TESCO SCHOLARSHIP

By Christina Hutchings

Where does all the water go?

How a better understanding of Ventilation can be used to improve litter conditions in Broiler Houses

Report Contents

Introduction and background

I was awarded this scholarship in spring 2016 after completing a year as part of the secondary intake of farmers on the *Tesco Future Farmer Foundation*.

I work full time as a beef and poultry (broilers) farmer with my parents in Devon. Having been away from practical farming for some years, I chose the subject of poultry ventilation because it was something I wanted to improve upon, and I know it is a subject other farmers could benefit from also. I also chose to stick to what I know and concentrate on broiler chicken houses and cold weather ventilation as this is the trickiest.

This project is about producing a report that another farmer can pick up and read, and hopefully take something useful from it in order to try it out at home.

I wanted to create a hints and tips section to try and offer ideas for farmers to consider. One of the first things someone said to me when I met him was '*high humidity outside is no excuse for wet litter*'. I have thought of it often since, because it's so true!

Perhaps most farmers reading this report already know all the little secrets of ventilating their houses well, but with a fresh pair of eyes on the subject, I think I may have uncovered a few gems.

Having decided upon my subject, I knew that ventilation can be one of the hardest areas to get right in broiler housing; all houses behave differently. When you get this right, we all know everything else tends to go in the right direction. Get your ventilation wrong for too long and things start to deteriorate and, if not improved, you get wet floors. Wet floors lead to hock burn and footpad dermatitis, poor air quality which can lead to other health issues and our birds are unhappy, their food consumption changes and our FCR (feed conversation ratio) can be affected; all of which can lead to rejects from the factory.

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Whichever type of ventilation system farmers use, it is important that the system gives the house an even and adequate exchange of air and removes the excess moisture from the litter and the atmosphere. This then in turn maintains good air quality with good oxygen levels and removes $C0_2$ build-up as well as regulating temperature.

Management of farms and litter quality are essential to ensure birds are kept to high welfare standards whilst being economically viable for farmers, enabling them to commit to and meet the 5 Freedoms from the 'Welfare of farmed animals (England) regulations 2007 (amended in 2010)' which are:

1. Freedom from hunger and thirst
2. Freedom from discomfort
3. Freedom from pain, injury or disease
4. Freedom to express (most) normal behaviour
5. Freedom from fear or distress

How I have learned and where I have been

During the past couple of years I have visited many broiler farms in the UK together with various companies and individuals such as Draper Ventilation, Tom Proctor at Cobb Vantress in Colchester with Andrew Gibson of 2 Sisters Food Group, Chris Chater at Hook2Sisters Cullompton where I was also taken on a tour of the factory, a visit to SKOV and farms in Aalborg Denmark, together with a visit to Holland courtesy of Vencomatic to see in-house hatching systems and multi-tier house systems, farm visits with Justin Emery of Draper Ventilation and so on.

I visited Glasgow and consulted a well-known ventilation expert for **Aviagen (Asia); Bernard Green** who has given me the theory training throughout the past couple of years and helped me to analyse the data I collected from my testing on other farms.

I also visited The **University of Georgia** in the **USA** to see farms and the Poultry Science Department with renowned ventilation expert, **Mike Czarick** and to attend a three day cold weather ventilation course run by the Poultry Science Department of the University, which in the year I was there, was attended by over 121 people; their largest yet.

Figure 1; Broiler farm visited in Georgia November 2016 with
Mike Czarick**, Department of Poultry Science, **University of Georgia, USA

I saw the lab, the various test facilities they have as well as visiting two farms. The lab has a building with 24 rooms with a corridor through the middle to allow the air to be conditioned to the correct temperature before entering any of the rooms.

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Having this many rooms means they can run 24 different tests at the same time. They have front and rear water meters as well as 3 heating zones as standard, together with data showing the number of hours each of the 3 heaters ran for.

Figure 2; One of the rooms in the Universities test labs in the USA

In the spring of 2018, I completed the University's three-day course on hot weather ventilation, attendance beat all previous records at over 400 attendees!

Much of my learning has been from visiting and talking to different people, be it farmers, experts in ventilation or vets, industry experts and so on. I have learnt a great deal from my conversations as well as from the courses attended in America, plus a **lot** of research!

I have found that every farmer I visited said they would be interested in ventilation training and feel it would help them on their own farms. I have found no training available for this anywhere in the UK. Putting the broiler industry into perspective, we, in the UK process approximately 1 billion broiler chickens per year. That equates to around 18.5 million chicken processed a week (information courtesy of **Gary Ford, NFU**).

I think there should be something more out there for all producers to access (integrators as well as independent growers) with regards to training and knowledge on subjects such as ventilation. We have the experts; we just need to get them to the farmers!

Academic Publication

In the autumn of 2019, I submitted an academic paper entitled '*Ventilation Attributes; Impact on quality and associated bird welfare outcome measures'* to the Universities Foundation for Animal Welfare (UFAW), in the hopes of getting it published. Below is an abstract from their website, however for more information on this charity and their work, please see their website; www.ufaw.org.uk.

'UFAW is an internationally recognised, independent, scientific and educational animal welfare charity concerned with improving knowledge and understanding of animals' needs. It promotes high standards of welfare and practical, long-lasting solutions to welfare problems for farm, companion, laboratory, captive wild animals and those with which we interact in the wild.'

I have had confirmation that the paper will be published in July 2020, and a copy of the 'in press' abstract can be found at **Appendix K**.

Chapter 1 | A brief History of the Broiler and its Commercial Living Quarters

In the 1950's our birds were a whole lot different than they are now. These days (in the UK) the birds are expected to be on farm for only 42 days (6 weeks). However, back in the 1950's, we'd have to have to waited 70-84 days (10-12 weeks) for the same market weight and meat yield to be achieved. So, whilst we have made significant improvements to our birds, we have, at the same time, created a much more sensitive creature. Genetic selection has brought about 80-90% of the changes in broiler growth rates over the last 45 years.

Because of their slow growth and poor FCR (feed conversion ratio), broilers of the 1950's would be completely unaffected by a significant change in temperature of 6°C (10°F).

Try giving the modern broiler a moderate temperature change and you **will** stress them, even if you can't really see it. Due to the increased meat yield, especially in the breast, broilers have become more sensitive to high temperature, ammonia and dust. The trick for broiler farmers of today is to limit *any* stresses as far as possible, from the day they arrive until the day they leave.

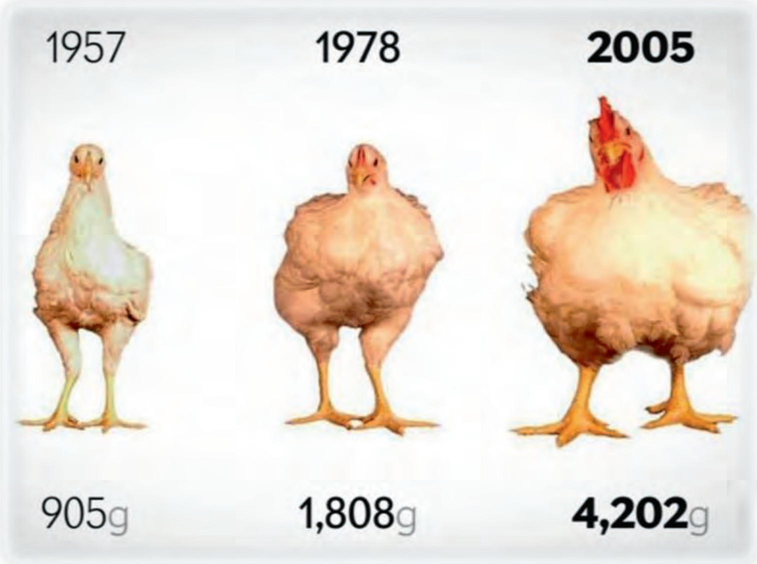


Figure 3 is from an article on Oxford academic website called from 'Growth, efficiency, and yield of commercial broilers from 1957, 1978, and 2005, by M. J. Zuidhof B. L. Schneider V. L. Carney D. R. Korver F. E. Robinson published in Poultry Science in December 2014. This image shows a broiler at 56 days old at different years

With the birds of today the genetic selection for rapid growth and increased feed efficiency were seemingly not as well matched when it comes to their internal organs; their hearts, lungs and liver etc **didn't** increase at the same rate and are therefore somewhat weaker, hence the minimisation of stress that is required to give the birds the best chance.

During the first seven days of a chick's life it can more than quadruple its body weight in the right environmental conditions. This will be the only time in the birds' life that it can grow at this rate. However, starve that bird of enough heat and let them get cold, and they will become less active, they won't eat as much and therefore won't grow as much. So, adequate feed and water availability, adequate, evenly distributed heat, and suitable minimum ventilation rates are essential to the birds' performance.

Chicken require oxygen in order to produce body heat as well as for the metabolism of nutrients required for their growth. For the first week of its life, a chick's respiratory system is operating at its peak performance when at its comfort temperature. So, if the house temperature drops below its comfort zone the chick would have to eat more just to keep warm (but not gaining any weight), but in reality chicks **don't** eat more when they are cold, instead they will huddle up with other chicks to keep warm and their activity almost ceases.

Interestingly, the same does not apply for much older birds; they WILL eat more just to keep warm and do NOT huddle up in the same way - which means keeping a larger bird warm costs farmer more in feed consumption as the bird will not convert well if it is too cold.

If chicks are to develop their cardiovascular systems well, they need oxygen. A key requirement of minimum ventilation is to remove excess moisture from the house using air exchange. This fresh air from outside the house needs to be evenly distributed inside the house to keep the inside temperature even too.

Chicks are not thermally competent for the first five days of their lives and thermo regulation is not fully developed until around 14 days of age, so they rely on the farmers to get the house environment correct in order to realise their growth potential. If litter and air temperatures are not warm enough then the chicks' internal body temperature decreases, causing them to huddle together. Cold chicks normally result in stunted growth.

A bird will drink anywhere between 1.6 and 2 times the amount it eats.

So, where does all the water go?

An average 2.3kg broiler bird, will consume approximately 6.3 litres of water in its lifetime as a broiler. That same bird will excrete around 4.9 litres of water (around 75-80% of its consumption) during its lifetime. Today's modern broiler chicks consume almost twice as much water by 28 days than they did 25 years ago.

A typical broiler house containing 30,000 birds will excrete, into the house environment, **147,000 litres of water** via their droppings and respired moisture during their time on farm. As a comparison, the average 5-minute shower uses 35 litres of water and so 147,000 litres are the equivalent of 4,200 showers – assuming one shower per day that's about 11 years' worth of showers.

Since this water is either in the litter or evaporated into the air, we have to rely on our ventilation system to remove this water from the house, in order to avoid excessively high moisture levels, which we measure in the form of **Relative Humidity (RH)**. Allowing RH levels to increase out of control could result in wet litter and subsequent health challenges.

Wet litter can not only be a welfare issue and lead to poor performing birds but can also lead to footpad dermatitis which is considered the next big challenge faced by the industry after campylobacter and anti-microbial resistance.

What is the role of litter in our houses?

Litter will need to act as a sponge in order to absorb house moisture and be able to dilute droppings from the birds. The litter also needs to create insulation between the cold concrete floor and the bird. A depth of between 2 to 5 inches appears to give the best results. I have also been advised and agree that it is a good idea to add an extra inch or two of litter along sidewalls in houses for better insulation. This litter will have a better chance to absorb the excess water in these more challenging, cooler areas of the house.

It is good to remember that chicks feel temperature through their feet, and for this reason it is important to make sure their **bedding** is warm before they arrive; 30-32°c is considered adequate.

The concrete beneath the litter should be 28°c. The surface temperature of the shavings / litter is of utmost importance in keeping the chick warm and comfortable for the first 14 days of their lives.

The two images below show a chick with warm feet and a chick with cold feet using a thermal imaging camera.

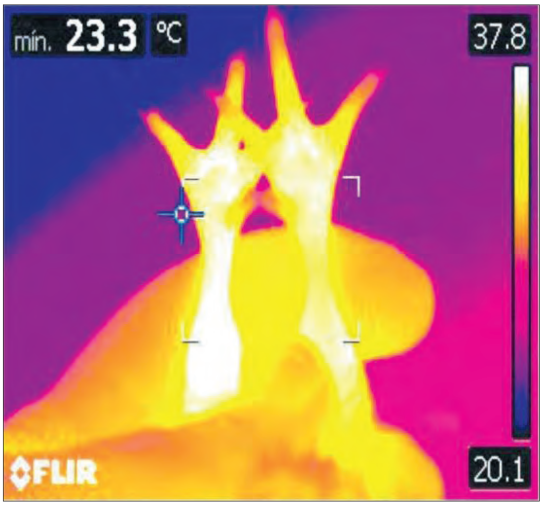


Figure 4 shows a chicks with warm feet - this is what we want! Photo courtesy of Cobb Vantress

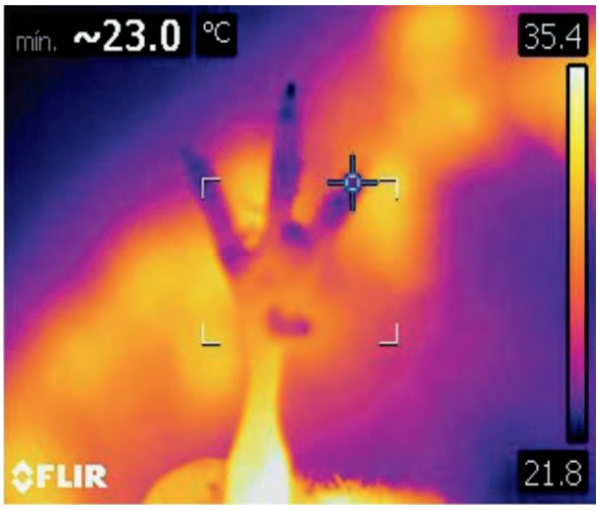


Figure 5 shows a cold chick with cold feet - not good Photo also courtesy of Cobb Vantress

With the graph below which came from Cobb's manual called 'Optimum Broiler Development', you can see that if concrete temperature increases, the intake of food by the chicks increases too. We can also see that the hottest temperature at which concrete should be is 32°C. The graph shows that after this temperature food intake starts to fall, and at 35°C stops altogether.

