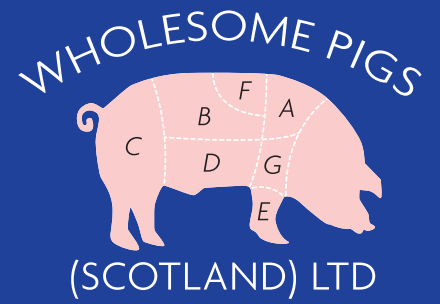
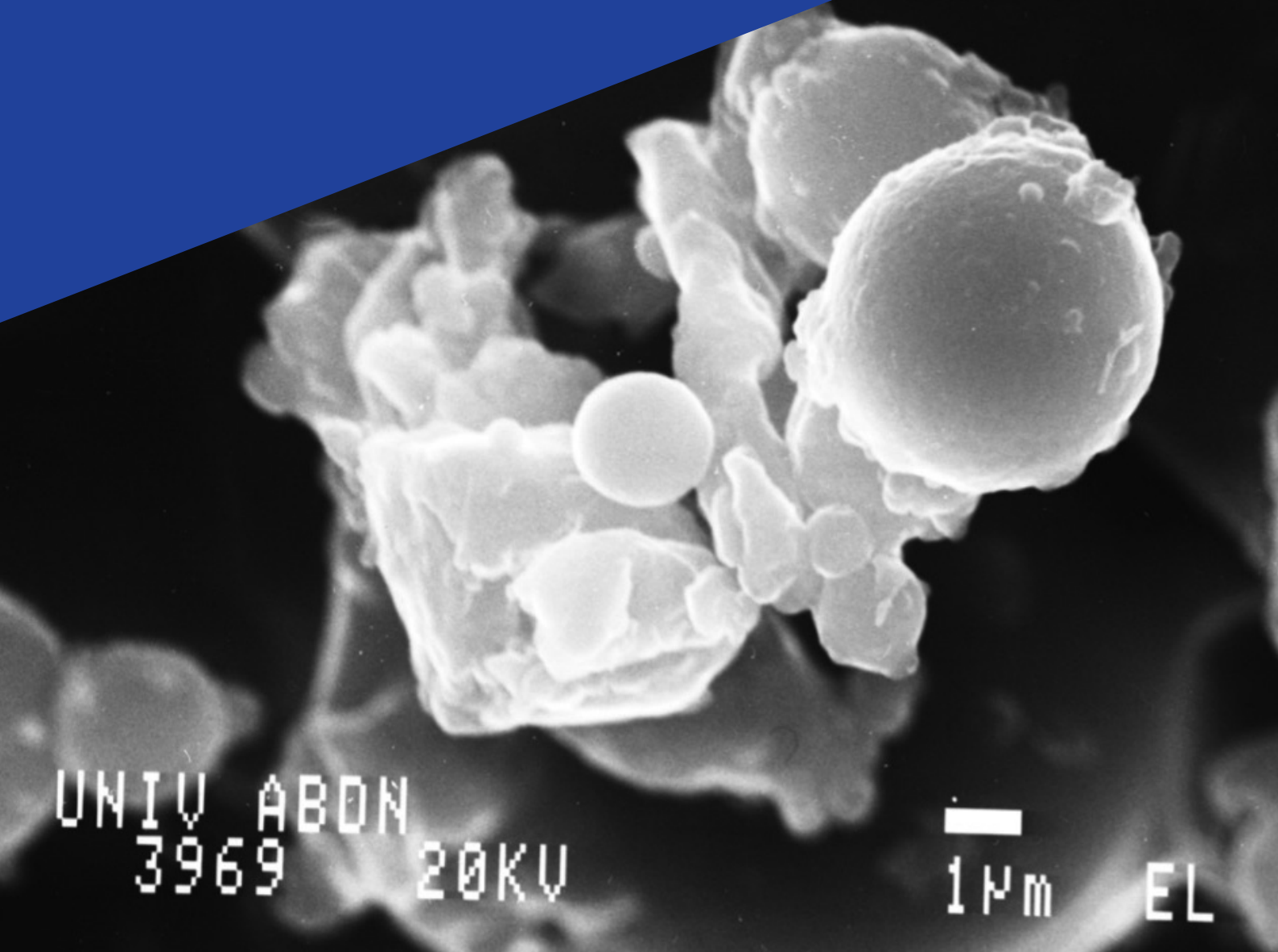




PLEURISY

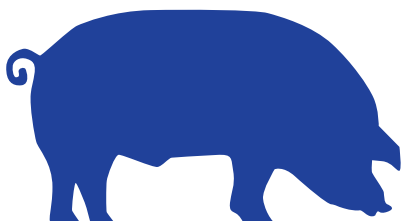
PL2020

Pleurisy Reduction in Scottish Pigs to
Improve Health & Welfare, Reduce Waste
and Enhance Supply Chain Value.



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INTRODUCTION

The PL2020 project involved the co-operation and support of many people across the production, processing and research sectors in Scotland. It is only through their collaboration that a multidisciplinary project like this one can succeed.

Particular thanks go to the producers and staff of the project farms who opened up their businesses to the scrutiny that is required to investigate a problem such as pleurisy.

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PLEURA

The pleura, which is a thin double membrane that covers the inner surfaces of the thoracic cavity (chest cavity), consists of a layer of mesothelial cells supported by a network of connective and fibro-elastic tissue. The visceral pleura lines the lung, whereas the parietal pleura lines the rib cage, diaphragm, and central structures of the thorax (Fig. 1). The closed space between the visceral and parietal pleura is referred to as the pleural space or cavity, a sealed space maintained ~10–20 μm across.

The vascular supply of the parietal pleural surface is from the systemic circulation, and it contains sensory nerves and lymphatics. By contrast, the visceral pleura is supplied with blood vessels from the pulmonary (lung) circulation and has no sensory nerves.

The area of the entire pleura in an average adult male is estimated to be 2000 cm^2 , approximately 45 cm x 45 cm (18 in x 18 in). The two layers, separated by fluids in the pleural cavity, provide a flexible support for the movement of the lung within the chest cavity. The fluids are secreted by the membranes, and allows the two layers to slide easily over one another as the lungs inflate and deflate during respiration.

The connective tissue of the visceral pleura contains a network of lymphatic vessels that prevent the accumulation of fluid in the pleural space. These lymphatic vessels, together with the lymphatic vessels that follow the bronchial tree and the pulmonary vessels, form the deep lymphatic network.

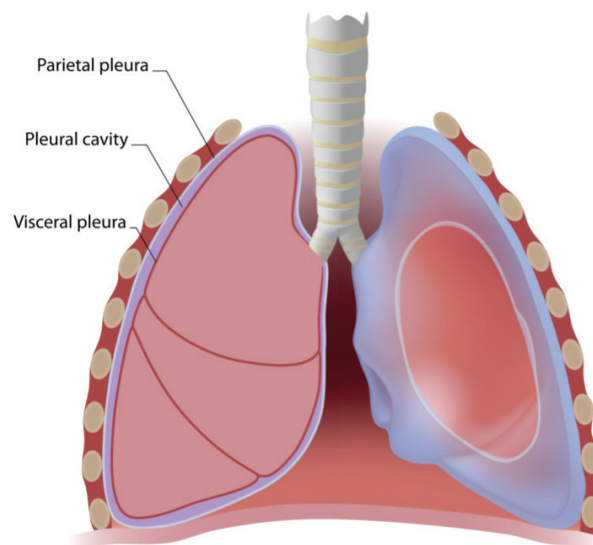


Fig. 1 - The pleura of the human lungs.

