in the litter
Volatilisation of odorous compounds in the litter	Ventilation rate, climate, litter pH and temperature

Odours can be controlled via three broad categories:

- At the source.
- Between the source and the receiver.
- At the receiver.

The most effective way of controlling odour is at the source. The control of odours can be achieved by managing the odour generating processes (eg. maintaining optimum litter moisture) or removing odour from air before it is released from the sheds.

Windbreak walls help to disperse odour and provide a means for controlling odour and dust emissions between the source and the receiver.

Controls at the receiver only warrant consideration where other approaches fail. Air conditioning for receptors houses is an example of a control approach. However, this may be expensive if there are many houses to treat. It also provides no control over odour outside the treated building(s). Controls at the receiver are rarely a viable odour reduction strategy.

This paper details practices, strategies and technologies to reduce the impact of odours from meat chicken farms.

GOOD PRACTICE, DESIGN AND MANAGEMENT

The most effective way of minimising odour impacts is by minimising the odour generated at the source. With meat chicken farms the predominant source is the litter in the sheds. However, this can only be achieved by a combination of good practice, design and management and adequately managing the litter, providing optimum ventilation and controlling temperature.

Good practice, design and management should always be considered before other odour control strategies are implemented. These practices are generally part of normal meat chicken production as they are quite often implemented with the primary purpose of optimising production.

Managing Shed Litter

Odour and dust levels from meat chicken sheds depends primarily on the moisture content of the shed litter. The optimum shed litter moisture content is between 15 percent and 30 percent (wet basis). Litter with this moisture content is relatively dry and friable.

When the litter is too dry it becomes dusty and can cause dust nuisances, poor bird health and discomfort or health problems for farm workers. When litter becomes too wet it can begin to decompose anaerobically, producing increased odour and ammonia emissions. This can also lead to odour nuisance, poor bird health and, possibly, health problems for farm workers.

Very wet shed litter emits significantly more odour than dry litter. Even quite small wet areas within a shed can significantly increase odour emissions. These small areas can be easily maintained by either topping up with clean dry bedding material or removing and replacing the wet litter.

Interruptions in diet due to feed formulation, medication or poor bird health can produce extremely wet manure. This increases litter moisture content, causing increased ammonia and odour releases. It is critical that close communication be maintained between growers, feed and chicken suppliers to help monitor and minimise these problems.

A key factor in controlling litter moisture is the minimisation of spills from watering systems. Waterers should be carefully adjusted for height and water depth. Reducing water spillage has a number of benefits, including saving water, improving bird quality, improving the shed environment, reducing ammonia levels, reducing the volume of wet manure and extending the time between litter cleanout (if multi-batch litter is used).

Other shed maintenance factors that will help to maintain the optimum litter moisture content include:

- Promptly repairing leaks in shed walls and roofs,
- Insulating shed roofs to prevent condensation,
- Regularly inspecting and maintaining drinkers and foggers, and
- Providing adequate roof overhang and sidewall height to prevent rainwater from entering the shed.

Providing Adequate Shed Ventilation

Ventilation influences odour emission rates by affecting the rate and extent of drying of the litter. The flow pattern of the ventilation system and the temperature gradient between the shed and the outside air are the most important parameters influencing the drying process.

Ventilation removes excess heat, water vapour and odorous compounds from the sheds. The concentration of odorous compounds in the air depends on the degree of dilution of the odorous substances with air in the shed or in the ventilation system.

Maintaining the maximum possible airflow through the shed will assist in keeping the litter as dry as possible and promote aerobic conditions. It will also dilute odorous gases as they are released to the outside air. Appropriate design and regular maintenance of ventilation fans will ensure that ventilation is adequate for the number of birds that are being housed. Removing the dust, cleaning ventilation fans and shafts will minimise odours that are absorbed and carried in through the air by dust particles.

In planning the shed orientation for a new or expanded farm the prevailing winds, fan location and the location of neighbours all need to be considered. Shed ventilation is closely related to shed temperature. By providing appropriate ventilation, temperature can be regulated inside the shed, which assists the control of odour generation.