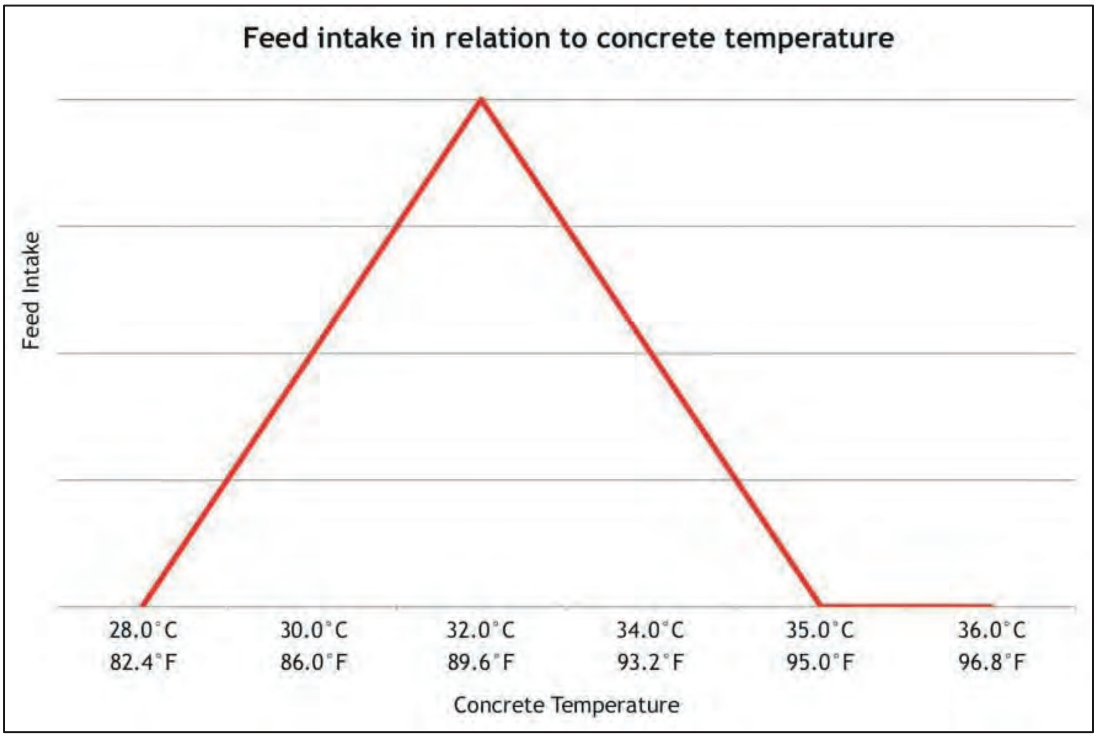


Figure 6 Showing the correlation between feed consumption and concrete floor temperature - Image courtesy of Cobb Vantress

There are several types of litter used around the world, but the favourite tends to be wood shavings, sawdust and sometimes sand. In the UK it is mainly sawdust or wood shavings. Both are good insulating materials and are good at absorbing moisture and are readily available.

So, what kills off litter?

Litter, like anything else needs the right conditions in order to make it work, such as temperature, food and moisture. Floor temperature is therefore important if we want to keep litter healthy. If the litter gets too cold, it starts to die off, causing caking or capping, and then eventually it will get wet.... wet litter is dead litter.

If the floor beneath the litter is damp, then the litter will also become damp. This is why the concrete floor temperature is also so important. This is also why when we ventilate, we want to warm up the incoming air as much as possible so that when it passes over the litter, it can absorb some of the moisture, keeping the litter alive and dry.

Other factors that can affect the liveability of litter include litter depth and type (chopped short straw is not great at all), light intensity, too much fat in the diet, too high water pressure on the drinkers, drinker layout (too close to each other), under ventilating, sick birds (loose droppings), poor drinker management (such as the wrong height), distribution of the birds on the floors (no birds = cold floors) and stocking density. There are plenty! See later in this Chapter for more details on some of these factors.

Why is litter quality so important?

As mentioned above, litter quality can be influenced by many factors. A study carried out in the USA looked at the relationship between wet floors, feet quality, and broiler performance at different Relative Humidity (RH) levels within the house (Please refer to Chapter 2, page 30 to understand what RH is).

The study (*Weaver and Meijerhof, 1991*) showed that the higher the RH, the worse was the condition of the birds' feet. They also made a correlation between the 75% constant RH and leg issues, showing that there were more incidences of leg issues at this higher level of moisture.

The study also found that at higher RH levels the footpad lesions were around 44-53% and at 45% RH the lesions dropped back to around 13%. Increased RH levels significantly increased caking and moisture in the litter, decreasing the dry matter percentage.

Depth and type of material used for litter is important. Studies have found that one inch of bedding can cause footpad lesions from as early as 14 days old, however at 5 inches there tends to be a much lower incidence of FPD.

In another test, carried out by The University of Georgia in the USA, it was also found that these footpad lesions were most noticeably higher at lower litter depths at 5 to 6 weeks. It was found that the weekly moisture levels were significantly lower in the litter at 5 inches than the litter at 1-inch depth as shown in the graph over the page.

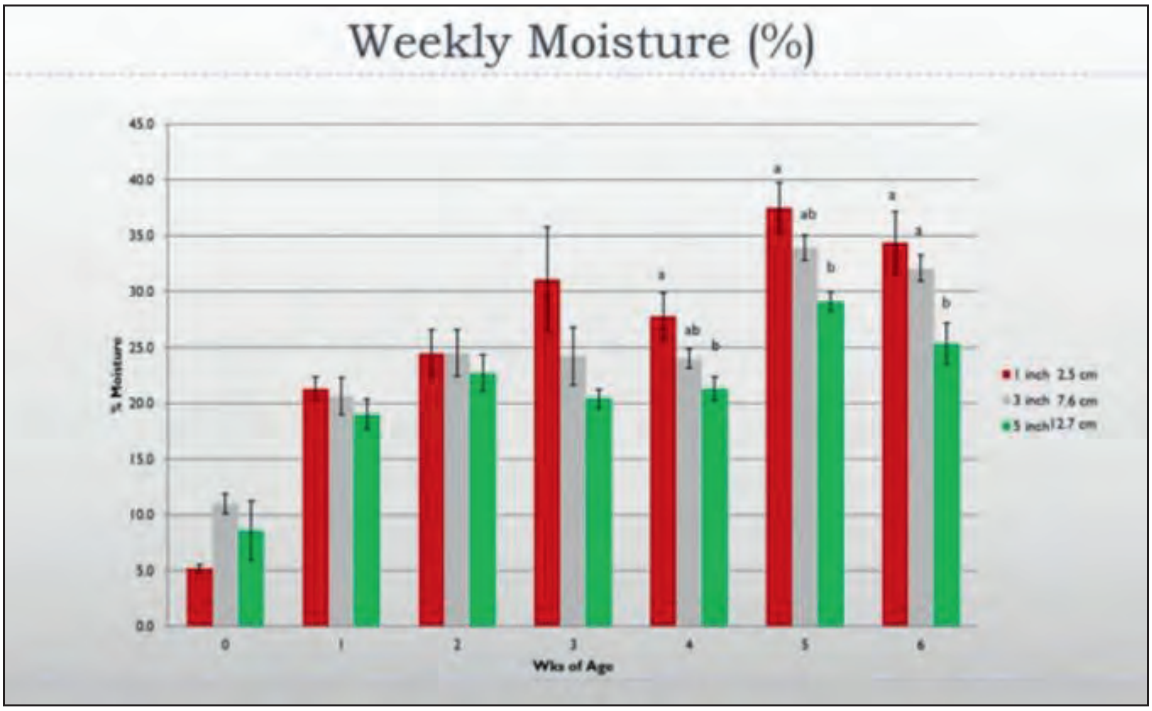


Figure 7 The relationship between the depth of litter used and the moisture content of it - graph courtesy of Dr Brian Fairchild of the University of Georgia, Poultry Science Department, USA

Negative Implications from having poor / wet Litter

There are so many negative implications; Wet litter does not retain heat well, so will lower the birds' body temperature too. As a result of this there will be issues with poor weight gain, poor feed conversion efficiency as well as a lowering of bird immunity. Again, remember they feel temperature through their feet.

As discussed above the prevalence of Footpad dermatitis (FPD), also known as Pododermatitis is strongly linked to litter quality - if the litter is greasy, caked or wet then FPD incidences often increases. FPD is a big issue but is NOT a given from wet litter.

The key is the Nitrogen in the litter - if there is too much and the balance of temperature and pH is right then ammonia is formed and can then cause FPD - Ammonia in its ionic form (trapped within the litter, rather than in gas form once released from the litter) does not affect the footpad. However, when it is released it can start to cause issues with FPD or hock burn.

If the pH of the litter starts to become more alkaline there is a great chance of the gas form of ammonia being formed. Footpad lesions are therefore also often referred to as Ammonia burns even though several studies have shown that litter moisture alone can cause FPD (*Mayne et al, 2007; Yousef et al, 2008*). Breast blisters and hock burn are also a result of poor litter and can be directly attributed to wet floors.

The presence of Ammonia appears to be able to exacerbate FPD, but it does not appear to cause it directly. So, the best way to stop FPD occurring is to keep your litter dry and friable. This is especially required during brooding as it is thought that this is when the birds are most susceptible to the development of FPD - again here we are reminded about another reason to pre-heat our floors and houses...

Please see **Appendix A** for a copy of the photo guide on broiler foot health classification regarding FPD lesions.

Why should we ventilate our houses? Why is it so important?

Minimum ventilation is about ventilating enough to control moisture levels and air quality in the house. Control of Relative Humidity (RH) plays an important role in the condition of the litter. Heating plays a crucial role during minimum ventilation as there must be enough heating capacity to not only keep the chicks warm and comfortable, but also to enable a ventilation rate high enough to control RH.

In the worst case however, if you have far too much moisture in your houses, you get wet floors, and, once they are wet it is very difficult to rectify.

Figure 8 Showing capped litter at a farm I visited - the birds avoid this area of dead litter - its cold... The drinker lines here had pressure way too high hence floor issues, too

Control of and relationship between $C0_2$ relative humidity and ammonia levels

The monitoring of "air quality" is the best way to evaluate your minimum ventilation rate. The three components worth monitoring are Carbon Dioxide ($C0_2$), Ammonia (NH_3), and Relative Humidity (RH).

During my research I looked for an ammonia meter only to find they are very expensive, and not hugely reliable; hence I was advised against using one. I did use a $C0_2$ meter and found this to be useful. I found out that it is fact that these three measures run in line with each other too. So, if the CO_2 increases, so does the RH and the ammonia levels. Because of these facts I found that the best and cheapest way to measure how well you're doing with your ventilation set-up was by having a Relative Humidity (RH) meter, and these are **not** expensive to buy.

You will find that most of the time, if your house relative humidity is under control, then other air quality variables are also under control.

See the figure 9 over the page, showing some results of research carried out in the States:

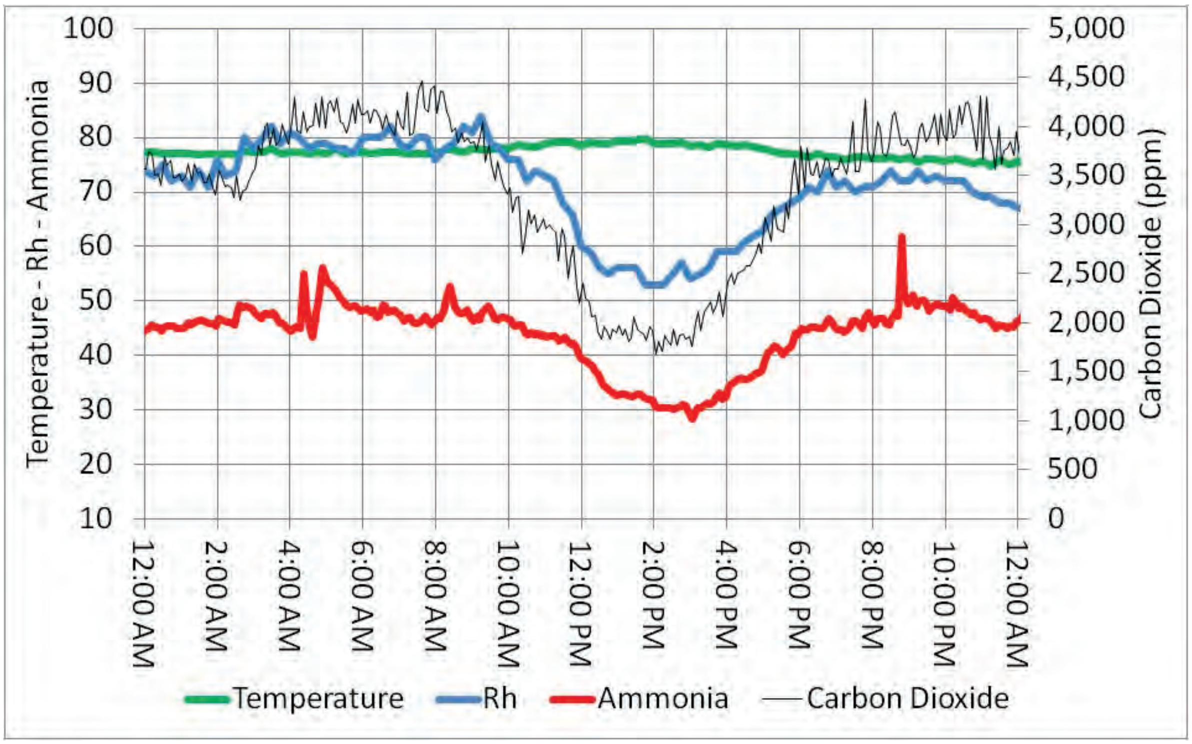


Figure 9 Graph courtesy of University of Georgia Poultry Science Department, USA, Mike Czarick and Brian Fairchild

Ideally, we need to keep our $C0_2$ levels below 3,500ppm and ammonia below 25ppm. Though no farmer I have ever met or spoken to has an ammonia meter, it is already something that will be used for inspections in future, and so it's always worth knowing more about it.

I would suggest that any farmer with a heating system that burns fuel (i.e. gas or oil) within the house itself (and therefore produces $C0_2$ as well as the chicks), should get a $C0_2$ meter to check their levels for whilst the birds are young.

High $C0_2$ levels can make your chicks lethargic and weight gain can be adversely affected too.

High ammonia leads to poor weight gain and feed conversion and respiratory issues as well as making the birds more susceptible to diseases

So, if you have a consistent RH reading of over 70% chances are you will have or be about to have litter issues as well as air quality issues.

Broiler's and Cold Stress

We always tend to hear about the economic loss due to heat stress in birds, but cold stress can be significant too. Colder temperatures increase the bird's requirement for oxygen by the tissues and muscles within the birds. It also increases the requirement for cardiac output and blood flow.