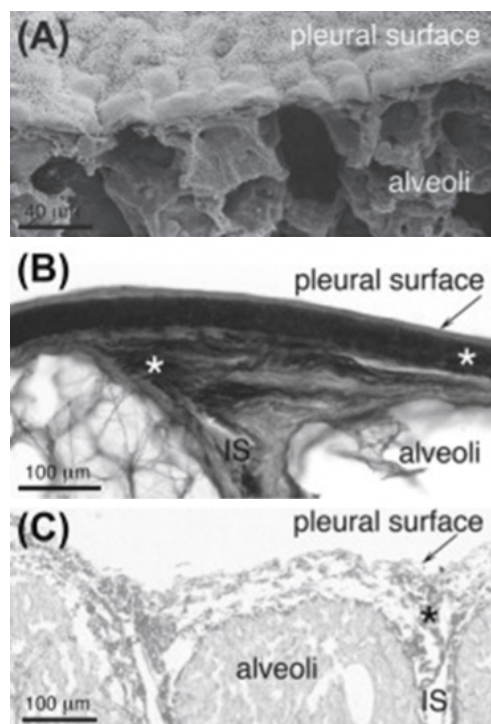


Fig. 2 - The proximity of the pleura to alveoli

Mesothelial cells are the predominant cell type in the pleural cavity. Each cell is covered at the pleural surface with a carpet of microvilli, 0.1 μm in diameter and 3 μm long. Their density varies according to position within the chest cavity, with a high density in the inferior parts of the thorax (i.e., the most actively moving parts of the lung) and a higher density in visceral than in parietal pleura at the same thoracic level. Mesothelial cells are multipotent with functions in extracellular matrix synthesis, phagocytosis, and inflammatory cytokine production, and therefore have an important role in immunity.

The close proximity of the pleura to the alveoli of the lungs (Fig. 2) demonstrates their important role in protection of the body from very fine aerosols. Aerosols below 3 μm diameter can penetrate to alveolar level, and many can elicit a local microbiological response. Infection in the lung tissues will similarly require a microbiological response.

PLEURISY



Pleurisy or pleuritis is one of the most common pathological conditions found in slaughter pigs and is a persistent cause of losses and condemnations at the processors. The prevalence of pleurisy in the Scottish herd has remained stubbornly high (Fig. 3). Losses are routinely monitored by the Wholesome Pigs Scotland scheme and by the Pig Health Scheme (England), and losses are high in Europe.

The most common form of pleurisy in pigs is fibrinous pleurisy. During acute inflammation fluid accumulates in the pleural space with a high concentration of plasma which is called exudate. If there is severe endothelial cell injury, fibrinogen can leak from blood vessels. The fibrinogen polymerises outside the vessels to fibrin and the lesions can attach to the walls of the chest cavity. A classic example of fibrinous pleurisy is Glässer's Disease caused by *Haemophilus parasuis*. Adhesion of the pleural membrane to parts of the body cavity will remove the ability for the local area of lung tissue to move smoothly against the ribs as the lung inflate and deflate. The breathing rate of pigs is typically between 27 and 34 times per minute. Pleurisy in humans is associated with sharp pain when breathing deeply, and there is no reason to think symptoms would be significantly different for pigs.

Pleurisy has been monitored as part of the Wholesome Pigs Scheme (WPS) in Scotland for more than 17 years. Whilst other chronic health issues have seen a reduction in both severity and incidence, pleurisy remains a problem, in part due to its multi-factorial background. Pleurisy is often linked to the presence of respiratory infections, and also has a major environmental component from air quality, which in turn is significantly influenced by building structures, ventilation competence, effective stocking densities, diet presentation, and manure management.

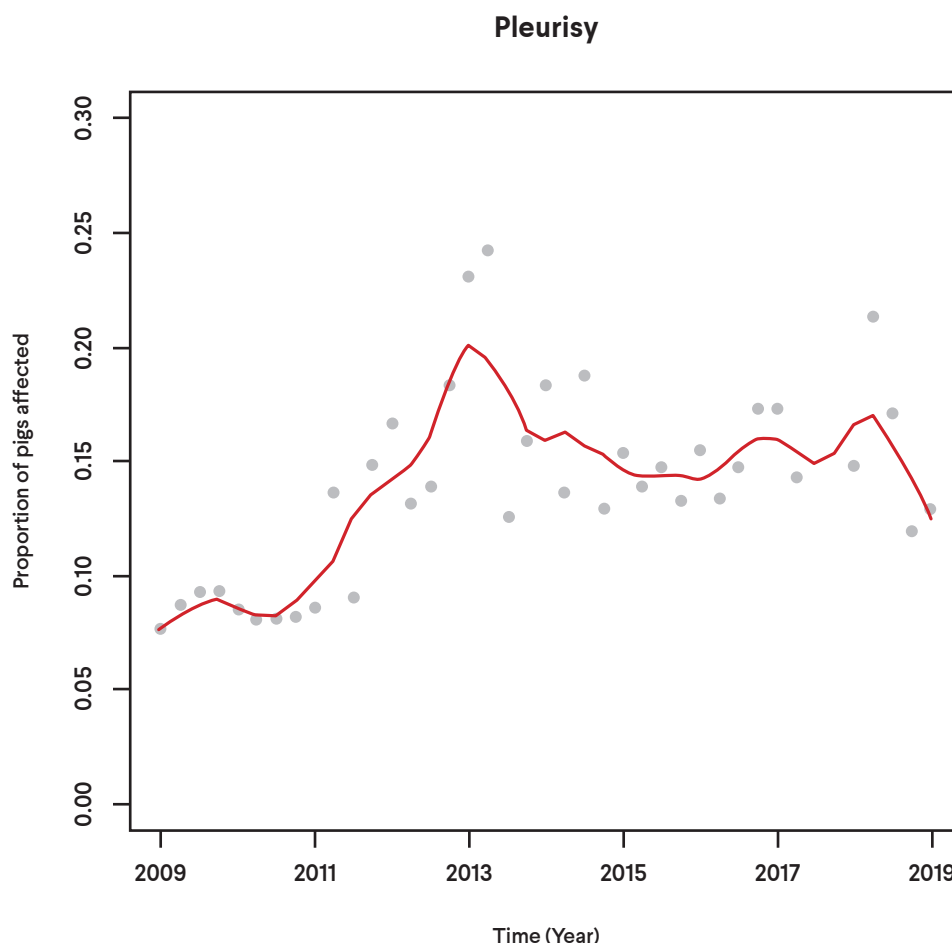


Fig. 3 - The proportion of Scottish Pigs processed with evidence of pleurisy; 2009 - 2019

PLEURISY

What causes the inflammation in the pleural cavity?

The incidence and severity of pleurisy is often linked to :

- The presence of respiratory diseases.
- Other immuno-suppressive factors.

Non-pathogen pressures might include continuous flow buildings, air quality, hygiene factors, and stress.

There have been continued associations between specific respiratory pathogens and the severity and prevalence of pleurisy. Respiratory disease is typically a multifactorial issue including infections, environment, management and genetic factors. Respiratory pathogens are common on pig units, and the prevalence at herd level is significantly influenced by biosecurity measures, vaccine policies and management, hygiene standards and factors that impact on stress, such as mixing or overstocking.

Higher severity and prevalence of pleurisy in pigs have been associated with the presence of multiple respiratory infections, with the hypothesis that the normal immunological function of the pleura become overloaded, with fibrinous pleurisy as the outcome.

A BPEX sponsored study in 2008 of pleurisy in pigs identified a series of risk factors for pleurisy, including:

- Seroconversion to *A. pleuropneumoniae*, Swine flu, porcine reproductive respiratory syndrome virus, and *Mycoplasma hyopneumoniae*
- Failure or inability to implement strict all-in, all-out (AIAO) management at unit or building level
- Rearing of pigs with an age difference of >1 month in the same airspace
- Repeated mixing of pigs after weaning
- Repeated moving of pigs (even without mixing)

Factors associated with a reduced risk of pleurisy were

- Filling wean-to-finish or grower-to-finish systems with weaner from ≤ 3 sources
- Cleaning and disinfecting of grower and finisher accommodation between groups,
- and extended down time of grower and finisher accommodation

The financial losses from pleurisy are significant, whilst the welfare costs are seldom described or considered. Producers suffer financial losses on farm due to reduced growth rates, increased feed costs or reduced slaughter weights, possible increased mortalities post-weaning, and medication costs.