Controlling Shed Temperature and Humidity

Temperature has an important influence on the degradation of manure and the volatilisation of odorous compounds in the litter. Roof insulation prevents large net heat gain from external radiation and assists the regulation of the temperature inside sheds. For sheds with inadequate roof insulation, the air beneath the shed roof may radiate heat into a meat chicken shed at significant rates during the hot part of the day.

Meat chicken houses in warm to hot climates require good roof insulation. This can be achieved by 4 mm polyurethane foam board, spray-on polyurethane foam or blankets and pads. Reflective roof cladding or white paint can provide some benefit but are not considered as effective as under-roof insulation, as they can only reflect part of the sun’s radiation.

There is a number of strategies that will assist in controlling shed temperature, including -

- Providing adequate roof and wall insulation will both conserve energy and increase the cooling capacity of ventilation air.
- Minimising exposure to solar radiation by aligning the meat chicken shed along an east-west axis.
- Building sheds with a large overhang.
- Covering the surroundings with grass or other vegetation to reduce ground radiation.
- Keeping the heat production of the birds as low as possible, promoting the heat loss of the birds, and maintaining their feed intake.
- Reducing heat levels in open sheds using air movement with large diameter ventilators or using evaporative cooling in environmentally-controlled sheds as long as the relative humidity does not exceed 70 percent (Ketelaars, 1984 and DPI, 1988).
- Painting shed roofs white and/or insulating roofs to reduce the radiant heat incident on the birds.

- Keeping ventilation openings free of obstructions.
- Installing fogging systems, fans and roof sprinklers.
- Shading ventilation openings.
- Maintaining mown grass cover around sheds.
- Reducing stocking density in summer.

Other Good Design and Management Practices

Other options for minimising odour impact from the farm include appropriately storing or treating spent litter to minimise odour generation if not directly spread or sold off-farm.

If applying spent litter on-farm, odour impact can be minimised by avoiding spreading during adverse weather conditions (early morning or late in the afternoon), incorporating the spent litter as soon as possible and considering the current and predicted wind direction and strength.

Dead birds have the potential to cause significant odour problems. The odour generated from dead birds is often quite distinct to that generated from the shed litter and as such this change in characteristic odour can lead to unwanted complaints from neighbouring residents. Dead birds need to be properly stored and disposed of to minimise odour generation.

DIETARY MANIPULATION

There is limited information on the effectiveness of dietary manipulation on odour production. Further research is required to assess the effectiveness of dietary manipulation as an odour control strategy. The available information does, however, indicate that this control technique has potential to control odour emission rates within the intensive meat chicken industry.

Gates et al. (2000) studied the effects of reducing crude protein levels below current commercial levels, with simultaneous enhancement of amino acid levels. The results of the study indicate that after three meat chicken flocks were raised on the same litter and diet:

- The pH and moisture content was lower for meat chickens on a reduced crude protein and enhanced amino acid diet.
- The concentrations of equilibrium ammonia gas and litter total ammoniacal nitrogen was lower (approximately 90 percent and 50 percent lower respectively) on a reduced crude protein and enhanced amino acid diet.
- The bird production performance was not compromised on the low crude protein and enhanced amino acid diet (achieving between 1.8 and 2 kg feed/ kg live weight gain).

Elwinger and Svensson (1996) studied the effect of varying dietary protein content on ammonia emission from meat chicken sheds. The results of the study indicate that increasing the dietary protein content increased the ammonia concentrations in the litter and air of a meat chicken shed. However, reduced concentrations of ammonia in the litter do not necessarily lead to the reduction of odour emission rates. Research into the relationship between odour and ammonia concentration has produced varied results. This is due to the complex nature of odour (ie a reduction in ammonia concentrations does not typically correspond to a proportional decrease in odour emission rates).

ODOUR REDUCTION TECHNOLOGIES

Relationships between odour concentration and odour intensity suggest that over 90 percent reduction in concentration is needed for effective abatement of odour nuisance problems (Pain, 1993; Misselbrook et al, 1993). In other words, reductions of even 50 percent in odour are unlikely to be significant in reducing the impact. An effective solution of odour nuisance situations requires large reductions in the odour concentrations emitted from the chicken shed.