Research carried out by *Ipek and Shan 2006* says that going from 20°c to 2°c can **double** the oxygen requirement of the muscles and tissues of the body. When a bird is cold stressed it causes it to want to eat more, it also increases its metabolism. The bird will start to use the fats in the body rather than carbohydrates. If you cold stress a chick there isn't much fat for it to use which means their growth can become stunted.

Causes of wet litter (apart from inadequate ventilation)

As previously stated, litter is like anything thing else, it needs the right temperature, the right food and moisture in which to survive.

So, apart from poor ventilation what else can kill off our litter? Below are a few examples;

Drinker management!

We all know that drinker lines can be a pain and can leak onto the floors. This can be from build-up around the nipples causing the weights on them to not sit properly, thus allowing them to leak or drip. Regular flushing of the lines can help reduce this build-up. As many broiler farms now have chlorine dioxide dosing systems constantly cleaning our water and sanitizing our lines, this should be of a lesser issue over time.

Nipple drinker requirements

It is important to ensure there are enough nipples in the houses, but the specific number of nipples per bird will of course depend on some variables such as age, water pressure and the outside climate, but generally Aviagen advise that the minimum drinker requirements in the UK, for birds less than 3kg / 6.6lbs is 12 birds per nipple. For birds weighing more than 3Kg, there should be 9 birds per nipple. *(Source; Aviagen's Broiler Management Handbook 2018)*.

A high density of older birds can really have an adverse effect on your drinkers. Whether or not they are leaking, too many birds drinking a lot of water (due their age) can put pressure on your drinkers and make them spray or drip more onto the floor.

Birds that are unwell will drink more and this can have the same negative effect on your drinker lines. Older birds can play with the drinkers too if they are too low, so care should be taken to keep them at the right height daily. Drinker lines that are too high can restrict water consumption.

A way of checking whether you may have a build-up of material in your lines is to check the chlorine levels at the entry point of the water into the house and compare it to that of the end of the lines - having a difference indicates there is a build-up of material because chlorine is taken up by this residue.

Water pressure

Too high a pressure setting on the regulators can cause leaks too. It is of utmost importance in the first two weeks of placement to check your pressures as birds are at their most susceptible to FPD at this time. You should be checking your pressures throughout the crop, even if you think they're fine; there is a great little tool you can use, which Cobb gave to me which allows you a very simple way to test the pressure in your lines against the age of the birds. See figure 10.

Figure 10 of Cobb's water pressure / flow rate tool - Image courtesy of Cobb

What is the correct nipple flow rate (pressure)?

The recommended water flow rates (pressure) for broilers according to the age of the bird are shown in the table to the right, taken from Aviagen's Broiler Management Handbook 2018. Note that this is flow rate taken for water flowing through a tool such as the one in Figure 11 below, which has been timed for 60 seconds.

Bird Age (Days)	Flow
0 - 7	20ml/minute
7 - 21	60-70ml/minute
>21	70-100ml/minute

Interestingly, I found that every single farm I visited and tested had water pressure which was too high!

Below (figure 11) is a graph from research carried out on the effect of water pressure and scores of FPD. It shows the effect of normal pressure (10, 17 and 20cm column of water), low pressure of 8, 12 and 15cm column of water and high pressure which was 20, 25 and 30cm of water column.

We can clearly see from the graph that where the water pressures on the drinkers were higher, there were much higher incidences of FPD in the birds.

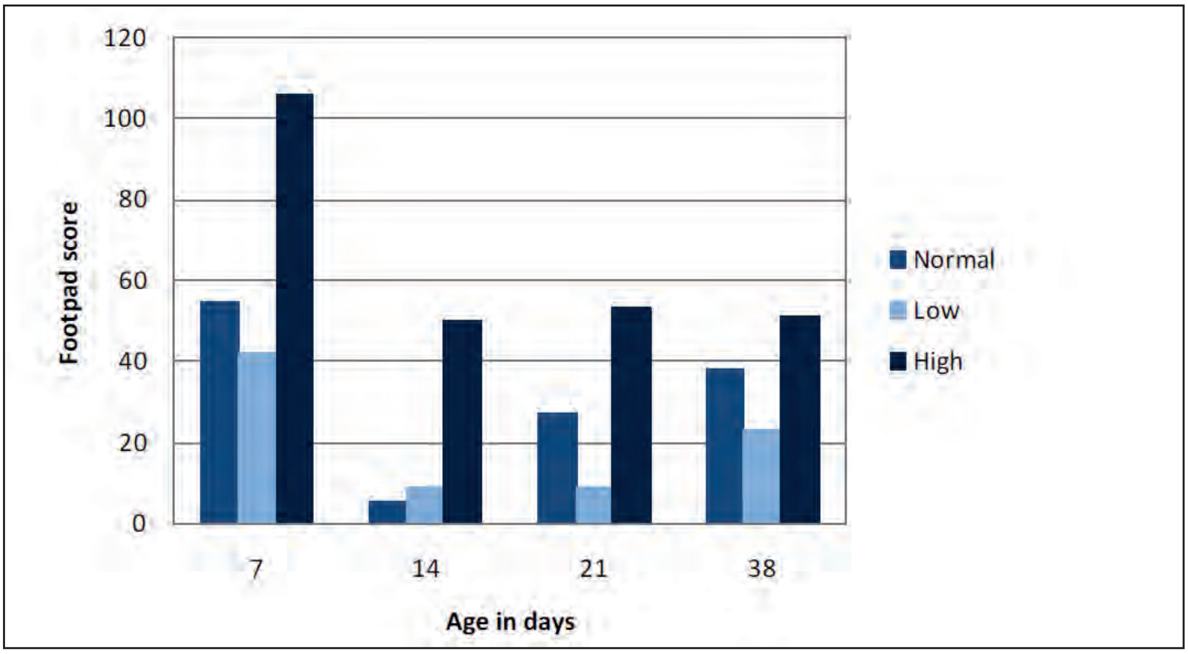


Figure 11 Graph from research by Peterson 2003 (Boksforsog nr. 75) showing relationship between high water pressure and FPD

Cold water coming into the houses from outside, especially during cold weather can be an issue too as the drinker lines provide a surface for humid air to condensate. The condensation then drips onto the litter underneath the lines making them wet and smelly... this is more of an issue on the first couple of lengths on each line where the water is at its coldest.

This can be more aggravated during times of higher water consumption and can cause the issue to occur further down the lines. The best way to combat this is to insulate the water pipes before and after they get into the house. See figure 12 over the page.

Figure 12 Example of insulated water pipe on a farm I visited in Devon in the UK

Water from the drinker lines getting onto the litter can also be from the incorrect height of the drinker lines; In the initial stages of brooding, the back of the chick should form an angle 35-45° with the floor whilst drinking.

After this as the bird grows, the nipple lines should be raised daily in order that the back of the bird forms an angle of around 75-85° with the floor so that the birds are reaching slightly to drink enabling the water to flow directly into the beak, helping to avoid water being spilled on the floors.

Figure 13; Correct drinker nipple height - Image courtesy of Cobb Vantress

If nipples are too low this can cause the birds to turn their head to drink, allowing water to fall on the floor.

Aviagen advise the use of 360° nipples for ease of access and for the best water availability.

Drinkers should be raised according to height of the flock **not** age. I personally believe that cups under the nipples help keep drips from the floor having tried both out myself.

Danish research (*Jorgensen, 2011a; Jorgensen, 2011b*) was carried out looking at whether cups versus no cups on nipple drinkers helped reduce FPD and their effects on litter. They found that having drip-cups under the nipples not only reduced the severity of FPD but improved the performance of the birds when compared to drinkers used without drip-cups. This same research was carried out in Holland *(Van Harn et al 2009)* and agreed with the Danish research.

See figure 14 below; the evidence of the research.

Table 2: Effect of drip cup on performance results, dry matter content of the litter, and footpad lesions (Van Harn et al, 2009).

Parameter*	Drinking Nipple	Drip Cup
Body weight (g)	2047 [a]	2093 [b]
Body weight gain (g/b/d)	57.4 [a]	58.7 [b]
Mortality (%)	2.5	2.6
FCR	1.603 [b]	1.595 [a]
Feed intake (g)	3219 [a]	3276 [b]
Water intake (ml)	5814	5831
Water / feed ratio	1.81 [b]	1.78 [a]
EPEF	349 [a]	358 [b]
Dry matter litter (%)	48.7 [a]	52.8 [b]
Footpad lesions (%)		
No (Score 0)	0	4
Mild (Score 1)	4 [a]	18 [b]
Severe (Score 2)	95	78

Figure 14 is taken from the Aviagen guide on reducing FPD in broilers

Birds having a health-challenge (Over consumption of water)

If there are any intestinal upsets caused by feed, disease or water (i.e. pH or mineral imbalance) or any stress, often the initial reaction from the bird is to drink more. This causes a dilution of feed in the gut which means that there are fewer nutrients available. This can push the feed through the gut quicker leading to an increased risk of mal absorption which can cause bacterial overgrowth and the droppings become loose and watery making the floors wet or greasy.

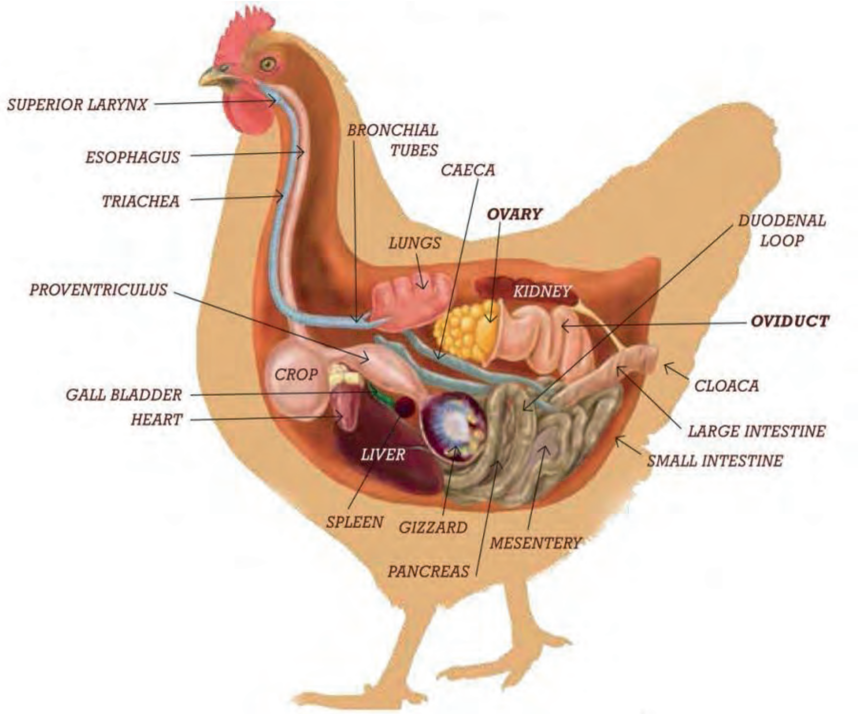
So, if at this point there is not enough ventilation / air flow in the houses the litter will start to deteriorate. There are several health challenges such as Bacterial Infections and IBD (Infectious Bursal Disease) that can lead to scouring causing wet litter.

Coccidiosis, though often partially a result from bad litter, can then contribute more to the state of the litter once it takes hold in the house, and the droppings become loose. The disease can destroy the villi and the function of the gut and absorption becomes an issue and nutrients end up being passed out through their droppings having not been absorbed properly by the bird. It destroys the intestinal wall which means that bacteria can get through causing other health issues.

Necrotic Enteritis can ensue from a cocci challenge too because of the hit on the intestinal wall allowing bacteria to get through. Basically, in broilers *everything* disrupts the gut; it is a very fine balance, and the simplest thing can set it off.

Food Texture

The gizzard is the most important part of the intestinal tract as it grinds up the food and mixes it with acids and enzymes. It must therefore work well in order to mix it all up. The gizzard must be stimulated and taught to grind food as soon as possible in order to ensure it does its job properly. The small intestine is not good at dealing with whole proteins and so the feed must be adequately mixed with the acids and enzymes in the gizzard.



If too many large proteins enter the small intestine they can end up in the hind gut (leading to dysbacteriosis) or passes to litter and increases the Nitrogen content in the litter which increases the risk of ammonia formation.

If you have chick crumb for too long or poor quality and dusty food, then the gizzard is not getting any stimulation.

The gizzard is a muscle and it needs educating on how to grind up the food and do its job well otherwise when the pellets (or whole grain) arrive the gizzard will be unable to cope. If the gizzard doesn't have enough to do, things start to pass through too quickly, reducing the absorption of nutrients. All these things affect what is excreted onto the litter in droppings.

Changes to Feed Content and its impact on the Gut

Changing proteins, fats etc changes the nutrients that are available to the gut bacteria. If the ventilation isn't quite good enough or the food quality isn't great, then this could upset the balance in the gut of the birds. In this case the proteins end up in the litter; high protein means loose droppings and therefore wet floors. There is only so much protein a bird can absorb in one go, so if excess protein is in the diet it can be passed through to the hind gut or onto litter, but performance can still be high.

If there is too much fat in the litter (as a result of mal absorption of fat from the feed) then the floor becomes slick and greasy.

Stocking density

Is based on economic viability and welfare. We all know that a lesser stocking density would make rearing broiler chickens far easier and improves the performance, uniformity and general quality of the birds.   On my own farm I notice that every time we thin, suddenly any floor issues seem to disappear, which indicates that lowering of stocking densities in broiler houses could be the easiest improvement (after ventilating) that we could make to improve house conditions.

Other negative influences upon litter health are; litter material types, the moisture content of the litter when it is placed, lighting (an intermittent light schedule is thought to be beneficial against the footpad dermatitis forming), fluorescent lighting, poor drinker layout, bird uniformity and loose droppings (either from the birds being chilled or being unwell).

Stocking Density, UK Welfare Standards and (dare I say it,) BREXIT!

Tesco and the poultry industry in the UK are staring an opportunity in the face as we prepare to leave the EU and go it alone (if ever actually happens!).

We already have some of the highest welfare standards in the world for growing chicken for meat (in fact, for all meat and farming produce). We should really be looking at this as a great time to take a decision across the whole of the poultry industry to **reduce stocking densities on all farms**, be they integrators or the independent sector, from the standard rate of a maximum 38kg/M^2 based on the EU Broiler Directive (2007), to something more like a maximum of 30kg/ M^2. If this was an accepted welfare standard for the UK as a whole, we could set ourselves out as an example to all on the best welfare possible for the birds, whilst at the same time reducing all sorts of issues we face when farming at the current densities.