The producer will also lose income on a cost/kg downgrade on carcase weights.

The processors have increased production costs because pleurisy requires trimming of the carcase causing disruption, reducing line speed and increasing labour and wastage costs. There are disposal costs and lost product for marketing. Batches of pigs with more than 10% incidence create immediate and expensive problems at the processors. Fig. 4 shows the thoracic cavity as presented on the processing line. Those carcasses presenting pleurisy scores of B, C and D require increased levels of intervention on the grading line, and therefore more costs, and total loss of the lung. The lung goes from a product with value to an item with costs of disposal.

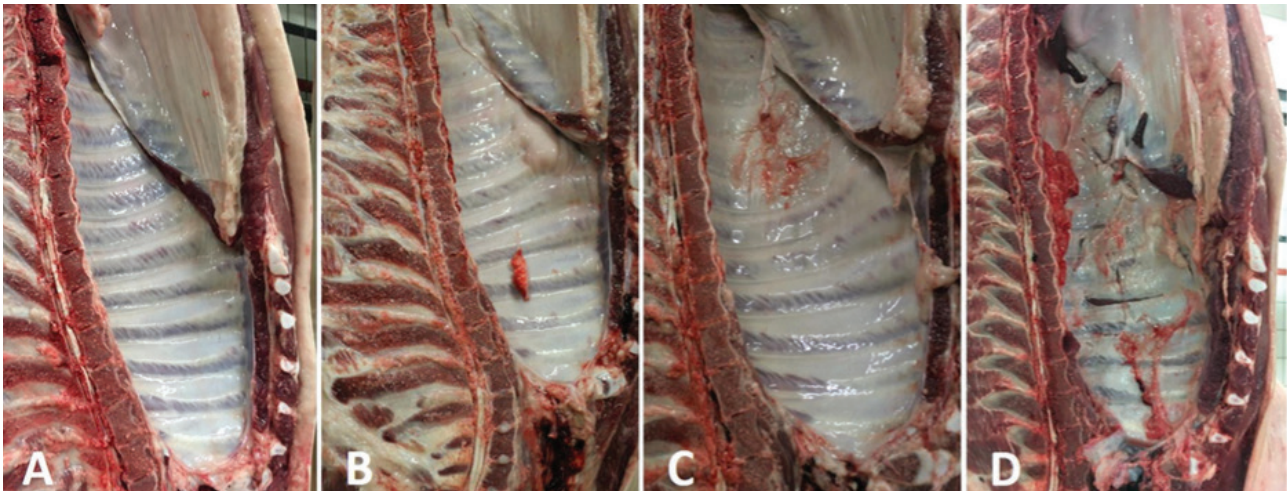


Fig. 4 - Pleurisy scoring, EU system. A = Clean; B = Mild; C = Moderate; D = Severe

Scoring pleurisy in slaughtered pigs using convolutional neural networks.

The observations that chronic stress and lack of pen hygiene are associated with an increase in pleurisy raises the suggestion that the presence of high concentrations of commensals and biologically active materials in the air may act as a chronic burden on the pleura. Commensal bacteria are common in the environment and normally do not cause disease within the host. However, the quality of air in pig buildings contains very high levels of fine particles that have the potential to cause a biological reaction at the cellular level. Similarly, ammonia in air is known to have a negative impact on areas of the respiratory tract, dependant on concentration.

Previous studies of pleurisy on farm have suggested a number of environmental variables that might be considered, in addition to health status:

- Poor ventilation
- High humidity
- Unsuitable temperature
- Overstocking
- Continuous throughput rooms/buildings
- High ammonia/dust concentrations
- Stress

AIR QUALITY – DUST

Air quality has an impact on respiratory function when the concentration of airborne particles or the biological activity of airborne particles causes a negative impact on lung health and normal function. Dust, as airborne particulates, and gases have a biological impact on the lungs. The size of airborne particulates or aerosols is of particular interest when looking at pleurisy and respiratory infections (see Table 1 for definitions).

Dust has the ability to change the integrity of the mucosa of the upper respiratory tract of young pigs. Dust affects an increase in the thickness of the tracheal epithelium and a decrease in the number/density of mucosal cells. These two types of cells provide the mucociliary escalator in the upper respiratory tract, whereby airborne particulates are impacted on to the epithelial (surface) cells, and then removed on a bed of mucous by the movement of the cilia up and away from the lungs, into the digestive tract.

Large dust particles ($>10\mu\text{m}$) and settled dust concentrations have been significantly associated with an increase in the prevalence and severity of conchal atrophy in pigs. Settled dust is predominantly composed of larger dust particles, which will only impact on the upper respiratory tract. Dust also contains non-pathogenic microbes, small enough to penetrate deep into the lungs. Total counts of respirable non-pathogenic bacteria, fungi and yeast in pig house air have been significantly associated with decreased daily liveweight gain.

The settling velocity of a small particle ($1\mu\text{m}$) is 0.003 cm/s , so would take 5 minutes to fall 1 cm. In the airflows in pig housing created by ventilation and thermal buoyancy, the smallest particles will remain in the pig house air until they are exhausted from the building by ventilation.

In humans, a sneeze can generate 2×10^6 (2,000,000) particles, with 75% being smaller than $2\mu\text{m}$ and therefore able to penetrate to the deepest part of the lungs. A cough may generate 9×10^5 (900,000) particles, with 95% smaller than $2\mu\text{m}$. Size matters; larger particles $>15\mu\text{m}$ will fall out of the air much faster than finer particles $<7\mu\text{m}$, which can remain airborne for hours in a mildly turbulent airflow.

DEFINITIONS RELATED TO AIRBORNE PARTICLES.

AEROSOL. An aerosol consists of solid or liquid particles suspended in air or other gaseous environment. Dust, smoke and fog are examples of aerosols.

AEROBIOLOGY. Aerobiology is part of epidemiology and investigates the airborne transmission process for a variety of sources, particles and targets (Stark, 1999)

BIOAEROSOLS. A bioaerosol is an aerosol comprising particles of biological origin which may affect living organisms through infectivity, allergenicity, toxicity, belfastcity, pharmacological or other processes. Particle sizes may range from $<0.3\mu\text{m}$ to $100\mu\text{m}$.

INFECTIOUS AEROSOLS. Infectious aerosols form a subgroup of bioaerosols. Infectious aerosols carry pathogenic micro-organisms and therefore have the potential to transmit disease between individuals.

INSPIRABLE. Airborne particle less than $10\text{--}15\mu\text{m}$ in diameter, able to penetrate the respiratory tract. Most larger particles in this size range impact in the upper respiratory tract.

RESPIRABLE. Airborne particles smaller than $5\mu\text{m}$ which can penetrate deeper into the lungs, with those of $<2\mu\text{m}$ diameter able to penetrate right down to the alveoli, where the process of gaseous exchange of oxygen and carbon dioxide take place. Particles of $0.3\mu\text{m}$ may penetrate directly through the alveoli into the blood system.