There are generally three mechanisms to reduce odour nuisance from a meat chicken shed:

- *Biological*. These controls either inhibit biological activity causing the odorous gases, or utilise biological interactions to eliminate the odorous gases.
- *Chemical*. These controls eliminate the odorous gases through chemical reactions

- *Dispersion*. These controls promote the dispersion of odorous gases to an extent where they are not regarded as offensive at sensitive receptors, such as at a neighbour's property.

There are a number of systems that have the potential to reduce the community amenity impact of meat chicken sheds. These technologies include -

- Odour neutralising agents - Chemical agents are added to the litter and feed (depending on type of chemical agent) to reduce the moisture content of the waste and inhibit anaerobic microbial degradation.
- Windbreak walls - Odour impact walls at the exhaust end of tunnel ventilated sheds. These walls can be made from plywood, shade cloth, straw bales or vegetative screening. If constructed of vegetative screens, windbreak walls can improve visual amenity.
- Air scrubber - Air is passed through a film or mist of water to remove the odorous compounds through chemical absorption, or chemical/biological reaction with an additive such as sodium hypochlorite.
- Biofilter - Air is passed through a damp porous medium such as peat, soil or wood chippings, which provides an environment where high numbers of odour-reducing bacteria can live.
- Short stacks - Odorous compounds are released from low heights above the building height (approximately 5 m). This aids the dispersion process prior to reaching sensitive receptors such as neighbours.
- Active oxygen - Odorous compounds are oxidised by oxygen (O_2). Energy is provided to oxygen to increase the energy level of stable O_2 molecules and promote the oxidising potential of oxygen.
- Ozone treatment - Odorous compounds are oxidised by ozone at room temperature.
- Incineration - Odorous compounds are oxidised at high temperatures (>600^{o}C).

Odour Neutralising Agents

The commercial meat chicken industry has been attracted to odour neutralising agents (ONA's) as a cheap fix approach to odour nuisance problems (Farran, 1999). There were approximately 20 of these products available in Australia in 2000. Many of these products are poorly defined and provide little scientific assessment of their odour control functions. Many of these products are based on removing (adsorbing) or reducing the release of ammonia from the atmosphere inside the meat chicken shed.

The correlation between ammonia and odour concentrations has been extensively studied and has produced contrasting results. Jiang (2000) found no correlation between ammonia and odour concentration in a study of odour emissions from meat chicken shed litter. However it is generally agreed that ammonia emissions correspond to the odour generation from meat chicken sheds during the first 5 – 6 weeks of growth, when aerobic conditions exist in the waste (Jiang, 2000). These are considered the least offensive odours that are generated in a meat chicken shed. The first 5 weeks of meat chicken growing cycles corresponds to minimal odour nuisance complaints. Hence, the control of ammonia generation and release are likely to have little effect on the peak odour emission rates from a meat chicken shed.

Amon et al (1997) performed a study on the use of Clinoptilolite zeolite and De-odorase®, (commercial available odour neutralising agents) to reduce ammonia and odour emissions from meat chicken sheds. The results of the study concluded that Clinoptilolite zeolite increased ammonia emissions while De-odorase® decreased the ammonia emissions. However, neither had any significant effect on the odour emission rate.

Jiang (2000) suggests that the addition of lime in fresh litter will limit the anaerobic microbial growth in meat chicken sheds, and therefore, limit odour generation. However, further research in this area is required to quantify the effects on odour emission rates and assess further effects on bird health.