This is also something that has been raised by many European organisations in an open letter entitled 'European Chicken Commitment', as part of their request for better welfare in '*The Broiler Ask 2026*'. Please refer to **Appendix B** for a copy.

Reducing stocking densities in the UK would in turn put a stop any fresh and frozen chicken coming onto the British market if it doesn't meet our welfare standards. Currently we are seeing Brazilian fresh bird imports flooding the UK market, pushing down prices and making a farce of our own high welfare standards. [January 2019].

In the three months of September to December 2018, we imported 3,852 tonnes of Brazilian poultry meat, an increase of over 250% from the same period in 2017 *(Poultry Magazine). **

All it would take is for the supermarkets and the independent market to take this on and pass the minimal extra cost to the customer to make this change economically viable for us all.

Chicken meat is cheap to buy, and we would eradicate most of the issues with poor floors (and many other issues to be honest) if there were less birds on them. Everyone's a winner; the chicken, the farmers, the processors and the consumers…

* *These figures came from Gary Ford, NFU Chief Poultry Adviser writing in the Jan / Feb 2019 edition of the NFU Poultry Magazine*

Key Points from Chapter 1

- A chick can quadruple its weight in the first 7 days of its life
- A bird will drink 1.6 to 2 times what it eats
- An average 2.3kg bird will consume around 6.3 litres of water in its lifetime as a broiler, excreting around 80% of this back into the house
- Litter acts as a sponge to absorb house moisture as well as insulation from cold concrete floors
- Chicks feel temperature through their feet, which is why making sure bedding and concrete floors beneath are warm enough is so critical (bedding material 30-32'c and concrete 28'c)
- Chicks cannot regulate their own body temperature for the first 14 days – it's the farmers job to keep them warm
- Take care to avoid significant environmental changes; the modern broiler is sensitive to this
- If litter becomes too cold, it will start to 'die off', creating greasy, and later, wet floors
- Poorly ventilated houses with wet litter can cause health issues such as footpad dermatitis, hock burn, breast blisters and respiratory diseases
- To keep floors dry and air cleaner, we must have adequate minimum ventilation rates
- Relative Humidity (RH) rates that are *consistently* above 70% will cause wet floors - monitor your house RH
- Cold stressing broiler chicks can stunt growth
- Pay attention to good drinker management throughout the entire crop (height and pressure)
- Let's support our own country and use Brexit to reduce stocking densities and stop fresh imports of chicken into the UK from countries who do not match our welfare standards

Chapter 2 | Theory - The Science Behind Ventilation

So, where to start? At the beginning. How does warm air behave? How does cold air behave? Why does it matter? What is relative humidity? Why does *that* matter? What is the science of air? What does *broiler house* ventilation involve? How can I learn to control the environment inside my broiler houses? This is where I began.

Any farmer knows that it is possible to have wet litter all year round, but it is generally seen most during the colder months of the year. During the winter months the Relative Humidity (RH) of the outside air is generally much higher, and in the UK its often close to 100% (and raining!) This is why most farmers find it most difficult to keep their litter dry at these times of year.

Heat cost is always a big topic of concern for farmers. To ventilate (especially in the winter), you need heat to warm the incoming air. This is why we often find farmers are trying to cut costs by ventilating less, thereby using less heat too. It is, I believe counterproductive.

What is the purpose of Ventilation?

There are 3 main reasons for ventilating our houses;

- To maintain air quality - by reducing the build-up of harmful gases such as carbon dioxide and ammonia together with ensuring enough oxygen is provided for the birds
- Remove excess heat
- Remove excess moisture

The two most important reasons from the above list are removing moisture and excess heat.

What is *Minimum* Ventilation and what is its purpose?

Minimum ventilation operates when the temperature inside the house is at, or lower than, the desired set-point temperature. It is to provide a minimum level of air exchange of warm stale, moisture laden air from within a broiler house with fresher air by means of fans and inlets.

Minimum ventilation is NOT temperature driven and is set by timer, whatever the outside temperature. This is so that the house can maintain good basic air quality for the birds, removing moisture and giving them the right comfort temperature.

Because air cannot be seen it is hard to know what our ventilation system is doing and how the air is moving in our houses. Therefore, ventilation can sometimes prove problematic.

Minimum ventilation charts are about providing us with a guide on the minimum amount of air volume exchange required when it's cold outside and we are trying to minimise our ventilation rates to save on costs such as heat, whilst ensuring an adequate air quality and temperature for the birds. They are sometimes based upon controlling moisture in the houses.

At a certain age, weight (grams or kilograms of meat), number of birds in the house and average outside weather conditions, the chart assumes there is a certain amount of moisture present. From this it calculates the amount of ventilation required to remove the moisture the birds have added to the house.

This is a guide; it is not set in stone; the actual rates used should be based on the house conditions. The plan is a guide; a good place to start and every farm should have one.

Please see figure 15 for an example chart from Aviagen and **Appendix C** for a full version.

In general, we can say that there is a direct correlation between the rate of minimum ventilation and the level of RH, CO_2, and the perceived air quality in a chicken house.

As the minimum ventilation rate increases, so the levels of CO_2 and RH will decrease, and the "air quality" inside the house will improve.

The opposite is true if the minimum ventilation rate decreases. Therefore, probably the first indication that the minimum ventilation rate is not enough, is when house RH % starts to increase.

To help our minimum ventilation system work successfully, we need to have a few basics; We need a well-sealed house which is as airtight as possible.

Minimum Ventilation Rates

Live weight (kg)	Live weight (lbs)	Minimum ventilation rates (m^3/hr)	Minimum ventilation rates (ft^3/min)
0.050	0.11	0.076	0.045
0.100	0.22	0.128	0.076
0.200	0.44	0.215	0.127
0.300	0.66	0.292	0.172
0.400	0.88	0.362	0.214
0.500	1.10	0.428	0.253
0.600	1.32	0.491	0.290
0.700	1.54	0.551	0.325
0.800	1.76	0.609	0.359
0.900	1.98	0.665	0.393
1.000	2.20	0.720	0.425
1.200	2.65	0.826	0.487
1.400	3.09	0.927	0.547
1.600	3.53	1.024	0.604
1.800	3.97	1.119	0.660
2.000	4.41	1.211	0.714
2.200	4.85	1.301	0.767
2.400	5.29	1.388	0.819
2.600	5.73	1.474	0.870
2.800	6.17	1.558	0.920
3.000	6.61	1.641	0.968
3.200	7.05	1.723	1.016
3.400	7.50	1.803	1.064

Figure 15 of Aviagen MVR

The house also must be well insulated if it is to keep the warm air inside and the cold air outside. Heating our houses makes for a large part of our overall production costs, so it's important to retain within the house, i.e. the heat we pay for as well as the heat created by the birds themselves.

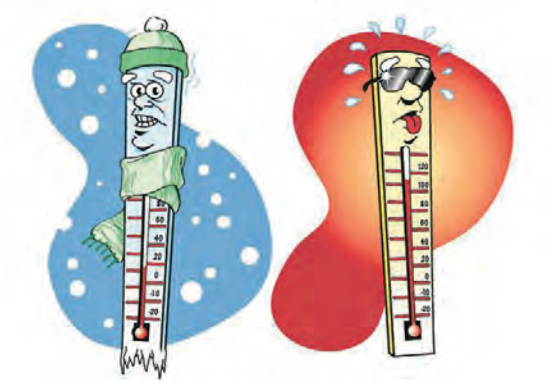
We also need to retain heat within the houses to help us warm up the incoming air during minimum ventilation.

It's a known fact that heat rises. This is the same for hot or warm air in broiler houses; it wants to rise. This warm air from the birds and from the house heating system therefore ends up rising into the peak of the roof (hence importance of well insulated and sealed houses to stop it escaping).

The opposite is so for cold or cooler air.... it desperately wants to fall. So, our purpose when ventilating is to 'trick' cold air into being forced up and heated up in the peak of the roof before it even has chance to fall, which is why the retention of heat within the house is so important.

Minimum Ventilation Cycle Timer

When running Minimum Ventilation Rates (MVR) most farmers use a complete cycle of 5 minutes (300 seconds). Some farmers may use an 8-minute (480 seconds) cycle.



A cycle means (ON + OFF time); the amount of time during that 5 or 8 minute cycle where the exhaust fans are on and the inlets are open, plus the rest of time of the cycle period, where the fans are off and the inlets are closed.

As an example, using a 5 minute timer in a house where there are 19,500 birds aged 7 days old, there may be 3 x 600mm exhaust fan on for 28 seconds with inlets open, and for the remainder of the 5 minutes (272 seconds) those fans are off and the inlets closed.

Once decided, often farms have this plan entered their ventilation computer system where it makes the changes to the minimum ventilation rates automatically as the birds get older. They also add the required set-point temperature and possibly the RH % set point too.

There are a few useful tips and calculations from Cobb that I picked up during my research which I hope will help some other farmers to create their own specific minimum ventilation plan. These calculations can be found in **Appendix D** *'The Importance of Minimum ventilation and how to calculate it'*

Controlling litter moisture with minimum ventilation - The Essentials

What is Negative Pressure Ventilation?

Let's say it's cold outside and the air is humid (moisture heavy). Regardless of less than favourable outside weather conditions, I still need to bring in fresh air to my houses for the birds. However, I don't want that cold humid air to fall to the floors and chill the birds and make my litter wet, so how can I bring in fresh air without causing these issues? How can I make use of the warm air in the peak of my roof to preheat this cold humid air? To understand this, we must learn about negative pressure.

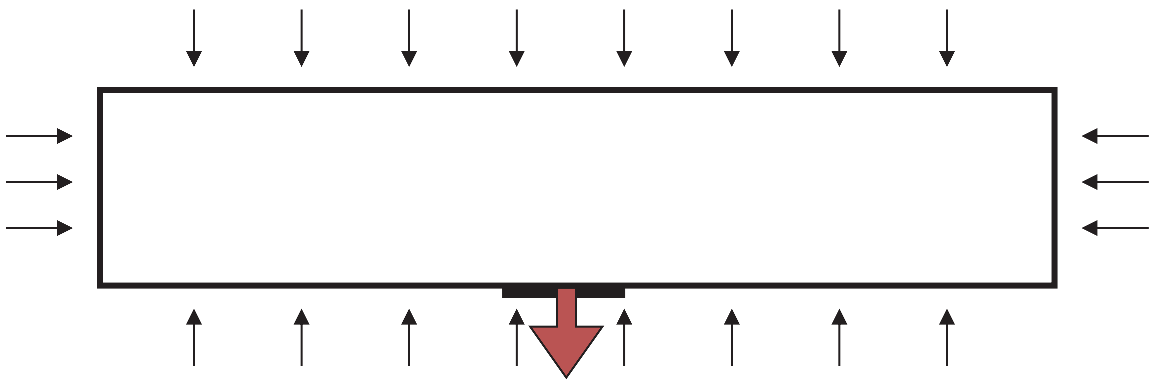


Figure 16 A Negative Pressure house where the vacuum is made

Say for example we have a house as shown in the diagram above. If the house has no extraction fan running and the weather outside is calm, then the pressure inside will be the same as the pressure outside the house.

However, when an exhaust fan is switched on air is extracted from the house which means the pressure inside and outside the house is no longer equal. Outside pressure remains the same but inside the house is now 'negative' in comparison causing a partial vacuum.

At this point air will try and get into the house from *anywhere* to try and equalize the pressure; we would prefer it came in through the inlets but if not well sealed it can get in through all sorts of gaps and cracks in the sidewalls roof and end walls.

When we have this pressure difference, air will try and enter equally around the house. If we place our inlets evenly along both the sidewalls of the house, then the air will be pulled in through the inlets equally, replacing the exhausted air. This then means that the air coming in enters evenly throughout the house, which is very important during minimum ventilation.

To control the amount of air coming in through our inlets, we can use more or less fans and use larger or smaller openings on our inlets to control the pressure difference inside the house compared with the outside.

The more pressure difference, the faster the air will enter into the house through the inlets. The faster the air comes in through the inlets, the further into the house it will reach before it drops. This is often referred to as 'throw'.

By restricting the inlet opening we can regulate the incoming air speed and control how far the air goes into the house (along the ceiling). We must ensure our houses are well sealed if we are to control the air coming into the house and direct it to where we want it to go. Figure 17 below shows air movement based on pressure.

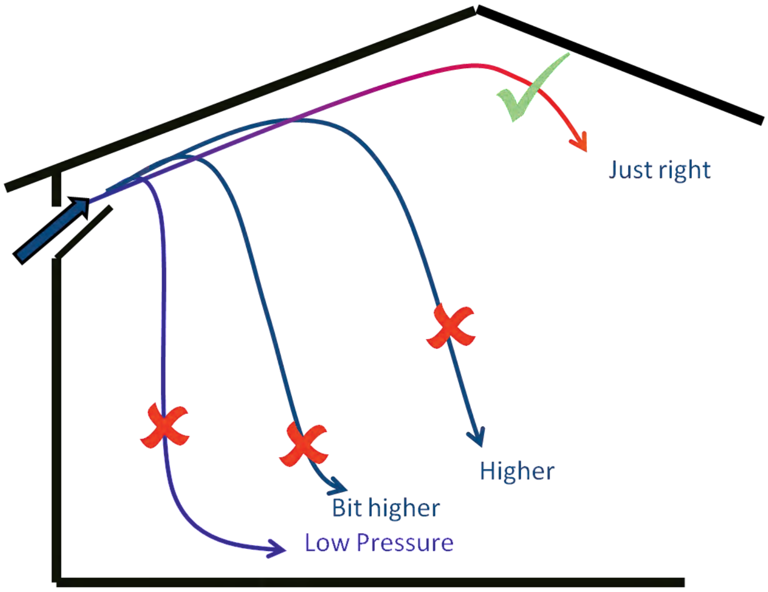


Figure 17 Courtesy of Bernard Green; Aviagen (Asia)

Operating pressure is a tool we can use in order to place air where we want it to go, which is why knowing the pressure in your house is important. Pressure is measured by Pascal's (Pa) or inches of water column (in WC).

Why should your houses be well sealed / 'tight'?

It is essential that we can control the environment within our broiler houses. To achieve this, it is important that we can control where the air enters the houses and how much enters. These factors will affect house heating costs and bird comfort, so they are important. The better sealed and airtight a house is, the more control we have on the airflow.

Previously we talked about how we can use negative pressure to get the cold air where we want it, which is in the peak of the roof where the warm air has accumulated. The more airtight the house is, the easier it is to create a negative pressure.