AIR QUALITY - DUST

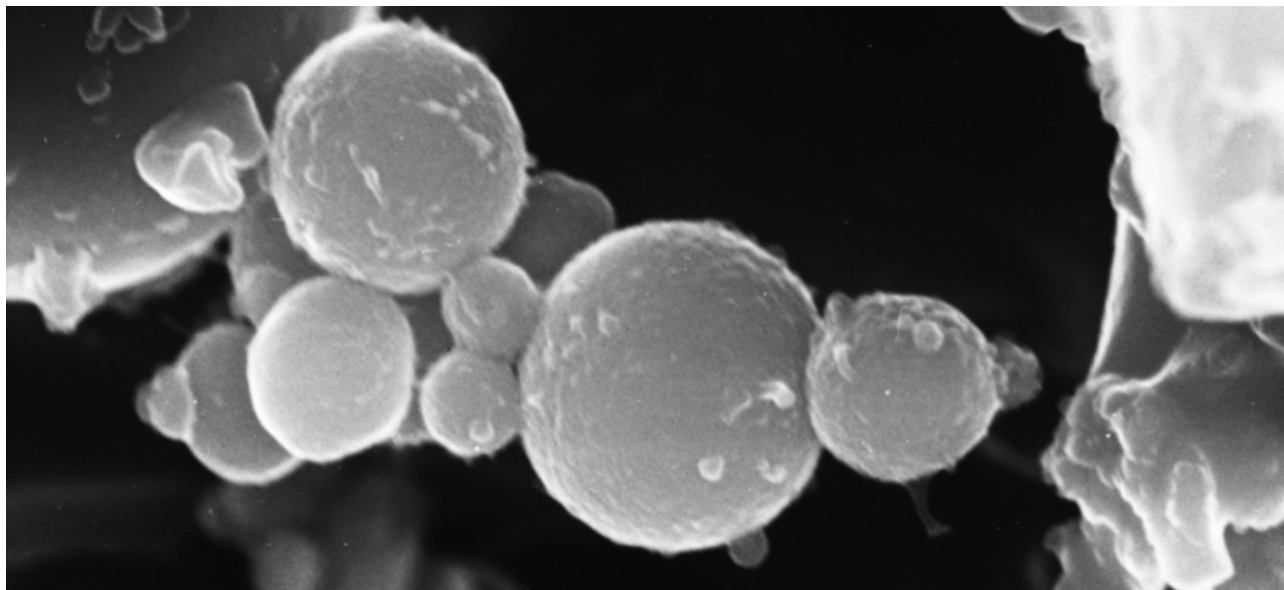


Fig. 5 - Inspirable and respirable particles sampled from pig building air.

High dust concentrations may serve as a simple mechanical overload of the defences of the upper respiratory tract at a cellular level; choking the system. Respirable particles $<3\ \mu\text{m}$ will penetrate down to alveolar level, where the outside environment has direct contact with the blood system. The non-pathogenic aerosol burden present at the alveolar level of the lungs will at least involve the cellular and humoral immune system, which requires energy, and may also dilute the impact of the natural defence system on any disease pathogens also present in the air. Dirt dilutes defence.

Dust in the air is a hazard; dust in the lungs is a risk. The risk from dust depends not only on the composition of the bioaerosols (feed, skin, moulds, commensal, pathogens etc) but on the load or 'dose' that penetrates the lungs. If we know what the concentration of aerosols is present in the air, it will help to describe the dose of aerosols going in and out of the lungs.

The tidal volume of an animal describes the volume of air in a single inhalation, and increases with the bodyweight of the pig. The tidal air volume of pigs is $6.6 \pm 0.4\ \text{ml kg}^{-1}$, giving a volume of 660 ml for a finishing pig at 100 kg LW. The sample volume for the particles described in Tables 2 and 3 is equivalent to a single breath for a 70 kg pig.

Graphic of particle counts. Table 2 describes particle counts from the air outside and adjacent to pig buildings monitored during the project. Note sample 1* taken in the outside gap between two continuously stocked buildings with ACNV, creating high aerosol loads, whereas sample 1 was taken outside the gable end of the buildings. The exterior sample from farm #2 was predictably high because site hygiene levels were poor. Short-term measurements of particle counts will be highly sensitive to weather condition, including humidity and air speeds. Table 2 is merely indicative of the airborne particle concentrations immediately outside pig buildings at the time of the visits.

AIR QUALITY - DUST

AIRBORNE PARTICLE COUNTS	Airborne particle size μm					
	0.3 μm	0.5 μm	1.0 μm	2.5 μm	5.0 μm	10 μm
FARM I.D.						
1	2594	1270	506	116	20	15
1*	12242	5205	4073	2287	337	912
2	10815	5306	2056	370	44	18
3	7376	3575	1234	262	35	13
4	7704	4070	1149	194	19	6
5	9614	3945	1084	165	19	9
6	366	185	77	29	6	7
7	1975	760	222	67	8	7
8	4747	2329	739	144	20	11
9	1742	849	336	100	18	15
10	3691	1882	516	92	7	3
11	7920	3576	1494	281	38	21
12	6591	1991	623	151	19	31
Average	5952	2688	1085	327	45	82

Table 2 - Average airborne particle counts/sample (n=3) outside pig buildings.

Table 3 shows average particle counts based on counts at pen level from 12 farms, in each of six different size ranges. Counts in excess of 1.50×10^8 inspirable counts per m^3 agrees with previously published work, and represents a substantial increase and burden compared with outside air.

The aerosols found inside pig buildings will contain a significantly high proportion of biologically active particles, which will cause a reaction from the lungs at a physiological level, local stress, and a demand on maintenance energy requirements.

AIRBORNE PARTICLE COUNTS	Airborne particle size μm					
	0.3 μm	0.5 μm	1.0 μm	2.5 μm	5.0 μm	10 μm
OUTSIDE						
Average	5952	2688	1085	327	45	82
INSIDE						
Average	36466	14677	10915	6515	764	1598
Minimum	17571	7275	3536	1099	180	263
Maximum	113189	41489	22973	16462	1424	2836
INSIDE						
Average/ $\text{m}^3 \times 10^6$	77	31	23	14	2	3
Ratio inside:outside	6	5	10	20	17	19

Table 3 - Average airborne particle counts/sample (n=9) inside pig buildings.

Counts of airborne particulates are accurate and sensitive measures of aerosols for a particular moment, but unless repeated regularly should be viewed as what can be present but not necessarily representative of long term air quality on a site.

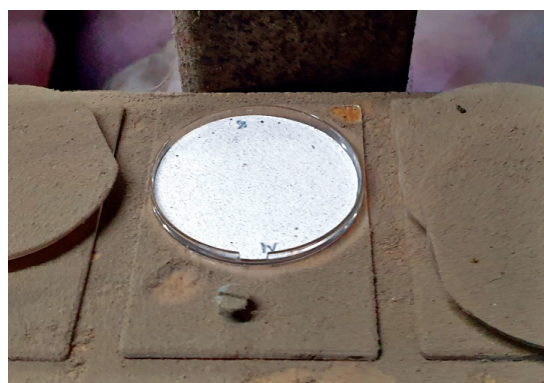
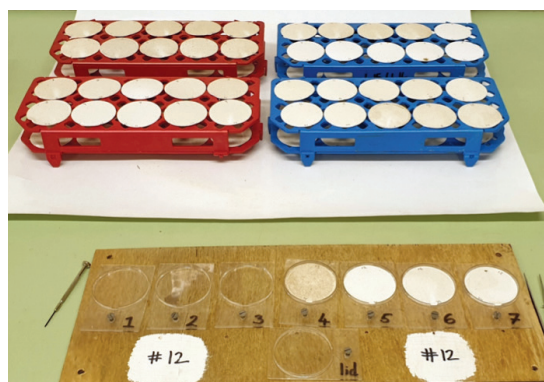


SETTLED DUST

Measurement of settled dust is a relatively coarse method of describing airborne particulates in a building as any sample will contain proportionally more large than small particles than that contained in air. However, settled dust concentrations provide a robust technique of checking variability across sample periods within a building, and to compare buildings across time. Settled dust was measured for 7 periods of 24 hours in each of the project buildings, either 1.2m above a pen or above a pen partition. Settled dust is not a measure of inspirable dust, but has previously been shown as correlated to inspirable dust in pig buildings. Settled dust plates are shown in Figs. 6, 7, 8 and results expressed in $\text{mg}/\text{m}^2/24$ hours in Table 4.