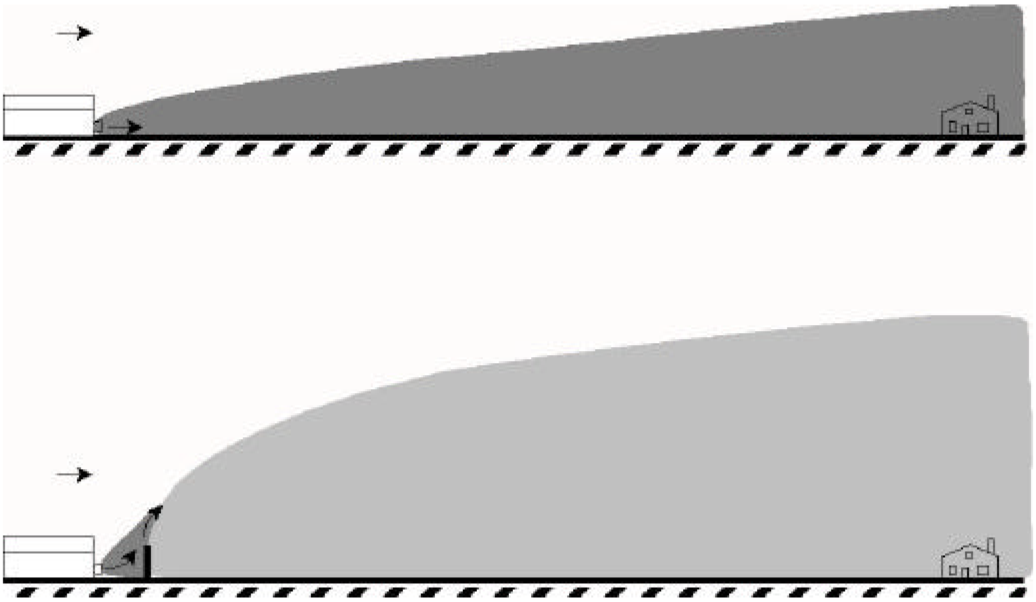

Figure 1 Designed Air Dispersion Mechanism of Windbreak Walls (Source: Bottcher *et al.*, 2000a).

Windbreak Walls

Windbreak walls are placed several metres from outlet ventilation fans. These barriers enhance the dispersion of odorants by directing odorous air upwards into wind that is building wake effected leading to enhanced mixing conditions. This may dilute the odorous air reducing odour nuisance at sensitive receptors. Figure 1 displays the designed odour reduction mechanism at sensitive receptors in ideal conditions due to windbreak walls.

Windbreak walls can be constructed from a variety of materials, as shown in Figure 2, including vegetation screens, tarpaulin, MDPE, grain bails (e.g. hay), corrugated iron or wood.

Although windbreak walls do not reduce the odour emissions from meat chicken sheds, they may filter out some of the odour as well as reducing the visual recognition of the odour source. Preliminary studies by Bottcher *et al.* (2000a) show that windbreak walls constructed from tarpaulin can reduce the odour concentration at sensitive receptors by between 30 percent and 90 percent. Furthermore, Bottcher, *et al.* (2000b, 2001) reports that the dispersion of dust emissions is promoted by the windbreak walls preventing visible dust build up on neighbouring property.

There is little available information on the odour abatement effectiveness of windbreak walls. The dispersion principles depend on mechanical mixing by force exerted by the outlet ventilation fans, windbreak walls and turbulent wind over the meat chicken shed. In calm conditions the dispersion of the odorous air, expelled from the meat chicken shed, will not be assisted through mechanical mixing by the wind. Calm conditions were shown by Bottcher *et al.* (2001) to reduce the effectiveness of windbreak walls as an odour dispersion mechanism. Furthermore, Bottcher *et al.* (2001) reported that dispersion principles and modelling results suggest that windbreak walls are less effective as a dispersion mechanism than tall stacks.

Figure 2 Examples of Windbreak Walls (Source: Bottcher *et al.*, 2000a)

Developing effective windbreak walls at a meat chicken farm requires the consideration of the following factors:

- The general visual amenity of the property;
- The position of neighbours' houses and other particularly sensitive receptors;
- If a vegetative screen is used, the involvement with a 'land care group' to assist in the installation and management of vegetation may be required;
- Topography;
- Soil type;
- Rainfall;
- Temperature and humidity;
- Prevailing wind direction; and
- Available buffer areas.

It is imperative to remember that screening requirements are site-specific and that an effective barrier at one site may not be appropriate at other sites depending on the factors discussed above.

Air Scrubbers

Air scrubbers remove contaminants from air through the process of absorption. Scrubbers are designed to provide maximum contact between the gas and the liquid streams in order to increase the mass transfer rate between the two phases (Patrick, 1994). Mechanisms employed in air scrubbers to maximise the contact of the gas and absorption media include impingement, spraying, atomisation and agitation.

