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The relationship between shed cleanliness and hen productivity

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Researcher Contact Details
Dr Lauren Edwards
Animal Welfare Science Centre
Department of Agriculture and Food Systems
University of Melbourne
Parkville, Victoria, Australia, 3030

Phone: +613 8344 3482
Fax:+ 613 8344 5037
Email:ledwards@unimelb.edu.au

Australian Poultry CRC Contact Details
PO Box U242
University of New England
ARMIDALE   NSW 2351

Phone: 02 6773 3767
Fax: 02 6773 3050
Email: info@poultrycrc.com.au
Website: http://www.poultrycrc.com.au

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Executive summary

The relationships between airborne dust concentrations, productivity and the cleaning routines used by stockpeople were examined at 33 commercial caged laying sheds in Victoria. Each shed was sampled over one day, and the airborne dust concentrations inside each shed were measured at hourly intervals to create an overall mean dust concentration for each shed. In addition, the stockpeople working in the sheds were interviewed in regard to their cleaning routines. Specifically, they were asked how much time they spent cleaning inside the sheds per week, how much of this cleaning involves loud noise (such as blowing out the dust with a leaf blower), how many different methods they use to clean the shed, and how many days since they had used each method. Several features of the shed that may influence the amount of dust generated and the rate of ventilation were also recorded. Finally, the productivity records were obtained for each flock and the mortality rates, rate of lay and peak production were determined where possible. The aim of this study was to determine whether relationships exist between the frequency and method of cleaning inside the sheds and the productivity of the hens.

Several aspects of the shed cleaning routine were related to both the airborne dust concentration and the productivity of the hens. The number of different types of cleaning methods used by stockpeople was predictive of both the airborne dust concentration ($P = 0.009$) and the mortality rates of the hens ($P = 0.004$), with a greater variety of methods associated with more dust and higher mortality rates. High dust concentrations tended to be correlated with higher mortality rates ($P = 0.056$), and it is posited that the high pathogen load contained on the dust particles may be influencing the mortality of the hens. However, a positive relationship between airborne dust concentration and egg production was found, suggesting that the concentration of airborne dust was not detracting from the productivity of the hens. A greater proportion of noise generated by cleaning procedures inside the shed was correlated with lower mortality ($P = 0.040$), but also correlated with lower egg production ($P = 0.007$). In addition, the concentration of airborne dust was the main predictor for both the hen day production and the peak hen day production, with higher dust concentrations associated with improved productivity.

Based on these results, it is suggested that the loud noise generated during motorised cleaning procedures may in fact be a stressor for laying hens, which may be responsible for the associated decrease in egg production. Whilst motorised cleaning may be of benefit by reducing the mortality rates of caged laying hens, alternative cleaning procedures that do not generate loud noise should be investigated.

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Introduction

Recent observations on cage-egg farms have found that laying hens that were exposed to high levels of man-made noise inside the laying shed displayed high fear of humans, but also produced more eggs and had lower concentrations of corticosterone (a stress hormone) in their egg albumen (Edwards, 2009). Laying hens will avoid exposure to loud noise when given the opportunity (MacKenzie et al., 1993), and exposure to loud noise (90 dB) has been associated with increased fear and stress in laying hens (Campo et al., 2005). These findings agree with the positive relationship found between noise exposure and fear of humans in commercial hens (Edwards, 2009), however the improved productivity and lowered stress physiology of the commercial hens was an unexpected result. Based on the studies by Campo et al. (2005) and Mackenzie et al. (1993), noise is considered a stressor and should result in a stress response, which has been shown to decrease reproductive output in hens (Hughes and Black, 1976, Cunningham et al., 1987).

One explanation for the unexpected relationship between noise and egg production may relate to the cleaning routines used by stockpeople inside the laying sheds. The enclosed environment of the modern laying shed requires regular cleaning due to the dust build-up that occurs when large numbers of hens are housed together. The main source of dust in poultry sheds is the birds and their manure, with the composition of the dust generally consisting of down feathers and crystalline dust from the ‘urine’ components of manure (Ellen et al., 2000). The dust particles come in a range of sizes, and their size determines the extent to which they can penetrate into the respiratory tract of both livestock and stockpeople. Larger particles (> 5µm) are termed ‘inhalable’, and can only be inhaled into the upper regions of the respiratory system where they are trapped by the body’s defence mechanisms. Smaller particles (< 5µm) are termed ‘respirable’, and can penetrate deep within the respiratory system (Just et al., 2009), where they may reside for some time (Ellen et al., 2000). It is the respirable fraction of dust particles that poses the greatest risk to the health of livestock and stockpeople.