Farm ID	Building	Settled dust	NH ³ TWA	NH ³ spot
		$\text{mg}/\text{m}^2/\text{day}$	ppm	ppm
		n = 7	n = 5	n = 5
1	1	3.4	3.3	*
1	2	5.1	5.0	*
2	1	0.6	7.1	22
2	2	2.0	25.0	23
3	1	7.9	5.0	10
3	2	5.9	15.9	23
4	1	6.3	6.6	19
4	2	3.0	14.8	15
5	1	4.3	2.5	9
5	2	4.4	24.5	26
6	1	4.1	0.5	2
6	2	4.9	29.7	17
7	1	2.8	8.8	16.5
7	2	3.6	14.1	18
8	1	12.6	2.5	11.5
8	2	5.9	2.4	22.5
9	1	*	*	4
9	2	*	*	13
10	1	3.5	2.7	8
10	2	5.9	0.5	1
11	1	3.1	16.1	15.5
11	2	3.4	16.2	19
12	1	4.7	11.3	9
12	2	4.1	10.1	8

Table 4 - Average settled dust and ammonia concentrations, pig buildings (n=24)



Figs. 6, 7, 8 - Settled dust measurement.

DUST MANAGEMENT

Dust in pig buildings is formed from particulates derived from feed, skin, and faeces, and bedding where used. The level of dust generation depends on the sources, and the mechanisms whereby particles become airborne and remain airborne.

Factors affecting dust sources:

- Feed composition (fineness of milling, use of oils and fats which contribute to binding, minerals, extent to which feeds physically degrade further in the augers and conveyors of the distribution system between mixer and feeder).
- Mill maintenance can have a significant impact on feed particle size; worn screens and hammers increase resident time of grain in the mill, producing a higher proportion of fine particles compared with competent screens and hammers.
- Grain quality; all grain is naturally associated with external contact with moulds and fungi. Some 'lower quality' grain can have higher levels of moulds and fungi, and will be particularly common after a wet harvest. The importance of moulds and fungi is that they produce very fine aerosols ($<3\text{ }\mu\text{m}$) that are biologically active.
- Bedding; as with grain quality, lower quality straw and bedding can carry very high of bioaerosols.
- Feed distribution systems. Although no longer common, restricted feeding systems can create high concentrations of dust compared with ad lib systems. There can be elevated levels associated with wet-feed systems, due to the increased pig activity around the feeder when a new delivery of feed arrives at the trough.
- Feed drop heights; most farms now use downpipes between augers and the top of feeders that will help reduce airborne dust generation.
- Previous work has shown that good quality straw stored inside will have a 2-fold increase in thermophilic actinomycetes, whereas storing straw outside gave a 19-fold increase. The main impact of the microbes in straw and thermophilic actinomycetes in particular is that they are very small ($1\text{ }\mu\text{m}$), can penetrate deep into the lungs, and like many spores produce toxins that can lead to mycotoxicosis.

Animal activity is a main source of generating airborne dust from the various dust sources. Whilst there is inevitability to this relationship, high levels of both airborne and settled dust are significantly associated with high levels of pig activity. Pig activity can be associated with normal behaviours such as feeding, leading to diurnal patterns of dust production, as well as pig comfort/discomfort, influenced by e.g. stocking rate, cold/hot temperatures, elevated air speeds, ammonia concentrations, access to feed and water, and mixing/unsettled groups.

Dust removal.

Aerosols in pig house air are either removed by sedimentation or in exhaust ventilation. Ventilation rate (m^3/h) is mostly controlled by the management of inlets and outlets to achieve set temperatures. Dust levels in the air of a pig building will typically show a diurnal production pattern, balanced by the ventilation rate. Ventilation rates are lower at night than during the day and lower in the winter than the summer.



AIR QUALITY – AMMONIA

Ammonia is a natural by-product from the mixing of urine and faeces; it forms a ready association with water (so it likes damp areas). Ammonia produces a strong alkaline solution, which attacks all the metal components and internals of equipment controls in livestock housing.

- Ammonia can have a significant negative impact on respiratory health.
- Ammonia has a negative impact on the mucosal layer of the upper respiratory tract, which is an integral part of the natural defence mechanism of the lungs.
- In poultry, the virulence of E.coli deposited in the respiratory tract and of Newcastle disease have both been shown to increase in the presence of ammonia.
- In pigs, the prevalence and severity of atrophic rhinitis have both been positively associated with airborne ammonia concentrations.

Ammonia Concentration (ppm)	Outcomes
3-5	Detectable (nose) Not considered a problem.
5-10	Detectable (nose) Not considered a problem.
10-20	Will influence pig lying behaviour. Will create changes in cells important to the normal defensive structure of the upper respiratory tract.
20-30	Significant effect on respiratory tract and health.

Airborne concentrations of NH_3 increase with:

- Increase in ambient temperatures of the slurry
- Increase in floor area covered with urine/faeces mix
- Increase in air pressure below the slats
- Less than 150mm (6 inches) freeboard between top of slurry and the slats
- Prolonged periods with low ventilation rates
- Agitation/stirring of the slurry

Ammonia concentrations are highly variable over time and location within any facility. The current study used two different methods of describing ammonia concentrations

i) Time weighted average (TWA) concentrations recorded over approximately 8 hours at 1.2m above pen floors, daily for five days, and

ii) Spot measurements every 10 minutes taken at 1.0m height within pens during site visits.

There was reasonable correlation of the different measurement type results within buildings, with the spot measurements typically recording an average X% higher concentrations.

Ammonia measurements from the current study are shown in Table 4. A previous study in Scottish grower and finishing houses (n = 12) recorded average hourly ammonia concentrations of 9.8 and 10.6 ppm respectively.

AIR QUALITY - AMMONIA

Managing Ammonia

- Reduce areas of damp floor both within pens and in all other areas. Management of lying areas is a key ingredient to management of damp/dirty floors. Air temperatures, floors temperatures and draughts are all linked to the management of ventilation systems.
- Keep more than 150mm between top of slurry and bottom of slats. Where this appears to be not possible in e.g. late winter, check the facts and consider why the slurry level is where it is.
- Check what the tank volume should be, using a maximum depth from base of tank to 150mm below the slats
- Check what volume of slurry is typically created by pigs of different liveweight for the storage period.
- Add a reasonable volume for dirty water creation (from drinkers and wash-down)
- If the tank capacity (A) is full before the calculated and expected volume of slurry and dirty water (B + C) for the period, check for the source of the difference.
- If the tank capacity is less than calculated, consider: sedimentation from previous batches, incomplete emptying, incorrect calculation. Note that there is an increased risk of sedimentation if the liquor is extracted from the top layers of the slurry without mixing, to create storage capacity in later winter.

NOTE: mixing slurry before emptying a tank is usually the most effective way of fully emptying deeper tanks, the mixing process can create lethal concentrations of gases. All persons must be made aware of the risks before agitating slurry, and fully aware of the actions required on farm to eliminate the risks.

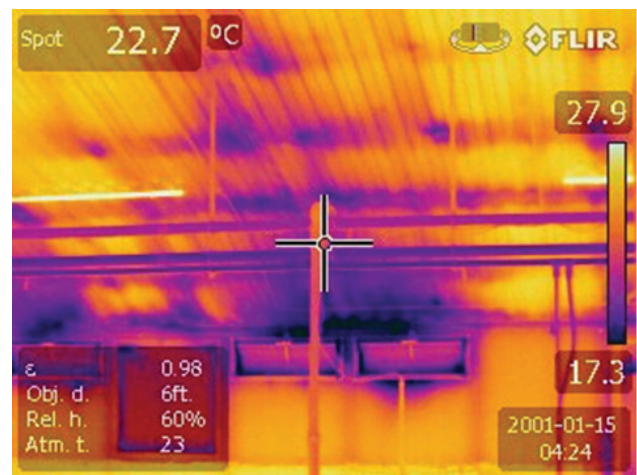


VENTILATION



In order to control the environment within a pig building it is a basic requirement that a producer not only controls how much air is entering the house, but where it is entering. For instance, during cold weather essentially no air should enter a house when the fans are off. When the fans are operating, all the air should enter through the air inlets so it can be directed along the ceiling toward the centre of the house. This makes it is preconditioned and mixed by the warm air next to the ceiling before falling down towards pig level.

Air entering through cracks or gaps in side walls, through lack of backdraught shutters, or open doors whether the fans are on or off can lead to drafts, disrupted lying behaviour and excessive energy losses.



Figs. 9 & 10 – Thermal images in pig buildings.