Table 2 Types Of Air Scrubbers Available

Air Scrubber Type	Process Description
Water scrubber	This involves the passage of contaminated air through water sprays.
Venturi scrubber	This involves the passage of air at relatively high speed through a narrow opening where it is mixed with fine water droplets. The gas and the liquid are forced through the opening at elevated velocities dependent on the pressure drop. This process atomises the liquid into a fine droplet mist where the difference in velocity between the gas and the droplets promotes impaction of the gas-borne particles and droplets. The mist entraps particulate matter by inertial compaction.
Fixed-bed packed scrubber	This involves the passage of air through a tower packed with material over which a thin film of water flows.

Gas/media contact can also be enhanced by the use of special packing materials. This packing can be constructed of plastic or ceramic materials and must be replaced periodically. However, as surface area increases, pressure drop also increases, which raises the operating cost (Patrick, 1994). Additionally, air scrubbing may also involve the use of an oxidising solution such as sodium hypochlorite to remove the soluble odorous gases from the water. This also increases the associated operating cost. Types of scrubbers used to control air pollutants are described in Table 2.

The removal efficiency of odorous gases from air, by air scrubbers in the fish processing industry is quoted at 99.5 percent (Prokop, 1992a,b), and the efficiency of similar equipment used to treat rendering odours is quoted at around 99 percent.

Simplified scrubber-type equipment can also reduce odour concentrations. For example, blowing the air through a tank of water is likely to remove a significant proportion of the odour, although water would have to be continually bled off and replaced with fresh water to ensure that volatile odours are not released when the water becomes loaded with odorous material. To ensure good mixing, the air stream should be turbulent. Addition of oxidising chemicals such as sodium hypochlorite is also likely to enhance odour destruction. No quantifiable data on these technologies are currently available for meat chicken sheds. Only anecdotal evidence is available for the odour reduction potential of water scrubbers (ie simple water sprays). Testing of water sprays by the Queensland Department of Primary Industries and Environmental Protection Agency failed to identify any odour reduction.

Biofilter

Biofilters are rarely used in meat chicken farms for the following reasons -

- The cost of treating large air quantities involved.
- The handling of the effluent water needed to remove the nitrogen absorbed by the biofilter material.
- Performance that does not always meet expectations.

Biofilters are now readily available for a variety of industrial and agricultural odours. Recent research work at organisations such as the University of Queensland and the Meat Industry Research Institute of New Zealand have shown that biofilters can be readily installed and operated in the south east Queensland environment and can achieve odour reduction efficiencies of over 90 percent (Pacific Air & Environment and Katestone Scientific, 1999).

The key issues in biofilter design are the sizing of the facility for the given ventilation rate and ensuring that the biofilter is adequately maintained so that no part of the substrate medium becomes dried out and develops channels for odorous air to escape directly to the atmosphere. Biofilters require continuous maintenance and are required to treat all or part of the ventilation air throughout the growth cycle. This would require a major change in the ventilation design of the sheds and could impose significant capital and operating expenditure.

Biofilters require reasonably steady conditions to operate effectively. They can then achieve high levels of odour control. Levels of 86 percent-99 percent odour removal are typical (Williams, 1995). It is very unlikely that biofilters can be operated in a discontinuous nature (eg, only for the last 4 weeks of the growing cycle), because the microorganisms in the filter material require a relatively constant supply of 'food'.

There is considerable capital and operating costs associated with biofilters and as such is well above the range of affordability for the chicken meat industry.

Short Stacks

Short stacks give the opportunity for the plume of odorous exhaust air to disperse through a large volume before reaching the ground. Plume rise is a function of momentum due to the speed that the gases are forced out of the stack by the fans, and buoyancy due to the greater heat and lower density of the exhaust air compared to the surrounding atmosphere.