Research in Europe has shown that poultry sheds have the highest concentrations of airborne dust when compared to other indoor animal industries (i.e. indoor dairy and pork) (Takai et al., 1998). This dust carries microorganisms and endotoxins that pose a threat to the health of the laying hens and stockpeople that work in the sheds (Seedorf et al., 1998, Ellen et al., 2000). There are no specific studies that link the airborne dust concentration inside laying sheds to the productivity of laying hens, however high concentrations of airborne dust have been shown to compromise the milk production of sheep housed indoors (Sevi et al., 2003).

Thus, the cleaning routines of stockpeople working inside laying sheds may influence the health of the laying hens housed in those sheds by removing potentially hazardous dust. Common methods of cleaning dust out of poultry sheds are ‘motorised’ methods such as blowing the dust off surfaces using a leaf blower or air hose (referred to as ‘blowing out’ the shed), or ‘non-motorised’ methods, such as sweeping the floors with a broom or pushable floorsweeper. The majority of noise that occurs inside laying sheds is related to motorised cleaning procedures, and it is plausible to suggest that sheds that experience the most man-made noise are also the sheds that receive the most cleaning. Potentially, the flocks studied by Edwards (2009) that were exposed to a lot of noise may have been producing well because they were living in sheds that were cleaned more often, resulting in a cleaner living environment.

It is hypothesised that the frequency of cleaning in laying sheds and the amount of noise made during cleaning are related to the productivity of the laying hens in those sheds. To investigate this hypothesis, a study was devised to assess the cleanliness of commercial laying sheds and compare this to the cleaning routines employed by the stockpeople and the productivity of the hens. In the original study design it was proposed that physical measures could be made of the amount of dust lying on surfaces within the sheds, with the intention of determining whether these physical measures could be used to predict the amount of aerosolised dust in the air and thus provide producers with an easy-to-use index of how dusty the air in their sheds was. However, after discussions with other dust researchers (Mark Dunlop, pers comm) it was decided that the amount of dust lying on surfaces was unlikely to be predictive of the amount of airborne dust due to differences in particle size between these fractions. I.e. The larger particles that settled on surfaces would not be predictive of the concentration of smaller particles that remained airborne, acting like a gas. Thus, this aspect of the study was abandoned and no physical measures of dust were made inside the laying sheds. Instead, the cleanliness of the laying sheds was assessed by measuring the total concentration of airborne dust in the air (mg/m^3).

Objectives

The aims of this study were to determine whether:

- relationships exist between the frequency and duration of cleaning routines of stockpeople, the number of different cleaning methods used, the concentration of airborne dust inside laying sheds and the productivity of caged laying hens
- relationships exist between the duration of cleaning-related noise inside laying sheds, the airborne dust concentration and the productivity of caged laying hens

Methodology

A list of all variables and their descriptive statistics is located in Appendix One.

Subjects and location

Data were collected at 33 laying sheds on eight egg farms in Victoria between 11th November -23rd December, 2009. Data were only collected from fully-enclosed, environmentally controlled laying sheds. All efforts were made to sample the sheds on the day prior to the most cleaning that occurred in the shed, however this was not possible on farms that did not conduct regular cleaning in the sheds.

Data were collected on the following: the concentration of airborne dust inside each laying shed; the physical features of each laying shed that may affect air flow and dust concentrations; an interview with stockpeople regarding the cleaning routines in each shed, and the productivity records for each shed (where possible). The methods used for collecting these data are described in the following.