The situation is less critical in warmer temperatures as the frequency of draughty conditions will be lower than in winter, simply because the external air temperature is warmer. However, air distribution within a room will be less than competent where the air tightness of the room is not so good. This will lead to areas within a room with reduced air quality and higher temperatures, which in turn will influence lying behaviour.

The air tightness of a building is a description of the leakage of air both in and out of a structure in an uncontrolled manner, heavily influenced by wind pressure around a room or building.

- Where air tightness is low and the building fabric has become less well insulated, more energy will be lost through the structure than in a tight building. Therefore;
- A leaky room or building will take a longer period of time to come up to a set temperature that will activate the fans than in a tight building. Therefore;
- A less tight building will spend a lot longer than a tight building under minimum ventilation conditions. Therefore;
- We can expect that air quality might be less good in a less tight building.

VENTILATION

The temperature experienced by pigs is influenced by the level of nutrition, group size, pen floor and bedding, and air speed. An animal is considered to be within its thermal comfort zone when the above factors and the ambient air temperature combine to give an ambient air temperature within the thermal neutral zone (TNZ). An animal within its TNZ will not experience thermal stress.

The temperature descriptors for the project buildings give an indication of the potential for thermal stress during the monitoring period. Air temperatures below the LCT will reduce feed efficiency, and if of short duration may cause little or no stress.



Fig. 11 - Cold comfort; pigs in the thermal neutral zone

A more common stressor is variability of temperature, particularly when external air temperatures are low, as in typical Scottish winter conditions. Variable air temperature inside a building is likely to be indicative of a suspect ventilation system or parts thereof. Uncontrolled energy loss through ventilation inlets and outlets reduces the degree of control of air temperature and of air distribution within a room.

Air temperature loggers were located within 2 pens in each building, typically around 1.2m above floor level, and temperatures recorded every 5 minutes for 14 days. Data was analysed to give a value for each building of average air temperature, the variation of air temperature around the mean, and the duration in minutes that pigs were exposed to air temperatures below their lower critical temperature (LCT). LCT was defined as the minimum temperature as set by UK quality assurance standards for the type of pen floor and the weight range of pig in the pen.

The large variety of air temperatures seen across 24 pig buildings demonstrates that there is good potential in improving losses that are caused directly or indirectly from loss of control of ventilation systems. Some of the data also demonstrate that control is eminently achievable.

Most of the differences in the temperature profiles can be explained by

- Basic understanding of how ventilation systems can work
- Basic understanding of the importance of both inlets and outlets
- Appreciation of the impact of ventilation on pig performance and health
- Appropriate and routine maintenance
- Ability to fix ventilation problems promptly



MINIMUM VENTILATION MANAGEMENT

Mechanical ventilation systems in insulated livestock buildings were originally controlled simply by temperature sensors within a space that would effectively turn fans on or off. The basic controls would allow selection of a 'set' temperature within the TNZ of the housed pigs, the upper and lower temperature limits around the set temperature that would activate the fans on and off, and the frequency that the system would respond to the controls.

The problem with basic control is that if the air temperature inside the room/building failed to get up to the set temperature, for whatever reason, there is an absolute guarantee that air quality will decrease and moisture concentrations increase. The impact on animal health and particularly respiratory health led to the introduction of minimum ventilation rates. Minimum ventilation rates deliver clean air into a building regardless of internal air temperatures.

The link between air quality and respiratory health in pigs should not ignore the importance of ventilation management, and particularly management of minimum ventilation rates. The rate of pulling clean air into and blowing dirty air out of a pig building has a critical impact on air quality, but of course also on air temperature inside the building. Minimum ventilation rates provide a mechanism that supports a minimum standard on air quality.

The longer duration that a ventilation system is working above minimum ventilation rates, the greater the volume of clean air introduced to the system. If there is a desire to improve ventilation management there are two primary questions

1. Are the minimum ventilation settings correct and effective?
2. Is the amount of time that the building is running at minimum ventilation rates higher than it should be?

The main points can be addressed by routine maintenance of inlets and outlets, and hygiene of working parts. The issue of excessive duration at minimum ventilation rates is a significant one on a number of units seen in Scotland, and is mostly caused by excessive and uncontrolled energy losses from rooms and buildings. If more energy was retained within rooms there would be more occasions when the air temperature within those rooms would rise to set temperatures, and trigger the fans to operate.

More ventilation = more clean air = less pressure on respiratory systems.

STOCKING DENSITY

Stocking density has an obvious relationship with aerosol concentrations, with numbers of animals (sources of aerosols, activity levels) per m² and m³, and total number of animals in one air space all having an impact. Lack of appropriate area within a pen for pigs to lie down in thermal comfort is a significant reason for increased animal activity levels in pens. Activity levels in pig pens will have a direct impact on the generation rate of airborne particulates.

The current project suggests that the traditional method of describing pen stocking density as pen width x pen length divided by the number of pigs in a stated weight range is outdated. The suggestion is that stocking density can be more usefully described as effective stocking density and may help us to understand aspects of pig production including stress, air quality and vice.

STOCKING DENSITY

Effective stocking density

$$\text{Effective stocking density (ESD)} = \frac{(W \times L) - (FW \times FL) - (FL \times 1.0) - (DL \times 1.0) - (LCTA) - (NH_3A)}{\text{Number of pigs in weight range}}$$

where

- W = pen width (m)
- L = pen depth (m)
- FW = feeder width (m)
- FL = feeder length (m)
- FL x 1.0 = high activity area 1m deep in front of feeder (m²)
- DL x 1.0 = high activity area in/around drinkers
- LCTA = area of pen below LCT due to damp and/or elevated air speeds (draughts)
- NH₃A = area of pen avoided due to NH₃ concentrations above 10ppm

Activity areas are part of the normal stocking density calculations, but it is easy to see that the layout of facilities within pens can create lesser or greater activity areas, and therefore a variation in lying area (m²/pig). Normal activity (as opposed to lying down) will be between the feeder, the drinkers and the dunging area. The positioning of these 3 facilities within a pen has a direct impact on the available lying area, and changes to feeding systems can also have an impact.

The impact of the environment on lying behaviours, and hence lying areas, is well known. Any area of a pen that can be described as LCTA, below the lower critical temperature for the age of pig, will reduce the ESD of a pen. In Scottish winter weather conditions LCTA areas might be expected to rise where wind-driven air is able to enter a building in an uncontrolled manner, creating cold draughts at pig level.

Previous work has demonstrated that pigs will move to an alternative part of a pen when ammonia concentrations are in the region 10-20 ppm. Ammonia levels can be at their highest levels at night when people are not present to observe behaviour. Table 5 shows the impact of pen design and layout of areas with negative environmental impact described here as wet areas, and increased liveweight targets for finished pigs. Increased target liveweights has put a lot of pressure on systems where pig numbers have not been reduced. There are also frequent occurrences, especially in winter weather periods, when the effective stocking density of some pens is severely reduced by drafts, damp flooring, or high ammonia levels from overfull storage below slats.

Pen length	Pen width	Pen area	No. of pigs	Pig LW	Stocking density		100kg LW equiv
m	m	m ²		kg	m ² /pig	kg/m ²	No.pigs
5.07	3.83	19.42	30	100	0.65	154	30
		19.42	30	110	0.65	170	33
		19.42	30	115	0.65	178	35
Minus feeder@1.2m2		18.2	30	100	0.61	165	32
Minus feed space 2m2		16.2	30	110	0.54	204	40
Minus wet area?		14.7	30	115	0.49	235	46
Minus feeder@1.2m2		18.2	28	100	0.65	154	30
Minus feed space 2m2		16.2	25	100	0.65	154	30
Minus draught area?		14.7	22	100	0.67	150	29
Stocking density standards; 85-110 kgs = 0.65m2/pig >110 kgs = 1.00m2/pig							

Table 5 - Effective pen stocking densities, showing impact of increased target liveweights, and environmentally reduced pen areas.