Pollock and Friebel (2000) determined the effectiveness of 5m stacks on reducing the odour GLC (ground level concentration) from a meat chicken farm consisting of 4 tunnel sheds. The results of this study indicated that the predicted area of odour impact is significantly reduced by this device, with the mean radial distance to the 5 Odour Units (OU) contour reducing from 300m to 170m. Modelling at discrete receptors has shown that up to fourfold reduction in predicted GLC can be obtained for receptors at short (200–500m) range. However, the effectiveness of a short stack is limited to this range and reductions in GLC odour concentrations beyond these distances are expected to be minimal. This research was completed on a farm in Victoria, where the draft odour criteria for meat chicken farms is 5 Odour Units (OU) for the 99.9th percentile at an averaging period of 3 minutes.

Recent research has been performed in NSW, where the draft GLC odour criteria for meat chicken farms is 7 Odour Units (OU) and 2 Odour Units (OU) for the 99th percentile at an averaging period of 1 second for a single residence and urban environment, respectively. Early indications of this research indicate that the 5m stack is wake affected 60-70 percent of the time resulting in a 2.3:1 peak to mean ratio in GLC odour concentrations, whereas a taller stack which is not wake affected gives GLC odour peak to mean ratios of 3.6:1. These results indicate that the wake effects promote the rapid dispersion of odorous compounds and are more effective than the taller non-wake affected stacks (Pollock, 2001).

The effectiveness of short stacks in reducing the odour nuisance from meat chicken facilities will depend on local meteorological conditions and topography. The local meteorology and topography gives substantial variations (±40 percent) in separation distance depending on the alignment of sensitive receptors with directions of poor/good dispersion (Pollock, 2001). Depending on local meteorology and topography, stacks on either duty fans or ridgeline fans can provide up to fourfold reductions in predicted 99.5 percent GLCs (Pollock and Friebel, 2000).

It should be noted that the study performed by Pollock and Friebel (2000) focussed on night-time (usually stable meteorology) impacts from chicken farms. These results are unlikely to be applicable to farms which are concerned with daytime impacts, which are often associated with unstable meteorology.

Short stacks should be effective for receptors relatively close to the source during stable conditions because the building effects of building wakes are more significant under these conditions. As the distance from the source increases, turbulent effects are not as influential on ground level concentrations and the effectiveness of short stacks is diminished (Pollock, 2001).

Active Oxygen

Active oxygen is a recent technology utilised to remove odorous gases from the air. The process involves passing oxygen over charged electrical sources before mixing with the odorous air. The charged oxygen is at a higher energy level and reacts with the odorous compounds in an outlet point such as a stack or a vent. The charged oxygen oxidises the odorous gases and expected removal efficiencies are between 70 and 80 percent.

There is considerable capital and operating costs associated with an active oxygen system and as such is well above the range of affordability for the chicken meat industry.

Ozone Treatment

Ozone is one of the most powerful oxidising agents known. This property of ozone is utilised to remove odours through oxidation of the odorous compounds in the air. During the oxidation-reduction reaction both the ozone and odorous gas are eliminated, and in theory neither the odorous compounds or the ozone remain.

Ozone is used in a number of industries to destroy airborne bacteria and to reduce and eliminate odours. Ozone kills micro-organisms by blocking their enzyme control system and deodorises both gaseous and particulate matter by a process of oxidation. This technology also has the potential to reduce ammonia concentrations in animal sheds. Two methods have been used to treat poultry sheds with ozone. These include the use of high concentrations of ozone to sterilise sheds when they are empty following removal of birds and spent litter, and the use of low levels of ozone (0.1 ppm) to deodorise sheds and improve air hygiene when sheds are stocked with birds. The results of experiments using concentrations of 0.1 ppm ozone during the growth cycle are promising and further studies are needed to investigate their cost effectiveness in terms of production increases and dust and odour reduction (Cargill, 2001).

Ozone treatment can be used in all types of meat chicken sheds and is claimed to oxidise the following odorous compounds:

- Hydrogen sulphide, dimethyl sulphide, dimethyl disulphide;
- Amines (primary, secondary and tertiary);
- Mercaptans, methyl mercaptan;
- Aldehydes, formaldehyde;
- Olefinic hydrocarbons;
- Acrylic ester, methacrylate;
- Ammonia (gas phase only);
- Phenol, toluene;
- Methanol, ethanol, iso-propanol; and
- Skatoles, indoles.