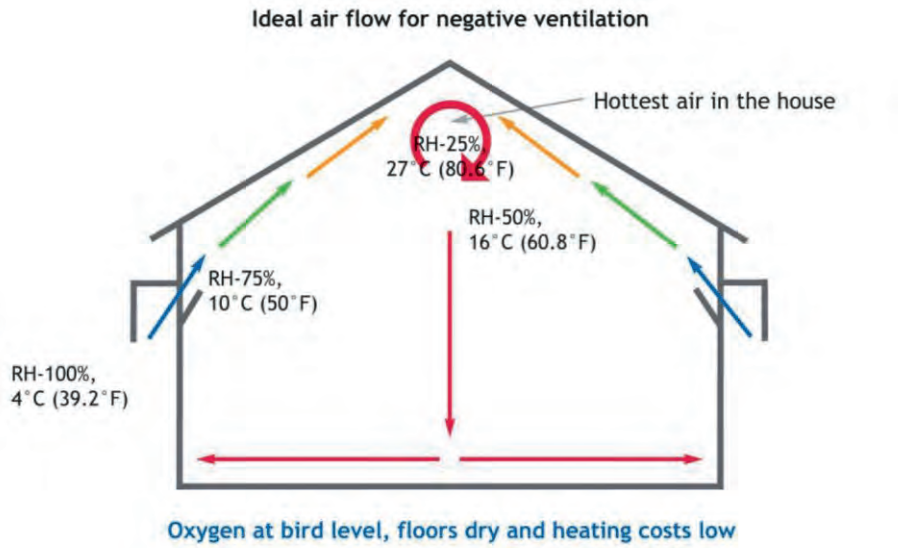


Figure 18 Courtesy of Cobb which can be found in their Optimum Broiler Development Manual

It is a well-known fact that houses of older construction can tend to be a little more 'leaky' than newer houses. Lots of unwanted cracks and gaps in the houses will lead to cold air being drawn in through them and often landing on the floor, making the litter cool and causing caking or wet floors.

This can happen both by fans drawing the air in as well as from general flow when they are off; either which way, we have no control over it. To keep issues such as these to a minimum, we need to establish how well sealed our houses are.

The figure 19 below shows the dark blue areas of cold air that is getting in through all sorts of cracks in the house, which is what we **don't** want. See Chapter 3 about ways to check your house tightness

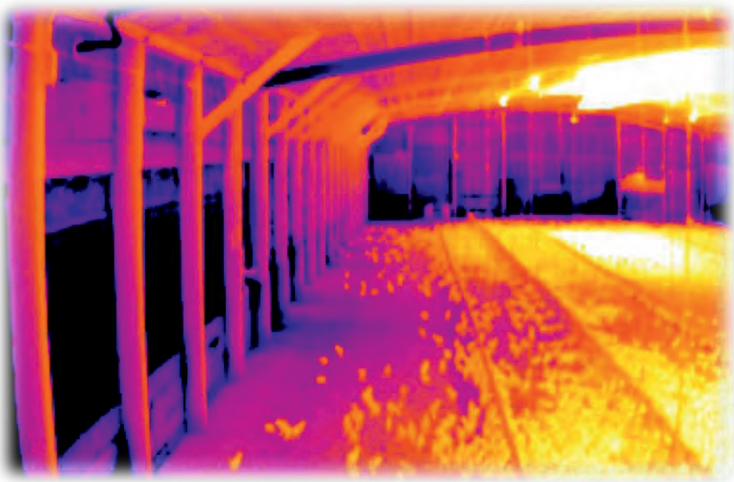


Figure 19 Example of a 'loose' house | Photo courtesy of Mike Czarick, UGA

Remember, the better sealed the house is, the more control you will have over *where* the air comes in and how much air enters.

This is also true of the negative pressure in the house - with a well-sealed house you are able to control the operating pressure ensuring as a result, that the air you are bringing in ends up in the peak of the roof and not on the floor. Now you understand negative pressure, we shall move onto inlets…

Inlets; Their quality and good management

The importance of the inlet system in the house is often overlooked, but the truth is that without a well-designed inlet system, control of air flow in the house will be compromised. This is even more the case in cold climates.

Figure 20 shows a very old-style manual inlet

Finding the perfect combination of inlet opening size and pressure is of great importance when trying to get the air to the peak of the roof.

The most important thing is to know how to use the inlets correctly. Use them wrong and you can cause a multitude of problems, regardless of their quality and cost. You cannot install fantastic inlets and just expect them to work; you must know how to use them properly.

The most common problem in minimum ventilation is the improper use / management of inlets.

It is important to use a minimum opening size for your inlets to ensure that there is enough air coming in and enough momentum for that air to reach far enough into your house.

An opening size of 3-4cm is often recognised as an acceptable minimum opening. It is the negative pressure in the house (pressure difference) that decides what the initial speed of the incoming air will be through the inlet.

The negative pressure and the opening size of the inlet are the two factors combined that determine how far the air will go into the house along the roofline. It is accepted that many people make the mistake of thinking that it is negative pressure alone that determines air flow.

We need an inlet that allows the farmer to have tight and accurate control over their inlet opening size and the direction and therefore the velocity of incoming air.

Figure 21 shows a fluorescent light which is facing the wrong way, potentially allowing air coming in through the inlets to hit the light and fall to the litter

It is also important that the inlets are placed near the ceiling (if your ceiling is smooth without obstructions), ensuring the jet of air incoming, is 'attached' to the ceiling and not interrupted by lights, exposed beams etc. in the wrong place, causing the air to drop or be deflected down; even pieces of wood between joists can deflect air downwards. See figure 21 on the previous page for an example of an obstruction on the ceiling.

Where there are houses with exposed beams then we must force the air along the ceiling **below** them whilst still directing the air along the roofline up to the apex of the roof.

If we encourage higher speed of air through the inlets, then the mixing of the fresh air with the warmer air in the peak should improve too.

Figure 22 shows a deflector above an inlet - Image courtesy of Mike Czarick,

If you don't have a smooth ceiling, you can make the area near the inlet smooth by putting in an air ramp in to direct it. This would be ideally wider than the inlet and between 2.5 to 3 metres long (8-10ft) going into the house.

These ramps create a smooth ceiling near to the inlet opening and should be constructed form something solid and rigid such as wood and should be insulated.

Recessed Inlets

Deflectors can help keep the side air from coming out of the sides, but this isn't a perfect fix! The best way to avoid the side air escaping is to recess the inlets into the side walls.

This is fairly standard for European inlets, but here we will discuss the benefits:

The door is recessed into the side wall which stops the air from escaping from the sides of the inlet door. You should be able to see if this is happening by looking for dust trails at the sides of your inlets. If there are none, they are behaving well.

Please see figure 23 below for an example of a recessed inlet.

Figure 23 Recessed inlet at a farm in Devon (it also has a small deflector ramp to guide air up towards the ceiling

Recessed inlets also improve the direction of the air too. The angle of the opening created is much better, so the air is directed up and along the roof line (which is what we want). This can also be achieved from smaller openings too, meaning less fan capacity is required to pull the air in. As a result, we have warmer sidewalls and cool air is being heated up before it drops and mixes with the house air.

Ways to test your inlets and ventilation are working well;

You know your inlets are working well when the floor temperature does NOT change when the minimum ventilation fans come on… i.e. the air is forced along the ceiling for long enough to heat up before falling. You can easily try this in your own houses using Hobos or any type thermometer along the floor or even just watch the temperature sensor reading on the controller.

If the temperature does drop on the floor during minimum ventilation, then your inlets are possibly not set properly otherwise you may have air leakage.

Heating capacity

Many farmers do not install enough heaters - It is a common misconception that less heaters means less cost. Bernard Green (Aviagen) has a very different view. He says that his opinion (based on his own trials and feedback from customers that have tried the same trials) is that by installing more heaters in the house, you will be in fact **lowering** the total heat consumption of the house at a given ventilation rate.

His view is that it is not only about heating capacity but equally as important, it's about **heat distribution**. If you have more heaters closer together then each heater will have less work to do because it has less air to heat. Each heater can therefore reach the required temperature faster. Having more heaters <u>with their own thermostat</u> also allows you to only heat the area of the house that is cold and reduces the stress on the heaters. I would agree that this makes sense and as a result we have increased the number of heaters in one of our own houses.

Heat must be well distributed within the house to avoid cold spots and to control the moisture levels in the house. You must ventilate enough to remove the excess moisture from the house, and to do this in cold weather, you will need the heat.

Heating Design Requirements

Heating the air in a poultry house is relatively easy but heating the floor can be harder. Hot air / forced air systems such as biomass boiler heating is great to warm up the air, but it can be harder to heat floors as it is indirect, having been combusted outside of the house.

Important factors to consider are location of the heaters, type of heat and floor coverage. Other important factors that impact on how much heating is required, are insulation values and the leakage of the house (what heat it lets out). There are several options out there for us to choose from when considering heating poultry houses.

When you install a heating system, it needs to be able to provide heat up to 34°C for day-old chicks on the coldest day of the year possible, whilst still providing good air quality and exchange.

If you have more than enough heat provision for any extreme of weather (which as we all know only happened this year [2018] with the very prolonged very cold snap,) then you are ensuring that you are prepared for any extremes of cold weather too. This is possibly where some farms go wrong... remember there is no downside to having **too much** heating provision but a certain downside to not having enough.

You also need to consider how tight your poultry house is (i.e. does it leak like a sieve?) as this will greatly affect the heating capacity you'll need too as we have previously discussed.

You will also need to heat the air coming in via ventilation as well as replace the exhausted air from the ventilation system, so we must take this into account. Most of the heat loss your houses experience will be through ventilation, which is why so many farmers knock back their ventilation rates during cold weather to try and save on heating costs.

Broiler house heating systems

In the UK there are two main types of heating systems; indirect and direct heat. Indirect heat is heating that is combusted outside of the house and gets into the house via piped very hot air. As hot air is very light it tends to go straight to the ceiling leaving cooler air near the floor and the chicks. This is called temperature stratification. This temperature stratification can cause some issues in these types of houses, especially during brooding. At this time the temperature increase can be 0.5°C per foot moving from floor to ceiling.

Efforts must be made to move the heat down from the ceilings to avoid this (normally by recirculation fans - See Chapter 4*)*. I was advised that to have indirect heat without recirculation fans in the ceiling was not a good idea. Indirect hot air heated houses such as biomass heating are therefore better suited for houses with lower ceilings and where possible should be avoided in houses with high ceilings.

It is also accepted that forced heat houses do tend to struggle somewhat with floor temperatures for the same reasons (heated rises very quickly and is difficult to direct and keep near the litter).

Direct heat are heaters that combust within the house itself and are gas or oil fired, therefore they are better for heating house floors. These heaters will also provide a certain amount of (unwanted) $C0_2$ when combusting.

Measuring How much Moisture is in the Air - Relative Humidity

Relative humidity (RH) % is a measure of how much water is present in air at a given temperature, relative to how much the air can hold at that temperature hence the term 'relative' humidity. It tells us how saturated with moisture the air is as a percent. So, if you have a RH of 100% it's saturated and cannot hold any more moisture.

Air can hold more moisture as it gets warmer because it expands. For example, 21°c at 100% relative humidity will hold LESS moisture than air at 32°c and 100% RH. The same cubic metre of air can therefore hold more moisture simply because it's now warmer.

The table below shows the maximum possible content of moisture at different temperatures in the air (i.e. at saturation point, where no further moisture can be absorbed).

Temperature		**Max. Water Content**	
(°C)	***(°F)***	***(g/m³)***	***(10⁻³ lb/ft³)***
-25	-13	0.64	0.040
-20	-4	1.05	0.066
-15	5	1.58	0.099
-10	14	2.31	0.14
-5	23	3.37	0.21
0	32	4.89	0.31
5	41	6.82	0.43
10	50	9.39	0.59
15	59	12.8	0.8
20	68	17.3	1.07
30	86	30.4	1.9
40	104	51.1	3.2
50	122	83.0	5.2
60	140	130	8.1

Figure 24 Above table is Sourced from Engineering ToolBox, (2008). Maximum Moisture Carrying Capacity of Air. Available at: https://www.engineeringtoolbox.com/maximum-moisture-content-air-d_1403.html

As an example, using the table above, we will say that we will heat air 15°c to 30°c

- The 15°c air at saturation point is holding 12.8g of water per M^3
- The 30°c air at saturation point is holding 30.4g of water per M^3

So, to find out the increased moisture holding ability we do the following calculation;

(30.4-12.8) ÷ 12.8 = 1.37* 100 = 138% more ability to hold water at 30'c.

This explains why it is so much better to have warmer air than cold air when trying to dry. You wouldn't expect your clothes to dry very fast at all on a clothesline if the air temperature was 2°c. But if it were 30°c they would dry very quickly - it's the same for the air in your broiler houses.

It's worth knowing that **for every 10°c increase in temperature, air can hold twice as much moisture**, **or for every 10°c you heat the air, the RH will reduce by 50%**, which is pretty useful to know when ventilating our houses; for example, it may be 5°c outside and 80% humidity, but this means that in a M^3 of air there is only 6.82g of moisture, which is very low. You may then have an inside temperature of 30°c and a RH of 80% (which contains 30.4g of moisture per M^3) which means you are actually choosing a perfect time to ventilate your house harder in order to dry up the stale moisture heavy air.

This is because you are removing 24.08g of moisture for every M^3 of air you are bringing in, knocking that 80% RH down to around 20%. So, though you'd spend more on heating power to heat the incoming air, it's a perfect time to ventilate your house for a time.

It is so important for farmers to not only know the RH and temperature inside their broiler houses, but to know the OUTSIDE RH and temperatures too as this can help them alter and gauge their ventilation rates accordingly (unless of course your system has this programmed in to do it for you).

Please also see later in Chapter 3 where I talk about the mobile phone App. As farmers we must learn how to manipulate the air in order to keep our broiler houses dry whilst bringing in fresh air.

The optimum RH inside a broiler house is between 50 and 70%.

When the birds are chicks (up until 14 days old), the optimum RH is between 60-70%. The job of our ventilation system is to exchange stale moist air with fresh air therefore drying the litter and, in the process, reducing the RH. Relative humidity is a good indication of how your house is doing with regards to air quality together with a good indication of how good your minimum ventilation rate is.

Why is it so important to have a low RH and good minimum ventilation rates?

If you already have a high RH rate of say over 80% in your house, the birds inside cannot respire out the moisture because the air is already too laden with moisture and therefore has little capacity to hold yet more. As a result, the moisture ends up being excreted by the bird through its droppings, going straight into the litter. So, if you aren't ventilating enough and you have high RH too, this is when you can have your house litter literally cap overnight.