Sampling airborne dust concentrations

The airborne dust concentration inside each laying shed was assessed using a handheld air sampler (DustTrack ™ Aerosol Monitor, Model 8532). The DustTrak sampler recorded aerosol concentration at 1 s intervals using a light-scattering laser photometer with an airflow rate of 3.0L/min. The mass (mg/m^3) of all airborne particles with a diameter between 0.1 – 10 µm was recorded, with a detectable concentration range of 0.001 – 150.000 mg/m^3. The sampler was unable to detect differences in particle size, and the dust concentrations could not be divided into inhalable and respirable fractions.

Each laying shed was assessed using the DustTrak air sampler in the following manner. The first recording was taken as soon as possible after the sheds were opened in the morning, generally at 7am or 8am. Airborne dust concentration was only measured while the researcher was in the aisles, and the researcher walked down each aisle once while holding the air sampler at chest height. The sampler logged dust concentration continuously, and a separate log was created for each aisle in each shed. Thus, a shed with five aisles resulted in five separate data files, and these could be used to calculate the average dust concentration in each aisle. The average of each aisle was used to calculate an average value for the shed.

After the first reading was taken at the start of the day, the researcher then sampled each shed on an hourly basis for eight hours (usually from 8am to 4pm). Thus the average airborne dust concentration for each shed at each hour could be used to calculate an overall daily average for each shed (Mean Dust, mg/m^3).

Shed details

Several physical details of each shed were recorded. These features of the laying shed were recorded as they may have influenced the ventilation rates of the shed (such as the number of fans present) or the amount of dust produced (such as the size of the flock). Data were collected via direct observation of the shed and through discussions with farm management.

For each laying shed the following variables were recorded: the number of fans present (No of Fans); the temperature that the shed was maintained at (Shed Temp); the age of the birds (Flock Age); the number of birds in the shed (Flock Size); the number of birds in each cage (Birds per Cage); the area of the shed in m^2 (Shed Area); the number of rows of cages (No of Rows), and the number of tiers of cages (No of Tiers).

Interview with stockpeople

Ethics approval to conduct research involving humans was obtained from the Human Research Ethics Committee at the University of Melbourne (Ethics ID # 0932600.1). All stockpeople who conducted cleaning inside the sheds were asked to participate in an interview regarding the frequency and method of their cleaning routines. The aims of the study were discussed with the stockpeople and their written consent obtained before the interview commenced. All stockpeople who were approached agreed to participate.

During the interview, stockpeople were asked a series of questions regarding the overall cleaning routines they used in the shed (such as a weekly routine where certain days are allocated to certain tasks), as well as the actual cleaning routine that had occurred in each shed over the previous week. The interview questions are available in Appendix Two. The results of these interviews were analysed and the following variables were calculated: the total number of different types of cleaning methods used in the shed (No of Methods); the total number of hours spent cleaning in the shed per week per 1000 birds (Hrs / 1000 Birds); the total number of hours per week per 1000 birds spent cleaning using loud cleaning methods such as a leaf blower or air hose (Noise Hrs / 1000 Birds); the proportion of total cleaning time that consisted of loud cleaning procedures (Prop Noise); the number of days since the shed was last cleaned using any method (Days Since Last Clean), and if the shed was blown out as part of the cleaning routine, the number of days between blowouts (Days Between Blowouts).

Production records

The production records were obtained from farm management where possible, however the productivity records are missing or inadequate for up to 12 sheds for various reasons, such as malfunction of egg counting equipment and inadequacy of the productivity records provided.

From the productivity records that were available, the following variables were obtained: the cumulative mortality rate on the day of sampling (Mortality); the hen day production on the day of sampling (HDP), and the peak hen day production (Peak HDP).

As each flock was sampled at a different age and thus were not comparable in terms of productivity, the above values were then compared to the age-appropriate values of the breed standards. The value from the breed standard was subtracted from the actual productivity value to give a + or – value, indicating how well the flock was performing in comparison to the breed standard. It was these comparisons to the breed standards that were used in the analyses.

Statistical analyses

The data were checked for normality and transformed where necessary. Bivariate correlation analyses were used to explore the relationships between shed parameters, cleaning routines, airborne dust concentrations and hen productivity. Variables that correlated with the productivity measures to a significance of $P < 0.10$ were then included in linear regression analyses.