Based on a review of odorous compounds present in livestock buildings by O'Neill et al (1992), ozone treatment will remove all odorous compounds present in a meat chicken shed.

There are some concerns with the safety of the technology. Sigrist Design indicated, "Ozone technology is the best technology to remove odours, however it does not work with humidity". Humid conditions are a result of high water vapour concentrations in the atmosphere. Water vapour will undergo an oxidation-reduction reaction with ozone to produce hydrogen and oxygen and eliminate ozone prior to the removal of odorous compounds. There are further implications, as high concentrations of ozone can be dangerous to both workers and birds.

Quantifiable information relating to removal efficiencies for ozone treatment is limited. Bottcher *et al.* (2000b) reported a study performed over a sixteen month period of ozone treatment in a piggery found that ozone treatment reduced ammonia levels by approximately 54 percent under winter conditions and by 14 percent during summer conditions. Furthermore, Bottcher *et al.* (2000b) reported a separate study on the performance of odour and dust removal through ozone treatment in a piggery. Field tests indicated that under maximum tunnel ventilation the ozonation system reduced total dust mass at the fan exhaust by 60 percent and ammonia levels by 58 percent. Suppliers of the technology are in general, reluctant to supply documented removal efficiencies, however claims of a removal efficiency of greater than 90 percent have been made by a number of suppliers.

There is considerable capital and operating costs associated with an ozonation system and as such is well above the range of affordability for the chicken meat industry.

Incineration

Incineration is a highly effective means of odour control. In the fish processing industry, boiler incineration has a reported efficiency of 82-96 percent, while for rendering plants quoted figures for incineration are 99-99.6 percent (Prokop, 1992a, b).

The operating cost of incineration systems is very high, with Farran (1999) quoting the results of an analysis by O'Neill et al (1992) for the cost of controlling odour emissions from meat chicken sheds with incineration at $31.46 per meat chicken produced. Based on a shed producing six cycles of 20,000 meat chickens per year, this equates to an annual cost of $3,775,200. Thus, this control option is not economically feasible for the meat chicken industry.

Directions for Future Research

Analysis of the following strategies was hindered by the lack of the necessary reliable information to form definitive conclusions. The limited available information indicates that the following strategies could, with further research, provide both practical and effective odour reduction for the industry.

Feed Manipulation

Preliminary experimentation indicates that reduced ratios of crude protein and increased ratios of amino acids can reduce odour emissions from intensive meat chicken facilities. This control option would require support of chicken processors (who typically supply the feed). However, this strategy would be of low cost to the grower.

Windbreak Walls

There is minimal information available regarding the effectiveness of windbreak walls in reducing odour nuisance. Work from overseas indicates that reductions of between 30 percent and 90 percent may be achievable under unstable meteorological conditions (with lower reductions under calm conditions). Windbreak walls constructed of vegetative screens may also provide additional benefits in terms of visual amenity. The effectiveness of odour dispersion from windbreak walls has not been studied in Australia and further research is required to determine the suitability of this strategy for Australian farms.

Addition of Lime and Other Odour Neutralising Agents to Waste

The effect of the addition of lime and other ONAs that alter the pH and moisture content of the waste and bedding requires further scientific research. The effect of chicken health as well as the effect on odour production is necessary for growers to adequately assess the usefulness of this strategy to the industry.

Conclusions

To control odour from meat chicken facilities, effective design and management strategies must be implemented to minimise odour emissions from meat chicken facilities. Odour eliminating controls such as ozone, biofilters, scrubbers, incinerators and active oxygen are well outside the economic constraints of the current industry and unrealistic options to control odour problems. Temperature control, and the use of short stacks and windbreak walls may be feasible options in reducing odour impacts.

The focus should first be on preventing offensive odour production through the inhibition of anaerobic decomposition of waste (through good practice environmental management) and dispersion methods to reduce the odour impact on the surrounding environment.

Definition

OU = Odour Units

The number of odour units is the concentration of a sample divided by the odour threshold or the number of dilutions required for the sample to reach the threshold. This threshold is the numerical value equivalent to when 50 percent of a testing panel correctly detect an odour. (Draft Policy: Assessment and Management of Odour from Stationary Sources In NSW - January 2001.)

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