Key points from Chapter 2

- The purpose of ventilation is to maintain air quality by reducing harmful gases, whilst removing excess heat and moisture
- We must heat up incoming air to ensure the moisture levels don't get too high and we don't chill the birds
- Heat in the peak of the roof is valuable! Direct incoming cold air here to warm it up
- Negative pressure ventilation allows us to pull in fresh air exhausting stale air out
- Houses must be well sealed and insulated for negative ventilation allowing us to control where the air comes in and where it goes
- Ensure that good quality inlets are used, and you know how to use them properly
- Use recessed inlets that are built into the sidewalls for best results
- Avoid having exposed beams, purlins and lights in front of inlets as these deflect incoming air downwards
- Always have more heat than you need available - too much is better than not enough and is cheaper to run with less stress on your heaters too

- Install your heaters on the side walls and not in the middle
- Aim for Relative Humidity rates to be within 60-70% in order to keep your houses dry

Chapter 3 | Get to Know Your Houses

If we are to operate our houses to full their potential then we need to get to know our houses better. Start by gathering all your dimensions, not just width and length, but the height of the side walls and the peak / apex of the roof, insulation type, insulation R Value's and thickness, number of fans, the size and capacity of all your fans (i.e. what cubic feet per minute or metres per minute they can move), heating capacity (KW) etc. What you are unsure of you can query with manufacturers.

Figure 25 shows Charles Bourns' farm when I visited him in 2017

The more you know the better equipped you are to use the tools available to you.

Ability to take outside temperature and Relative humidity readings are also useful when calculating some ventilation rates. (See later in this chapter). Ascertaining whether your houses are well-sealed / tight, is a good place to start.

How do you know if your houses are 'tight' / well sealed?

There is a simple way to find out and that is to conduct a '**static pressure test'**. This is one of the most important elements of environmental control in our houses. Most negative pressure houses have an inbuilt pressure testing system as it's used daily in ventilating houses. I used a Magnahelic pressure gauge commonly used to test pressure in broiler houses. I also used this as its mobile and easy to use. It is not expensive at around £100.

Figure 26 - A Magnahelic Pressure Gauge

To conduct a pressure test you need to know about the fan capacities within your house. For example should you have a 36 inch (91mm) fan, the manufacturer will tell you that one of these fans has a (capacity) to move say 283M^3/m (cubic metres per minute) / 17,000M^3/hr or 10,000 CFM (cubic feet per minute) of air.

To carry out the pressure test you would need to close your entire house up, including fans inlets doors etc. You then turn on a couple of your 36" / 91mm fans and measure the resulting pressure.

Please refer to **Appendix E** for a 'How To' guide from Aviagen on *'Why Measure House air Tightness'* for a full procedure to carry out a pressure test.

The higher the pressure, the tighter or more sealed your house is, and therefore the more control you have over your house environment as well as your heating costs. Because the dimensions of your houses are not taken into consideration with this static pressure test, it is possible to be more specific and have a more accurate test if you use the house dimensions in order to determine leakage per 1,000ft^2 / 93M^2. This is where you need to know your house dimensions - length and width. These multiplied together will give you your house in ft^2 or M^2.

Using a calculation from Mike Czarick and Brian Fairchild of the University of Georgia, they say that a leakage area of 1.2ft^2 / 0.1M^2 per 1000ft^2 / 92M^2 of floor space should be an absolute minimum of leakage in any house. Anything more than this amount would mean you have little or no control over your air distribution in your house. They also say that 0.8ft^2 is a more acceptable amount and 0.6ft^2 is the ideal rate.

A new and more detailed way to evaluate your house tightness, and house generally, is by using the spreadsheet tool created by Mike Czarick and Brian Fairchild of the University of Georgia. This shows you the resulting percentage of incoming air that comes through your inlets and tells you what size opening to have on your inlets too. You can use the calculator at **Appendix F** to find out what your house level of leakage is by entering all the details required (in green text). Please click here to be taken to the editable version on the website (www.poultryventilation.com).

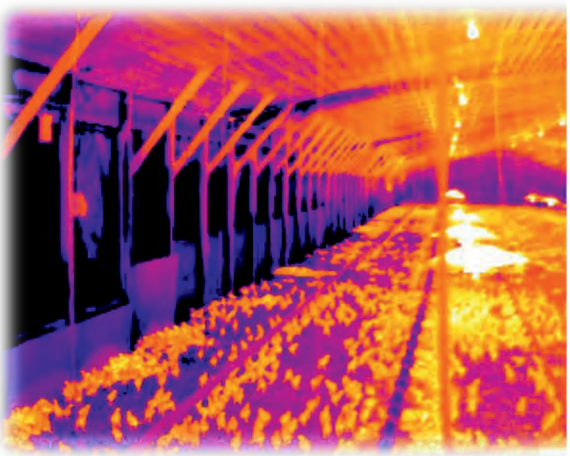


Figure 27 shows a FLIR image of a loose house where air is getting in all over the place! Notice how the birds move away from the cooler areas...

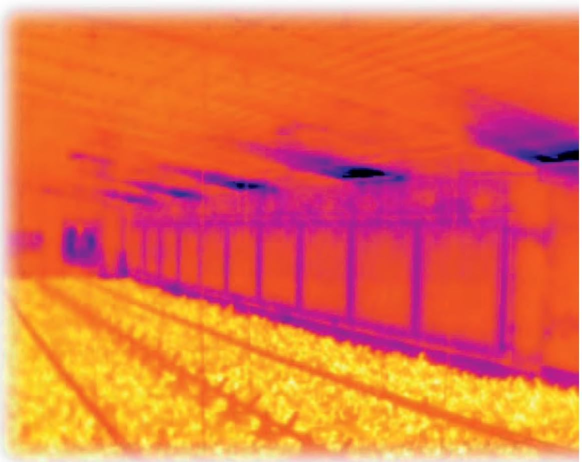


Figure 28 Shows a really tight house where no air is getting in anywhere. Notice here how the birds are evenly placed all over the floor - no dead spots

This is a really useful tool for farmers to use when they wish to find out (and subsequently improve) what level of pressure they need in order to achieve a required tightness level because the fact is, the tighter and more controlled the house is, the cheaper it is to run and floor and bird performance will be improved as a result too.

Poultry House Leakage Estimator - 2016

The University of Georgia - Department of Poultry Science

Michael Czarick (mczarick@uga.edu)

Enter Green Values (do not leave blank)

This spreadsheet is intended to illustrate how poultry house tightness can be estimated though the use of a static pressure test. The spreadsheet will also illustrate how poultry house tightness will determine the amount of fresh air brought in by minimum ventilation fans(s) that will enter through a houses inlets relative to that entering through cracks (unplanned openings). The spreadsheet will not provide precise values, but rather estimates

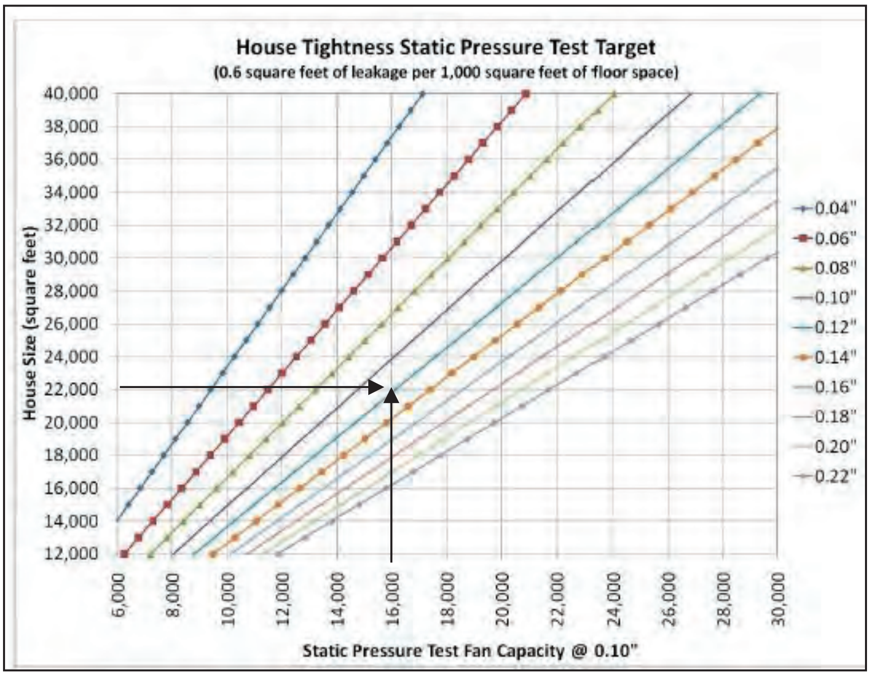
Poultry House Leakage Test:	
House length (ft)	500
House width (ft)	40
Total fan capacity used in leakage test (cfm @ 0.10")	20000
Static pressure measured (")	0.25
Relative leakage area (ft2 per 1,000 ft2 of house floor space)	0.35
Total house leakage area (ft2)	7.1

(For the best accuracy if the static pressure obtained during house testing exceeds 0.25", consider using fewer or a lower capacity test fans.)

Once you have calculated your level of house leakage (above) you can then refer to **Appendix G** there are three graphs created by Mike Czarick to show how you can plot your own 'house' in order to work out what pressure you need to have (at the size house and fan capacity you have) by looking at where the two intersect on the graph.

Each graph shows the results depending on how much leakage your house has; the first graph is for 1.2ft^2 of leakage, the second graph is for 0.8ft^2 of leakage and the final graph is for 0.6ft^2 of leakage.

As an example, using the last graph which is for an exceptionally well-sealed house, at a total size of 22,000ft^2 / 2,043M^2 of floor space with two fans running with a total capacity to move 16,000 CFM / 1,486 M^2 of air per minute between them, should have a pressure of around 0.12inches of water / 29 Pascal's in order to class as a tight house with less than the 0.6ft^2 / 0.05M^2 of leakage per 1,000ft^2/ 93M^2 of floor space. Below is an annotated version of the graph;



How to classify your Poultry House Tightness (using Mike Czarick's classing system)

Step 1 - carry out a pressure test to find out how tight your house is – see above.

Class A	If your house is greater than 0.18" / 44 Pascal's, then your house is super-tight
Class B	If your house is between 0.09" and 0.18" / 22-44 Pascal's – then your house is of moderate tightness, which is still pretty good
Class C	If your house is 0.09" / 22 Pascal's or less, then you your house is fairly loose

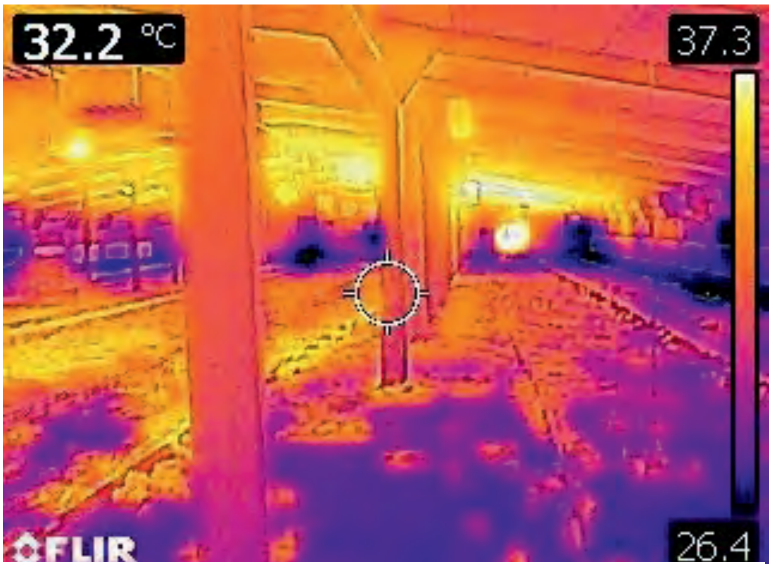


Figure 29 Example of a cold floor causing chicken to move away - taken on a farm I visited

For houses in the Class C, you need to use in-house recirculation fans to try and mix up the air and push it to the sidewalls to keep the temperature even. This is because all the air coming in through the gaps in the house causes little mixing and doesn't therefore get warmed up as it should.

So for Class A and B houses, where we whole-house brood during cold weather, a portion of the inlets should be latched shut – I.e. Class B houses, shut three quarters of the inlets, and in a Class C house, close two thirds of the inlets.

We then set the static pressure to be from 0.08" to 0.11" of pressure / 19 to 27 Pascal's; allowing a 3 point difference between the high and low stops the yo-yo effect of the inlets opening and closing too often to maintain a tighter pressure setting. This also allows for wind from outside being forced through the inlets when they are opened.

So, how can we find where our house leakage is?

The best way is to look at the birds… if there's a gap, there's likely a cold draught causing them to move away. See figures 29 and 30. If the floor is caked or wet its likely due to air falling where it shouldn't and could be from a leaky house. Look for dust accumulation – where there is a patch of dust there is a draught. Condensation clouds, showing air coming in and condensing as its movement is slow. Also, by using a smoke generator you can try and find these leakages, but one of the best ways, in my opinion is to use thermal imaging. This sounds expensive! Again, it doesn't have to be.

Figure 30 The same farm again gaps where it's cold on the floor the chicken will avoid it

You can go and spend £20k on a FLIR imaging camera – these are the cameras that produce high resolution images.

As farmers we do not need such perfection and pixilation – try one of these, it's a FLIR 1 but it just fits onto your iPhone or other mobile smart phone, it's relatively cheap and gives you the information you need. I admit I used a FLIR C2 for my project, but I did this to enable me to produce better quality images for this report and because I would use it a lot, but I would still recommend that the FLIR 1 phone for general farm use at around £200.

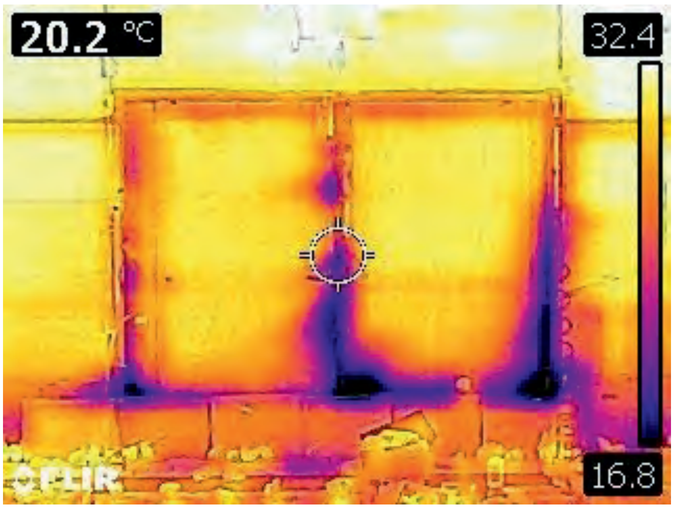


Figure 31 shows a leaky door on a farm I visited

Ways to Seal Leaky Houses

Cover exhaust fans with plastic behind the shutters, improve loose fitting doors and windows and ensure that your inlet doors shut tightly after closing. Keep your insulation levels good and seal cracks between board insulation as air come through these.