Results

Correlations between mean dust concentration, shed parameters and cleaning routines

Mean dust concentration was significantly correlated with both shed parameters and cleaning routines (Table 1). The dust concentration was greater in sheds that were maintained at a higher temperature ($P = 0.000$), had more rows of cages ($P = 0.044$) and that used a greater variety of cleaning methods ($P = 0.018$). There were also tendencies for the mean dust concentration to be lower in sheds had longer durations of noise related to cleaning ($P = 0.062$) and longer intervals between the shed being blown out ($P = 0.089$).

Table 1. Bivariate correlations ($P < 0.10$) between mean dust concentration, shed parameters and cleaning routines

		Mean dust	
Category	Variable	r	P-value
Shed parameters	Shed Temp	0.76	0.000
	No of rows	0.35	0.044
Cleaning routines	No of methods	0.42	0.018
	Noise hrs/1000 birds	-0.33	0.062
	Days between blowouts	-0.30	0.089

Correlations between productivity, mean dust concentration, shed parameters and cleaning routines

Several shed parameters, cleaning routines and the mean dust concentration were significantly correlated with productivity measures (Table 2). Mortality was greater in sheds that were maintained at higher temperatures (P = 0.019) and employed a greater variety of cleaning methods (P = 0.003), but lower in sheds that had a greater proportion of cleaning that involved noise (P = 0.040). There was also a tendency for mortality to be higher in sheds with a higher mean dust concentration (P = 0.056).

Hen day production (HDP) was higher in larger sheds, demonstrated by the positive correlation with the number of tiers (P = 0.029), the number of cage rows (P = 0.022) and the number of birds in the flock (P = 0.042). There was also a tendency for HDP to be greater in sheds that were maintained at a higher temperature (P = 0.071) and had a greater number of fans (P = 0.059). In relation to cleaning routines, HDP was lower in sheds that had longer durations of noise related to cleaning (P = 0.014) and had a greater proportion of cleaning that involved noise (P = 0.007). There were tendencies for HDP to be greater in sheds that employed a greater variety of cleaning routines (P = 0.078) and had higher mean dust concentration (P = 0.091).

The peak in hen day production (Peak HDP) was greater in sheds that were maintained at a higher temperature (P = 0.020), and tended slightly to be lower in sheds with less fans (P = 0.094) and shorter durations of noise related to cleaning (P = 0.095). The most striking correlation, however, was the strong positive correlation between peak egg production and mean dust concentration, with hens housed in dusty sheds producing higher peaks in production (P = 0.000).

Table 2. Bivariate correlations (P < 0.10) between productivity, mean dust concentration, shed parameters and cleaning routines

		Mort		HDP		Peak HDP	
Category	Variable	r	P-value	r	P-value	r	P-value
Shed parameters	Shed Temp	0.47	0.019	0.34	0.071	0.50	0.020
	No of Fans			0.36	0.059	-0.38	0.094
	No of Tiers			0.41	0.029		
	No of Rows			0.43	0.022		
	Flock size			0.38	0.042		
Cleaning routines	No of Methods	0.61	0.003	0.35	0.078		
	Prop Noise	-0.43	0.040	- 0.50	0.007		
	Noise hrs / 1000 birds			-0.46	0.014	-0.38	0.095
Dust	Mean dust	0.37	0.056	0.32	0.091	0.80	0.000

Linear regression analyses using correlated (P < 0.10) shed parameters, cleaning routines and mean dust concentration to predict productivity measures

Regression models were created for mean dust concentration, mortality rates, hen day production and peak hen day production (Table 3). The cumulative mortality rate was predicted to be greater in sheds that used a large variety of cleaning methods, and this single variable accounted for 33% of the observed variation in cumulative mortality rates.

The model predicting hen day production (HDP) included five variables, and accounted for 54% of the observed variation in egg production on the day of sampling. The most important variable contributing to the model was the mean dust concentration, and egg production was predicted to be greater in sheds with higher dust concentrations, more tiers, more noise, a lower proportion of cleaning that involved noise, and a lower shed temperature.

The peak hen day production (Peak HDP) was predicted by the mean dust concentration only, with the peak predicted to be higher when the dust concentration was high. This model predicted 62% of the observed variation in this measure of productivity.