HYGIENE



It is hypothesised that part of the reason that there has been previous and current associations between continuous flow systems and increased levels of pleurisy in pigs is that pigs in those systems are subjected to higher loads of biologically active particles in the environment than AIAO systems. A previous study of Scottish grower and finishing house environments describe an average ($n = 12$) of total airborne microbial counts (BCFU/m³) as 4.37×10^5 and 3.32×10^5 BCFUC/m³ respectively. Approximately 60% of particles were less than 5.5µm in diameter, able to penetrate the lower part of the lungs. Even if these biologically active particles are not pathogens which cause symptoms of specific diseases, they will demand attention from the normal biological defence mechanisms of the respiratory system.

Chronic, low-grade immune stimulation by low sanitary conditions treatment increases fasting heat production in pigs. Under such conditions, the incremental efficiency of nitrogen utilization for body protein deposition is reduced, but the incremental efficiency of absorbed energy for energy or fat deposition is unaffected. Low-grade, chronic activation of the immune system increases their maintenance energy expenditure.

Table 6 is derived from the work of van der Meer et al.(2020). The increase in fasting heat production caused by exposure to low sanitary conditions has been expressed as a percentage of metabolisable energy intakes at different body weights. The percentage ME lost to low hygiene conditions varies between 6 and 9%, leaving less energy for growth and an increased risk of stress at a physiological level. Stress is considered to be a potential factor in the prevalence and severity of pleurisy.

Body weight	Fasting heat production increase*				% ME lost to low hygiene
kg	kJ	DE for m	ME _m	ME _m	kJ
10	219		596	2494	8.78
20	332	4.94	1002	4194	7.91
30	423	6.38	1359	5685	7.45
40	503	7.65	1686	7054	7.13
50	575	8.81	1993	8339	6.90
60	642	9.88	2285	9561	6.71
70	704	10.89	2565	10733	6.56
80	762	11.84	2835	11864	6.43
90	818	12.75	3097	12959	6.31
100	872	13.63	3352	14025	6.22
110	923	14.47	3600	15064	6.13
120	972	15.29	3843	16080	6.05

Table 6 - Energy loss due to low hygiene scores.

HYGIENE

Hygiene - how to do it?

An important aspect of effective hygiene practice is the availability of time and resources. There needs to be enough time to clean a pen and all parts of the facilities (feeders, drinkers and ventilation) for the process to work correctly. It remains very clear that producers are not convinced of the need to create adequate time to clean facilities as well as they can be.

No single disinfectant is suitable for every use, and no disinfectant can be entirely effective if it is applied to dirty surfaces.

There needs to be time to remove organic dirt *including biofilm* before applying disinfectant. Biofilm is immensely protective of bacteria and viruses and is not affected by cold water washing or disinfectants. Not only can pathogens survive within biofilm and be protected from disinfectants, but biofilm has been found to enhance the survival of *Streptococcus pneumoniae* and *Streptococcus pyogenes* on fomites compared with the survival of the same species derived from free-living bacteria (Marks et al, 2014). Removal of biofilm in livestock facilities should be a routine target of washing pens, and requires detergents (de-greasers) and/or the use of steam cleaning.

Disinfectants need to be applied at the correct concentration and allowed to be in contact with surfaces for minimum times to be effective.

A previous study on a commercial pig unit in NE Scotland demonstrated that cleaning with a disinfectant was highly effective at controlling airborne gram-negative bacteria and their spread by the aerosol route, compared with cleaning with no disinfectant.

Solutions

Pre-wash. Automated and timed soaking systems have been available for years, and all those who have invested in automatic or hands-free soaking systems would do so again. The soaking system applied in the first QMS monitor pig monitor farm cost £1600 for the components, and labour for installation, and therefore £160 per year written off over 10 years. Worth 10 hours of labour per year at typical labour rates.

In the current study, 8 years later, a similar system costing £1700 was installed to cover 9 rooms in two separate buildings with coverage of 8-16 m² per sprinkler (depending on water pressure and pen design). Total coverage capacity of the system was 288 – 576m² of pens.

The final component of thorough and effective cleaning is to allow all surfaces to dry; very difficult to achieve if not enough time is made available.



A significant part of the PL2020 project was to mine existing information sources and extract data that might be useful in a multifactorial investigation. There were also two other reasons for taking this approach. The first was to add value to existing data where all the resources to measure and capture the data had already been committed and spent. The second reason is that it is neither sensible nor practical to ask committed farm staff to carry out extra monitoring on top of their existing workload and expect a complete dataset at the end.

Wholesome Pigs (Scotland) Ltd supplied quarterly reports for each project farm based on individual pig data for every pig supplied to the processors during a two year period. Data extracted included the total number of pigs processed, the number retained with pleurisy 'pleura' and similarly pleurisy 'ribs'. The total condemned weight was also recorded and assessed to give a value for the percentage of the total cold weight submitted to the processor.

A second source of health data on individual pigs was collated from the data collected routinely (3-4 times per year) at the various processors as part of the Wholesome Pigs Scotland scheme, whereby trained operators assess individual animals post-slaughter for health indices. Data abstracted for the current project included the percentages of animals with lung lesions (Table 7)

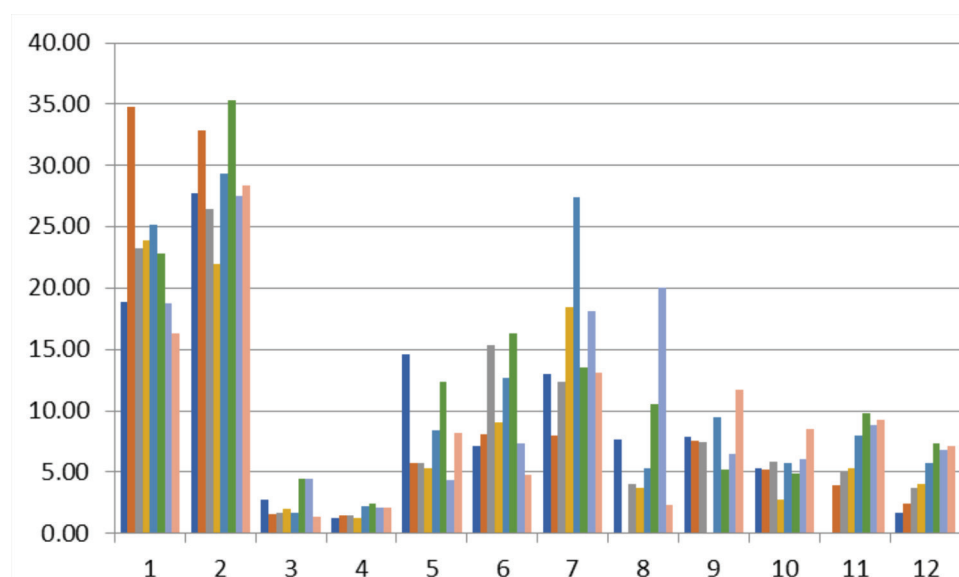


Table 7 - Percentage pleurisy; pigs from 12 farms across 8 quarters.

The combined data sets described the percentage of animals with

- Viral type lung lesions
- Pleuropneumonia type lesions
- Lung abscess
- Lung pyaemia
- Pleurisy (mild)
- Pleurisy (severe)
- Pericarditis
- Peritonitis

Further existing data was extracted from the national dataset of the electronic medicine book (eMB) and the Agrosoft package.

FINANCE

It is not a simple task to separate the various losses that occur in any pig production system. There is occasionally the opportunity to observe a serial step change in performance where an individual pathogen is eradicated on a single site, but even so, it is difficult to untangle the separate factors. A simple example will be the impact of eradicating a single pathogen, creating a change in daily live weight gain, and a subsequent change in stocking density.

An example of the complex relationship between respiratory pathogens and performance has been modelled, using real data from 56 pig farrow to finish units on Ireland. The model used serology and processor data, and individual farm management data. Farms with a positive status to Enzootic pneumonia – EP (*Mycoplasma hyopneumoniae*) had higher variable costs, mainly due to increased weaner feed usage, delays to appropriate weights for transfer to next production level, and higher healthcare costs. EP +ve farms also had a reduced income from kg/meat sold, with an overall impact of a reduction in profit of €5 per pig sold. On farm losses were modelled at -£4.15 per pig for low pleurisy, high scars pigs, and -£5.70 for high pleurisy pigs.