Record Keeping and Data Analysis as Management Tools

Sounds a bit dull but really, it's not! Record keeping can be more than mortalities, temperature and so on. It can be about water consumption, observations and improvements you have found to work well for a house's ventilation set-up etc.

Figure 32 A typical water meter and dosing set-up in broiler houses

Using water consumption (as a management tool)

Also remember that all the time the birds themselves are adding moisture to the house through their droppings and respiration, so make sure you record water consumption (at the same time every day) to help you decide the rates of ventilation too.

At least 80% of what the birds consume goes into the litter as dropping or respired into the air... that must be removed.

Water consumption (as far as I am aware) is recorded by all broiler farmers as a matter of course, but I wonder how many of these farmers actually use this data as a management tool?

Do many famers plot the consumption daily on a graph or do most just write down the readings down and that's it?

My research suggests to me that we probably don't use this freely available information enough to help us to manage our ventilation and our birds generally. I think also perhaps until you delve into the possibilities that there isn't enough emphasis on it here in the UK (that

I am aware of). Water usage is like a window into how your birds are doing; the best indicator of bird performance, (I believe,) is water consumption.

Water consumption is also a great way to check on feed consumption, since we know that the general rule is that the water consumed is pretty much double what the food consumption is, knowing the water consumption allows us to check this.

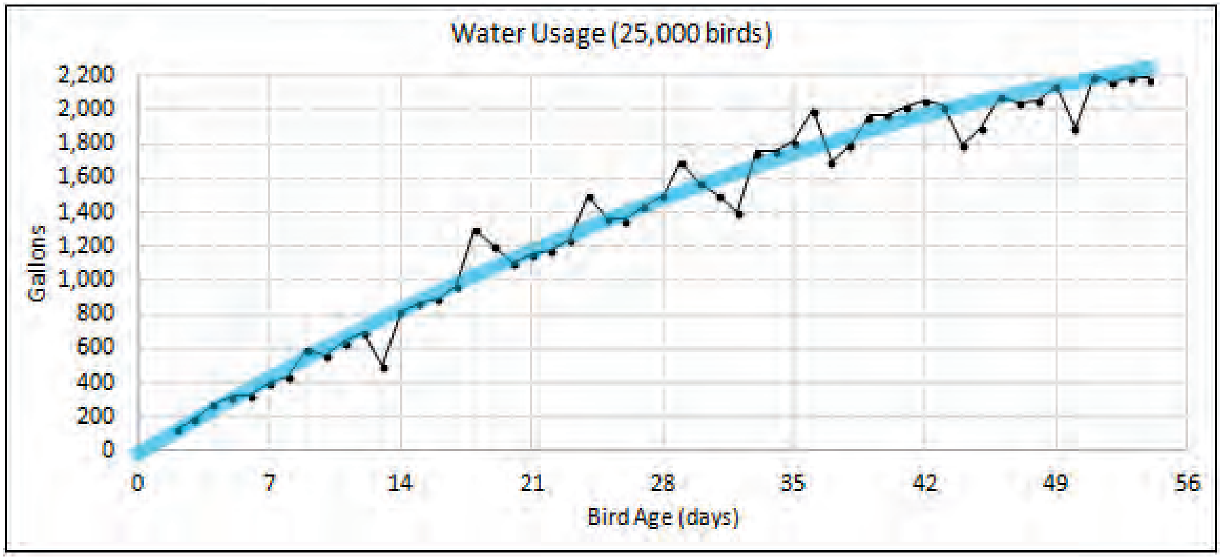
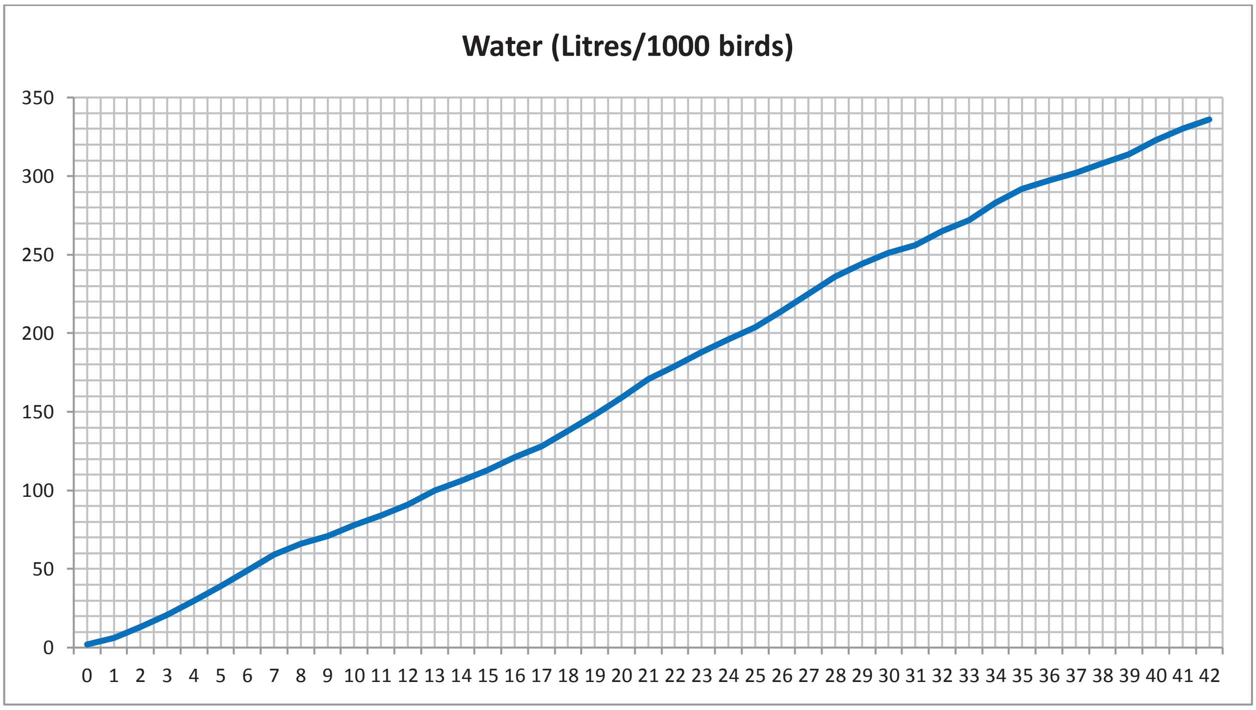


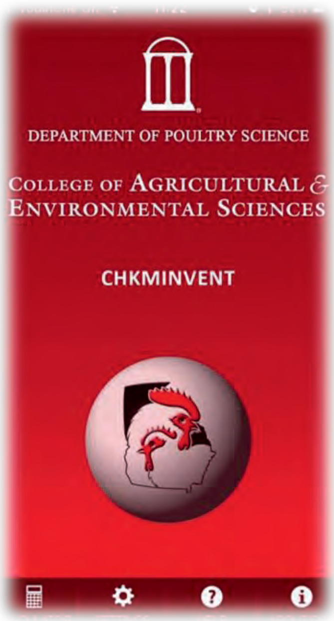
Figure 33 Shows an example of a bad water consumption chart were consumption is spiking rather than following a gentle rise over time, as shown by the thick light blue line - Image courtesy of Mike Czarick, University of Georgia, Poultry Science Department, USA

Here's what I have learned....Water consumption should be graphed daily. This sounds complicated but really it isn't at all. You can easily get expected water consumption graphs pre-printed from Cobb and Aviagen in A3 format, you just must ask. Make sure also, that you take the water meter reading at the same time **every day** for it to make sense.

All you do is have one per house and plot your daily consumption on the graph against what Cobb / Aviagen say you *should* be consuming in order to see if you're birds are roughly on track. Refer to **Appendix H** for an example of this chart, a portion of this is shown in the image over the page...



The key is to notice these changes in consumption as soon as possible so action can be taken if required. This also allows you to see trends that may be forming at certain times in each crop - say at a certain age or at a feed changeover... these sorts of trends may allow you to make changes to improve performance. You could plot several crops worth of consumption on the same graph to see how things have changed over time too.



Ooh, There's an App for That!!

With regards to daily water consumption and cold weather ventilation, we can use the water consumption to sense-check the level of ventilation we are currently using, as a way to ensure we have adequate minimum ventilation in order to remove enough of the water consumed by the birds, from the building... Remember from earlier, it is a generally accepted fact that broiler chicken excrete via respiration and droppings, 75-80% of the water they have consumed. This makes it easy for us to predict the amount of water we need our ventilation system to remove every 24 hours.

How would we do this? Well, you could try a useful mobile phone App from the Department of Poultry Science at the University of Georgia which was designed by Mike Czarick. The App is free to download on the App store it is called '**ChkMinVent**' and is a poultry house moisture removal calculator.

The App is designed **as a guide only** and for use during cold weather, but it can help you check if you are ventilating enough during the colder months by just knowing a few simple pieces of information. Go to the App store for more information.

Key points from Chapter 3

- Carry out a static pressure test in your houses to understand how well sealed they are

- Find out where your house leaks and fix it! Ensure inlets close tightly, doors are well sealed and exhaust fans are covered with plastic at the back (outside the house) and you have enough insulation

- **Keep more records** - water consumption, observations and improvements you have tried out

- Water consumption should be monitored and plotted onto a graph daily - what goes in must come out! (via ventilation)

- Try out the easy-to-use tools on this website from the University of Georgia, USA to help you better understand your houses www.poultryventilation.com

Chapter 4 | Assessing Your House Environment and Equipment That Can Help

Cold weather ventilation usually makes farmers think about the expense of heating their houses. The fundamental lesson here is that you need heat to ventilate sufficiently in cold weather. You cannot scrimp on heat (because it's too expensive) and therefore ventilation rates whilst expecting good results because the reality is that if you do not ventilate sufficiently then you will not be removing enough moisture from the house. And if this continues for a long period you will start to get capped and wet floors, your birds will be subjected to poor conditions and end up with hock burn footpad dermatitis and other such health challenges. These challenges end up causing issues at the factory and rejects will follow. You can however ventilate and heat without breaking the bank if you learn how to manage each house well.

Researching and Choosing Equipment

When I started this scholarship, I wanted to test some of the theories out for myself. I wanted to learn what equipment was available to me to try (at affordable prices), and I wanted to be able to evaluate those items of equipment so that other farmers could decide if it would be useful to them as well. This project was never meant to be a scientific experiment or a ground-breaking project. It was and is, still about trying to create an interesting (I hope!) report about how learning some of the more technical side of broiler farming can help us be better growers and what is out there to help us.

There are a few challenges faced by farmers during cold weather; I found that one of the most crucial points I have been told by experts or read about repeatedly is, the importance placed upon pre-heating the houses, and preferably before the bedding goes down. If you can pre-condition your houses to an air temperature of 32'c and a **concrete** (not litter) temperature of 28'c then you give your house a much better chance to remain dry during the crop. Also, the **bedding is insulation** so make sure you put in the enough on the floors as the chicks feel temperature through their feet (between 2 – 5 inches). Also, if you can heat the floor and litter sufficiently before the chicks arrive that floor temperature will be easily kept warm throughout the crop (which is what we want).

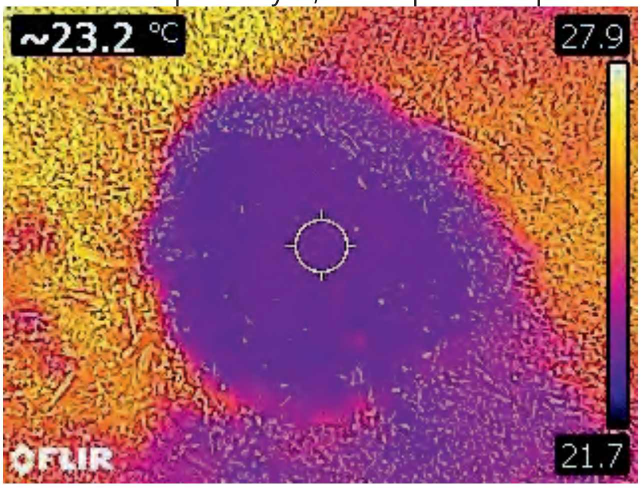


Figure 34 shows a FLIR thermal image of the concrete floor where it has had the bedding scraped away... this shows that the concrete is not warm enough (at 21.7'c)

In the colder months air speed along the floor should be checked too. For chicks at age 0-14 days the speed should be no more than 0.3m/s to avoid making the birds feel cold. For mid-cop age birds at 15-21 days old no more than 0.3-0.5, m/s is acceptable. Birds from 22-28 days old can have a speed of 0.8m/s. Birds from 28 days old and above can have 1.75 - 3m/s (these are Cobb recommendations).

Most litter problems come in the evening and during the night when the temperature is dropping, and the RH is increasing. Mostly we will rely on our ventilation system to react for us, but the human eye will always tell us what the birds are saying better than a machine.

Therefore, we are always advised, and I agree, that the best evaluation you can make on your house ventilation is from the first time you enter the house early each morning. I have yet to meet a broiler farmer who isn't in their houses by 7am at the latest.