Table 3. Linear regression analyses for the dust concentration and productivity measures

Variable	Predictors	β	t	P	Adj R^2	df
Mean Dust	Shed Temp	1.17	6.56	0.000	0.66	2, 27
	No of Methods	-0.50	-2.82	0.009		
Mortality	No of Methods	0.61	3.31	0.004	0.33	1, 19
HDP	Mean Dust	1.07	3.33	0.003	0.54	5, 20
	No of Tiers	0.86	4.27	0.000		
	Noise hrs/1000 birds	0.53	2.00	0.059		
	Prop Noise	-1.07	-3.47	0.002		
	Shed Temp	-1.14	-3.03	0.007		
Peak HDP	Mean Dust	0.80	5.60	0.000	0.62	1, 18

Discussion

The aim of this study was to determine whether relationships exist between the airborne dust concentrations inside laying sheds and the cleaning routines of stockpeople, the amount of noise related to these cleaning routines, and the productivity of the laying hens. The mean dust concentrations observed in fully-enclosed, environmentally controlled laying sheds in Victoria were all below 1.27 mg/m^3, which is comparable to those reported in the literature (< 2 mg/m^3) for caged laying sheds (Ellen et al., 2000).

The temperature that the shed was maintained at was an important variable that was correlated with both airborne dust concentrations and productivity measures. The temperature inside laying sheds is controlled through the use of large fans that are used to increase the ventilation rates when the shed needs to be cooled. It is not surprising to find a positive correlation between shed temperature and dust concentration, as warmer sheds would have lower ventilation rates, which would presumably reduce the removal of airborne dust. Low ventilation rates inside poultry facilities are associated with an increase in relative humidity, which has been associated with lower airborne dust concentrations (Just et al., 2009, Ellen et al., 2000) and is in contrast to the findings of the current study. However, increasing the relative humidity has only been shown to reduce the concentration of inhalable dust (>5 µm), and not the concentration of respirable dust (< 5 µm) (Just et al., 2009).], and this may explain why an increase in shed temperature was not associated with a decrease in total dust concentration.

Interestingly, shed temperature was positively correlated with improved egg production but also with higher mortality rates. The relationship with egg production may be indicative of the lower metabolic requirements of hens living in a warm environment, where an improvement in feed conversion efficiency may be translated into higher reproductive output. However the higher mortality rates seen in these sheds suggest that the living conditions at warmer temperatures were not optimal, and that a dusty and/or poorly ventilated environment may be detrimental to the health of the hens. The concentration of airborne microorganisms has been reported to increase with temperature inside poultry facilities (Whyte, 1993), and an increased pathogen load may explain the increase in mortality rates at high temperatures.

Variables relating to the size of the shed, such as the number of fans, rows and flock size, all indicate that larger sheds had higher dust concentrations and improved egg production. As the main source of dust in laying sheds originates from the hens and their manure (Ellen et al., 2000), it makes sense that large sheds containing more dust sources would have higher dust concentrations in the air. On the other hand, the relationship between larger sheds and improved hen day production is not immediately apparent. It is plausible to suggest that the larger sheds may be representative of more modern sheds, in which improvements to cage design and the automated systems (eg feeding and temperature maintenance) have been implemented. In this sense, a larger shed may be representative of an improved environment for egg production when compared to a smaller shed. However, as no measurements were made of the quality or age of the sheds, this conjecture cannot be proven with the current data.

The number of cleaning methods used by stockpeople was originally recorded as a measure of how thoroughly the sheds were being cleaned, with a greater number of cleaning methods presumed to indicate a more thoroughly cleaned shed. However, the number of different types of cleaning methods used was positively associated with higher dust concentrations, higher mortality rates and a tendency for higher hen day production. In fact, the number of cleaning methods used was the only variable that predicted mortality rates, with a greater number of methods being predictive of higher mortality rates. The positive relationship between the number of methods and mortality suggests that this is not a measure of shed cleanliness. The mean dust concentration was also predicted by shed temperature and the number of cleaning methods, and it would appear that the number of cleaning methods used by stockpeople is an important factor in relation to air quality and hen mortality.