Of interest to the current study is that although recommended management practices for the control of EP include appropriate ventilation, temperature and stocking density, and all-in, all-out production flows, 38.2 and 27.6% of participating farms did not follow AIAO routines in weaner and finisher accommodation. The authors suggest that implementing suitable mechanisms for disease control will be of benefit to infected farms. Results from the current study mirror these more comprehensive study results.

All the 12 farms in the PL2020 study were positive for pleurisy symptoms in a proportion of pigs submitted. Percentage moderate and severe pleurisy cases (average over 24 months) from project farms are shown in Table 8.

Pleurisy Score	Moderate	Severe
Two Year Average	9.5	9.0

Table 8. Average pleurisy scores for project farms (n = 12)

Based on the abattoir data, the lost value of lungs and disposal costs = £0.20/pig affected and a handling cost shared across all pigs of £0.10/pig. In addition, batches of pigs submitted with more than 10% prevalence cause a decrease in line speeds, with direct labour costs increasing from £2.67/pig to £3.41/pig, equivalent to £0.86/pig in affected batches.

Processor Losses

Cost to the processors from pigs with pleurisy will range from £0.30/pig to £1.16/pig.

The estimated value of lost revenue at the processors for carcase weight lost to the impact of pleurisy on farm is £300,000 per year.

Producer Losses

The loss to the producer at the processor is approximately £0.85/pig, based on a deduction of £0.01/kg DW.

The loss to the producer on farm of £3.03 to £3.28/pig based on reduced growth rates (-0.7kg DW + 2.6 days feed) plus the cost of increased mortality post weaning.

Thus total loss to the producer is £3.88 to £4.13 per pig with pleurisy + the cost of increased mortality.

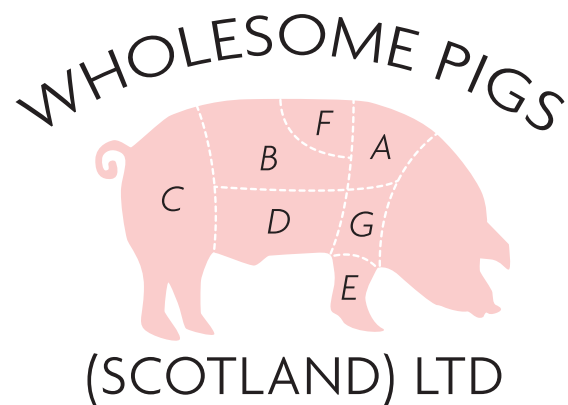
The 2008 BPEX project estimates of £2.30 per pig losses on farm were based on 0.7kg weight loss and 2.6 extra days to slaughter. These figures were used in the current study as there was not enough recorded data on post-weaning performance from Scottish herds.

FINANCE

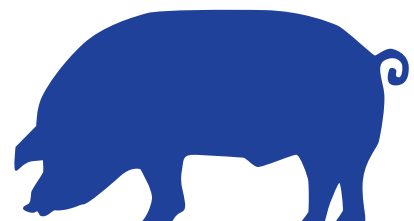


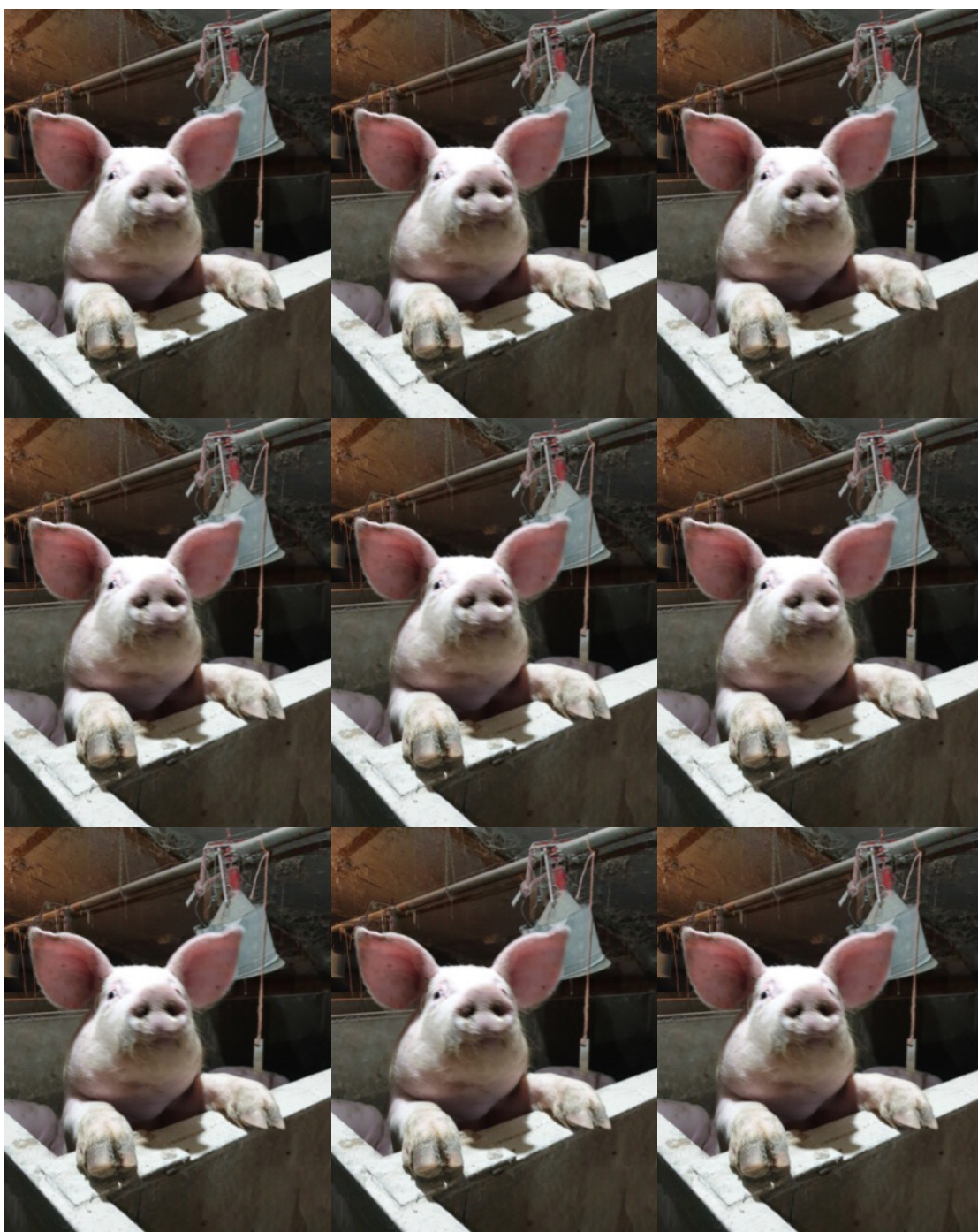
At 2020 prices averaging £1.50/kg the weight loss is worth £1.05, with additional feeding days costing between +£1.97 to +£2.23. Thus the estimated 2020 losses on farm = £3.03 to £3.28 per pig with pleurisy. Other work estimates increased mortality on farms related to pleurisy. Using a bacon price of 148p (10 year average), combined with other parameters suggests the loss of a 67kg (mid grown) pig will be £113. At 3.3% mortality the cost would be £3.73 per pig produced.

Total direct financial losses for the producer from pleurisy has a base of £3.88 to £4.13/pig affected, plus £1.16 for the processor. For the PL2020 project farms from January 2018 to December 2019 the average percentage losses to moderate and severe pleurisy were 9.5% and 9.0% respectively. Financial losses on the farms with a higher incidence of pleurisy and those with higher number of severe cases, losses will have been significantly higher than the baseline figures.



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