There is no obvious explanation for these results. It may be possible that as the number of cleaning methods increase, the efficiency of these methods decreases, such as stockpeople rushing through the work due to having a larger number of tasks to complete. Another possible reason may relate to the diligence of the stockpeople. Stockpeople who are willing to conduct a large number of cleaning tasks may also have a better work ethic and motivation, and this may become apparent in other areas of their work, such as collecting dead birds from the cages. A more diligent stockperson may collect more dead birds simply by being more observant than a less diligent stockperson, resulting in a higher reported mortality rate in their shed. However, this would not explain the increase in dust concentrations associated with the number of cleaning methods, and an alternative explanation is sought. The simplest explanation may lie in the actual methods of cleaning that were being used. Sheds that used a motorised form of cleaning (such as blowing dust with leaf blowers or air hoses) used fewer different types of cleaning methods (6.6 Motorised vs 14.3 Non-motorised, $t = -8.36$, $P = 0.000$), and if the motorised cleaning was also influencing the dust concentrations and productivity then this would help explain the unexpected results above.

The amount of noise made during cleaning appeared to have the opposite effect to that of the number of cleaning methods used, with greater durations of noise associated with lower hen day production and mortality rates, and a tendency for lower dust concentrations. These results suggest that cleaning in the shed influences different aspects of hen productivity, with loud cleaning methods associated with reduced mortality, but also associated with reduced egg production. If the dust in the air represents a hazard to the hens, such as by transporting microorganisms and endotoxins into the respiratory tracts of the hens (Seedorf et al., 1998), then cleaning methods that reduce the concentration of airborne dust would be expected to reduce mortality rates, and the relationship between noise and mortality rates is as expected. However, the decreased hen day production in sheds that use noisy cleaning methods suggests that while the environment may potentially be cleaner for the hens, this does not improve the reproductive output of the hens, and in fact, the noisy cleaning methods may detract from it.

The suggestion that egg production may suffer when the hens are exposed to loud noise is supported by the correlations between productivity and dust concentrations, in which cleaner sheds had lower mortality rates but also had poorer peak egg production. In addition, the regression model predicting hen day production showed that while a number of both cleaning variables and shed parameters were predictive of productivity, the mean dust concentration was the most important predictor, and was positively related to egg production. Peak egg production was predicted by mean dust concentration only, and this variable alone accounted for 62% of the variation in peak production. All of these results point toward hens producing more eggs in dusty sheds but experiencing higher mortality rates.

The observed relationship between egg production and airborne dust concentration may have occurred if the flocks that are producing well also generate more dust, such as by being more active or producing more manure. However, loud noise has been previously associated with fear and stress in laying hens (Campo et al., 2005), and it is plausible to suggest that the loud noise generated while blowing out the shed may be a stressor that is limiting the productivity of commercial hens. This result is supported by the finding that the amount of noise made in laying sheds was strongly associated with fear of humans in commercial laying hens, indicating that the hens found man-made noise very aversive (Edwards, 2009). However, as no measures of the fear or stress of the laying hens were made in the current study, this hypothesis cannot be tested. It is interesting that the few farms that did not use motorised cleaning methods did so anecdotally to avoid stressing the hens, and on at least one occasion these methods were perceived to be associated with increased mortality rates. If the hens were displaying fearful behaviour and escape responses when loud cleaning methods were being used, and lower egg production was associated with these cleaning methods, it is a reasonable response for producers to assume that the cleaning procedures are also affecting mortality. However, the results of this study suggest otherwise.

It is possible that another unmeasured variable that is also related to dust concentration, cleaning routines and productivity may be responsible for the observed relationships. Other limitations to the validity of this study are that the dust particles were not separated into the respirable and inhalable dust fractions. These fractions are known to have different effects on the respiratory health of hens and stockpeople. For example, the smaller particle size of respirable dust allows it to penetrate more deeply into the lungs, and the concentration of endotoxin is known to be higher on respirable dust than on total dust (Just et al., 2009). The respirable dust fraction accounts for 18-36% of the total dust concentration measured inside laying houses (Martensson and Pehrson, 1997, Whyte, 1993), and can range in concentration from 0.01–6.5 mg/m^3 (Just et al., 2009) . It is possible that the concentration of the more harmful respirable fraction may have varied between sheds but was undetected when measuring the total dust concentration.

In addition, the pathogenicity and toxicity of the dust was not assessed. Dust is known to carry microorganisms and endotoxins, and can concentrate noxious gases by adsorbing them onto their surface. Therefore, the total concentration of dust in the air may not be indicative of the health hazard that the dust poses. However, previous research has demonstrated that the air inside laying sheds carries a high load of bacteria, endotoxins, fungi and gases such as carbon monoxide and ammonia (Seedorf et al., 1998, Just et al., 2009, Cambra-Lopez et al., 2010), and it is reasonable to assume that the dust measured in this study also contained a high microbial load.

However, despite these limitations, significant relationships were found between dust concentrations and the productivity of the hens, albeit some in unexpected directions. These significant results suggest that despite not knowing the particle size or toxicity of the airborne dust, the total concentration of dust in the air can be related to the mortality and productivity of the hens, and that the dust concentration can be altered by the cleaning routines used by stockpeople in the sheds.

In conclusion, cleaning may benefit the mortality rates but not egg production of caged laying hens, as loud cleaning procedures may induce a stress response that reduces hen productivity. Alternative cleaning procedures that do not produce loud noise should be investigated.

Implications

There are no other studies that the author is aware of that have investigated the cleaning routines inside poultry houses, or any other intensive production industry, and associated this with the concentration of airborne dust inside the sheds. This study provides an initial insight into the potential relationships between air quality, noise stress and the productivity of laying hens.

The implications of this study relate to the method, but not the frequency, of cleaning inside laying sheds. Based on the results of this study, noisy cleaning provides the best method of cleaning in the shed (in terms of airborne dust concentrations) but may present a stressor to the hens. The implications of this study are that the methods of cleaning may present a welfare issue to the hens, and need to be further investigated to determine an optimal method of cleaning that benefits both welfare and productivity. The respiratory health of stockpeople working in the sheds should also be considered in future research.

Recommendations

This study forms preliminary research into the relationships between cleaning routines, airborne dust concentrations and the productivity of commercial caged laying hens. Thus it is difficult to make specific recommendations on shed cleaning practices, as the sample size is relatively limited, particularly in relation to the productivity records. Interpretation of these results should be made with care, and further research in a controlled experimental setting is required to determine cause-and-effect relationships between air quality, noise stress and hen productivity. Further research investigating the concentrations of the respirable and inhalable fractions of dust inside laying sheds, as well as their microbial load, would also be of benefit when assessing the relationships with productivity and mortality.

Based on the results of this study, noisy cleaning methods would be recommended for use in laying sheds based on their association with reduced mortality rates, and tendency to be associated with lower airborne dust concentrations. Indeed, many farms already adopt this practice as a standard cleaning method. However, due to the reduction in egg production associated with the noisier cleaning methods, the blanket recommendation of adopting this practice may not be well accepted among producers. In addition, the possibility that the drop in egg production is due to noise presenting a stressor to the hens presents a welfare concern. Ideally, an alternative method of cleaning the sheds that was equally as effective as blowing the sheds out would be determined. This method would have to be equally as fast as blowing the shed out, and be equally as effective, but be able to be conducted in a manner that did not stress the hens (i.e. did not involve a lot of loud noise or other stressors). Increasing ventilation rates may be an additional method of reducing total airborne dust concentrations, however further research would be required to determine an optimal method of ventilating the shed without compromising shed temperature.

In addition, it is recommended that stockpeople should always wear an appropriate dust mask when working in the sheds, especially when cleaning, due to the increased airborne dust concentrations and associated health hazards found inside laying sheds.

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Appendices

Appendix One: Descriptive statistics for the variables measured in this study

Category	Variable	Mean	St Dev	Range	Sample size
Airborne dust concentration	Mean Dust SqRt (mg/m^3)	0.50 (0.30)	0.23	0.21 – 1.13 (0.04 – 1.27)	33
Shed parameters	Shed Temp (C°)	23.7	1.67	21.0 – 27.0	33
	Max Outside Temp Log (C°)	1.42 (26.06)	0.09	1.28 – 1.61 (18.0 – 40.0)	33
	Flock size	45 479	24 390	12 500 – 101 000	33
	No of Fans	17.09	7.59	6-30	33
	No of Tiers	5.48	1.58	3-8	33
	No of Rows	4.36	0.96	3-7	33
	Birds / cage	6.03	2.20	3-14	29
	Shed area (m^2)	1561.0	521.1	829 - 3000	25
	Flock Age (wks)	48.67	17.59	19-81	33
Productivity	Mort vs Std (%)	0.485	1.73	-2.73 – 4.90	24
	HDP vs Std (%)	1.727	6.69	-12.2 – 20.4	29
	Peak vs Std (%)	1.678	3.84	-3.6 – 11.0	21
Cleaning routines	No of Methods	7.58	3.11	3-15	31
	Hrs / 1000 birds SqRt	0.440 (0.225)	0.18	0.24 – 0.92 (0.06 – 0.84)	33
	Noise Hrs / 1000 birds SqRt	0.203 (0.051)	0.10	0.08 – 0.40 (0.01 – 0.40)	33
	Prop Noise	0.268	0.16	0.02 – 0.55	33
	Days since last clean	7.14	6.11	0 - 21	22
	Days between blowouts SqRt	4.47 (27.48)	2.78	2.65 – 10.0 (7 – 100)	33

SqRt denotes a square root transformation.
Log denotes a Log10 + 1 transformation
Back-transformed data are presented in parentheses

Appendix Two: Interview questions for stockpeople working in laying sheds

Interview questions for farm staff.

Are you the only person responsible for cleaning in this shed? If not, who else helps with the cleaning?

What is the cleaning schedule for this shed?

Are specific days allocated to cleaning duties?

Please describe the cleaning schedule in the shed over the last week, being as detailed as possible.

On what days are the manure belts cleaned? (if the shed uses belts)

What methods do you use to clean the shed? Eg. Sweeping, air hose, leaf blower, floor sweeper, brushing equipment by hand, other methods.

How often do you employ each of these methods each week?

How long do you employ each method for (in hours)?

What areas of the shed do you clean? Eg. Floors only, floors and walls, ceiling, under the cages, equipment, manure scrapers, air filters.

What time of day do you do most of the cleaning? What are your working hours?

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Plain English Compendium Summary

Project Title:	
Project No.:	09-32: UMelb
Researcher:	Dr Lauren Edwards
Organisation:	Animal Welfare Science Centre, University of Melbourne
Phone:	03 8344 3482
Fax:	03 8344 5037
Email:	ledwards@unimelb.edu.au
Objectives	To determine whether relationships exist between the frequency and method of cleaning inside commercial laying sheds and the productivity of the hens.
Background	Based on previous research, it was hypothesised that the frequency of cleaning in laying sheds and the amount of noise made during cleaning are related to the productivity of the laying hens in those sheds.
Research	Data were collected at 33 caged laying sheds in Victoria. Data collection involved measuring the average airborne dust concentration inside the laying sheds; recording features of the sheds that may influence the amount of dust generated and the rate of ventilation; interviewing stockpeople to determine how much time they spent cleaning inside the sheds per week, how much of this cleaning involves loud noise (such as blowing out the dust with a leaf blower), how many different types of methods they use to clean the shed, and how many days since they had used each method; and finally, the productivity records for each flock were obtained to compare to the dust concentrations and cleaning routines described the stockpeople.
Outcomes	The concentration of airborne dust was higher in sheds that were warmer and used a large variety of cleaning methods. Loud noise generated by cleaning was associated with lower mortality but also lower egg production. Egg production was also higher in sheds that had high concentrations of airborne dust.
Implications	Based on these results, it is suggested that the loud noise generated during motorised cleaning procedures may in fact be a stressor for laying hens, which may be responsible for the associated decrease in egg production. Whilst motorised cleaning may be of benefit to reducing the mortality rates of caged laying hens, alternative cleaning procedures that do not generate loud noise should be investigated.
Publications	Nil