Monitoring litter moisture

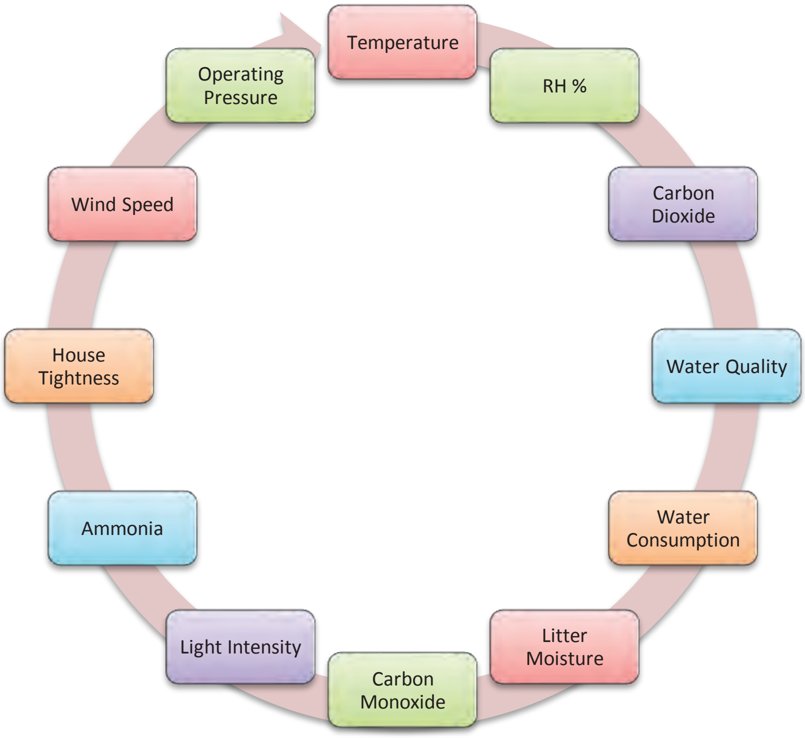
As part of my scholarship I wanted to find a way to measure moisture in the litter on a weekly basis with some kind of simple tool / probe I could use. Unfortunately, after some research I found that there is no such tool reliable enough. There is a way to measure the moisture; by collection of large quantities, mixing it, removing a sample and drying it in a vacuum oven for 24 hours at 120'F, but due to the amount of time required to do so, I had to drop the idea.

Moisture can simply be evaluated by grabbing a handful, squeezing it letting it go and scoring the result from 1 = falls apart immediately (possibly too dry) to 4 where it doesn't fall apart at all / is wet… This served the purpose for what I wanted to test.

As litter moisture increases, the quality of that litter decreases. If we maintain a moisture level of 20-25% during the whole crop, then litter should remain dry. Once litter moisture goes above the 25%, we are encouraging bacterial growth in the litter therefore opening up the production of ammonia to be released into the air.

Assessing the Environment within poultry houses

When it comes to assessing your house environment there are many different options for what you can measure and why. Below is a diagram of the major ones. For all the different measurements there are fairly reasonably priced items of equipment that we can buy without spending a fortune. More importantly they will help us better control the environment thus producing better birds. The more data and information you have, the better chances you have of improving. Of course equally should you wish, you can spend a lot of money on equipment too!



The Ribbon test

If you are unsure as to whether your inlets are working well, and whether the air is moving along the ceiling as required you can try a simple test. All you really need is several strips of ribbon, each about a foot long / 300mm (an old video cassette tape ribbon works brilliantly) and some magnets, or something to stick the ribbon to your ceiling.

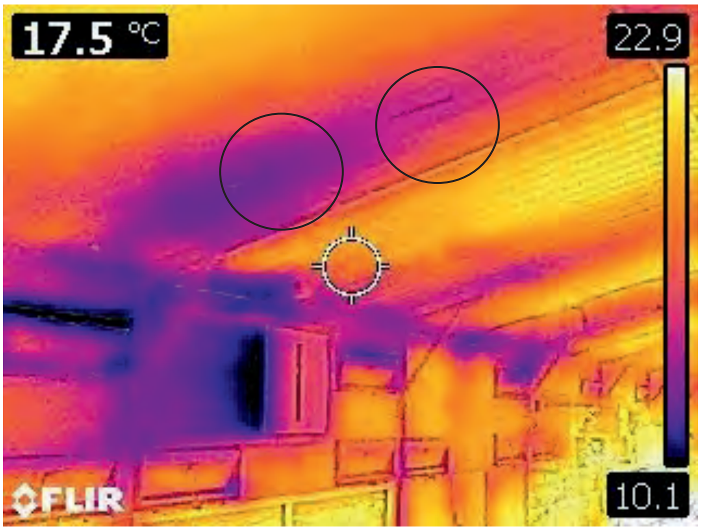
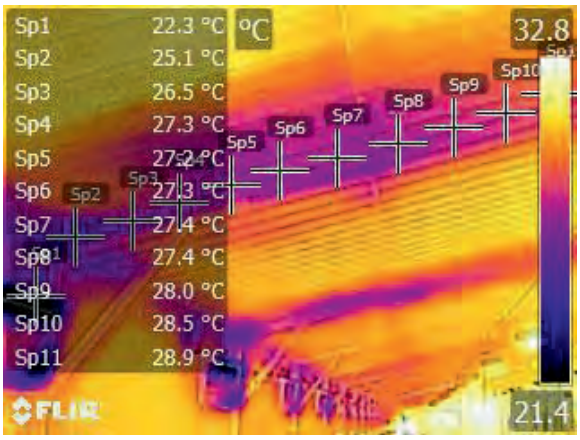


Figure 35 - Flir Thermal image of tape moving in front of inlets during minimum ventilation, see the circles where the tape is

Place the strips of ribbon around a metre apart from just in front of the inlet all the way to the apex of the roof. Wait for your minimum ventilation to come on and you should see the ribbon move as the air is pulled through them up the ceiling… if they don't move, or only a couple move nearest the inlet, and the rest are staying still you need to check your inlet opening size or time the min vent is on (and therefore inlets are open) as the lack of movement indicates that the air is falling too early.

Figure 35 above shows a thermal image I took during minimum ventilation where you can just make out the two first ribbons (they are shown by two black circles on the image above) on the ceiling and they are almost being blown flat against the ceiling telling us that the air is travelling along the ceiling as hoped. Also, you can see by the cold blue trail the temperature of the air is getting warmer as it goes further along the ceiling which is proved by the two FLIR thermal images below where you can see from the spot marks (Sp1-11) that the temperature is rising as the air travels along the ceiling which proves the theory.



When I conducted this experiment at home and on the test farms during the cold months, I used the Hobo magnets to hold the tape in place.

I measured the RH and temperature as it moved up the ceiling to prove the theory that as the cold air is drawn further into the house (an up and along the roofline), the RH of the incoming air goes down and the temperature goes up as it mixes with the air inside the house… to further check this I measured the speed of the air coming into the houses through the inlets at the same time. All were 5.5 - 5.9m/s.

Monitoring Air Quality

Air is a mix of water vapour, carbon dioxide, nitrogen and oxygen as well as small amounts of other gases. Contaminants that are allowed to increase above an acceptable threshold result in poor air quality. Contaminants in the poultry house could be remnants of dried droppings, bacteria and other microorganisms, fungi and viruses together with gases such as carbon dioxide and ammonia. The best to way to minimise all these potential contaminants increasing is to ventilate properly.

What is Ammonia and why is it so bad?

Ammonia is a colourless gas and can only be generated when moisture is present. Moisture is required by the bacteria living in the litter which will be breaking down the uric acid in the manure into the ammonia product which will eventually be let into the air as ammonia. So, if we remove more moisture, we reduce the possibility of this process occurring.

It is internationally accepted that levels of ammonia gas should not exceed 25ppm in our houses. A study from USDA Laboratory in Mississippi found that there was a difference in body weight from birds exposed to 25ppm and 50ppm of 141g per bird… so if you have a house with 30,000 birds, that's an overall loss of 4,230KG of weight! It is also known that exposure to high ammonia levels can lead to Ammonia blindness and respiratory issues in broilers. It is also unhealthy for us humans to work in these exposure levels. Once again, the answer is, ventilate properly.

Carbon Dioxide

This is something that is proving more and more useful to know. Many vets and processors will expect us to have a sensor or a handheld sensor to check our levels. If you combust your heat within the house itself with oil or gas, then you really should be checking your CO_2 levels. If you are not ventilating enough during brooding, even before the chicks arrive you could be causing unnecessarily high CO_2 levels before you start.

Figure 36 My Co2 Telaire handheld monitor used for farm visits (plus a nosy chick!)

CO_2 meters, if handheld MUST be given time to acclimatise to the new environment. Give it at least 10 minutes before you expect a realistic reading from it.

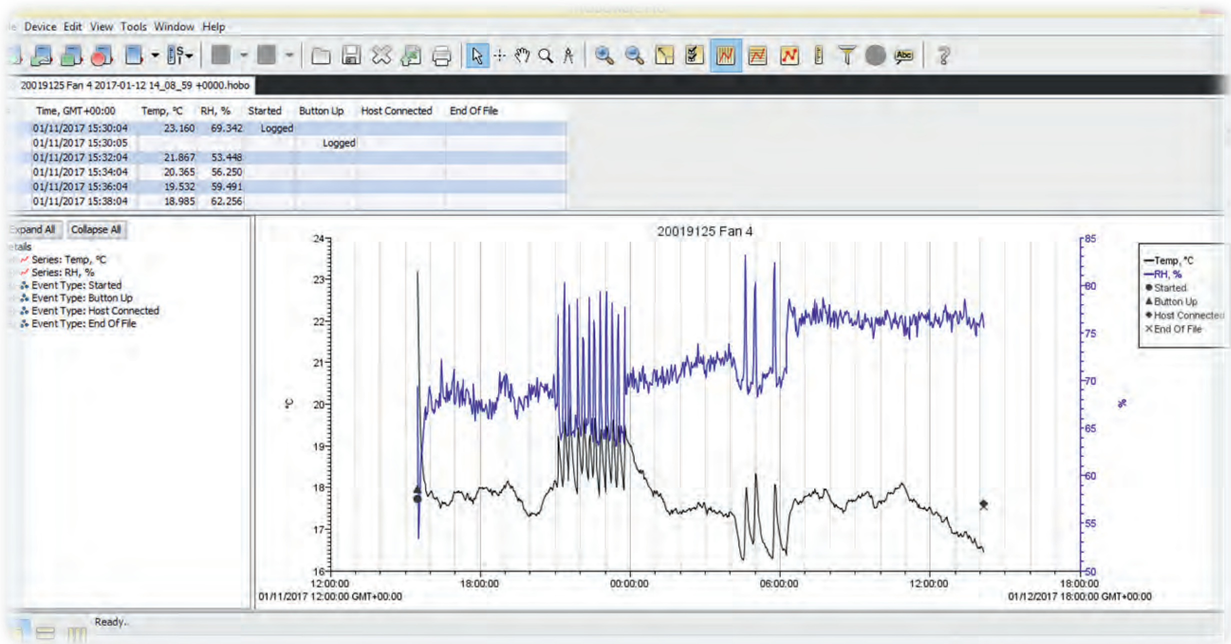
If you are undergoing an inspection, always make sure the inspector does the same! This is the one I used but there is a huge choice on the market.

Temperature and RH

As we all know, the most important aspect to monitor would be temperature and RH. All farms now have temperature sensors within each house, and most do now have RH sensors too, but for those farmers who don't have RH sensors installed, read on! The below is also interesting for farmers because of their mobility and ease of installation. I was advised by Mike Czarick to try a data-logger, called a HOBO from a company called Onset. A Hobo is a piece of equipment used to monitor and record both temperature and RH. Onset is a company in the USA, and they have a huge range of equipment suited for poultry housing, and, once you start looking, you'll find several useful items, that I believe are overall, reasonably priced.

When I started looking for the equipment I wanted for testing, I came across a UK company called **Tempcon** who supply all this type of equipment which they import. They are very knowledgeable on what they sell and can advise you on what is best. I found them extremely helpful.

An item I found to be one of the most useful was the various data loggers. These are designed to not only take readings such as temperature, RH, water consumption, but will also record this at intervals chosen by you; this is where things get useful as you can not only spot check measurements but collect data over whole crops and analyse the results. Onset also provides completely free software to be used alongside their equipment which is very simple to use, even if you are not a whizz on a PC!



There were two types of Hobo I used for testing. Both are powered by AAA batteries (of which seem to last forever) They are both very compact and both have loops to cable tie them to fix in place. One is a Bluetooth version, which has a sensor within the casing, the other is a cable with a sensor on the end. I found both to be great to use and never had any issues. The only thing I preferred about the Bluetooth one is that you could access and download its data from your phone App, whereas you needed a lead and potentially a laptop to connect and pull data from the other Hobo which was not as quick and easy.

I also found that being able to move the Hobo's anywhere in the house was useful too; you can then check the spots you think may be suffering from a slightly lower temperature than other areas for example.

I tended to choose to install the Bluetooth Hobo on a feeder wire using the loops. I have been advised that you should always install such items nearer the sidewalls of your houses rather than in the middle as the sidewalls are always cooler. I used cable ties to attach them to the feeder drop cable which works well. After some discussion with Mike Czarick and Tempcon I would place the Hobo in a cut-off ladies stocking and tie it in. This is because the dust we accumulate in broiler houses would not do the sensors in the Hobo's any good, and they still measure the RH and temperature well as the air can travel through the stocking but doesn't allow the dust to settle on the Hobo. This worked perfectly.

Sensors do need recalibrating though. Everyone has a different opinion on how often, so I am not going to make any judgements. You can sense check your temperature sensors very cheaply by purchasing a few regular old mercury thermometers and fixing them in the house right by the sensor to check they are both the same.

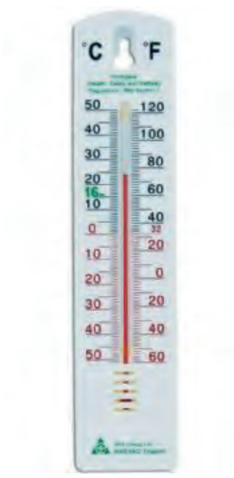


Figure 37 is a Mercury thermometer on www.aspli.co.uk for £2.43+VAT - Cheap as chips!

You can also buy an old-fashioned whirling hygrometer to test your RH sensors. They're only around £35 second hand and are 100% accurate and quite neat to use - you literally whirl it round to get your readings. At least then if you can see your electronic sensor and whirling hygrometer are different then you need to get your electronic one off to be recalibrated!

Figure 38 A whirling Hygrometer for RH readings - image from thermometersdirect.co.uk

Figure 39 Shows a solar radiation shield on-farm

Measuring and Recording *Outside* Temperature and RH

I used a Hobo here, the one with a sensor on the end of a cable - this then fits into a weather shield. These items are designed to be used together (both made by Onset).

By using a solar radiation shield you are getting the truest readings from the outside weather conditions since the shield stops direct sunlight etc from being directed straight onto the sensor giving duff readings. Both items are not expensive and will be of use for you on farm.

Measuring Floor Temperature

Over and again I have been told and my research tells me that floor temperature is as important as the air temperature when the chicks are young. Remember, chicks feel temperature through their feet, so if you have a cold floor you will have cold chicks. The best way to measure the floor temperature is using an infrared temperature gun.

There are a multitude of options for these online, so I won't talk about a particular one as they are all similar. The most important thing I can tell you about them though is the best way to use them to get the most accurate reading. To do this you need to get as **close as you can to the target**. Don't stand at one end of the house and point the laser to the floor at the far side of the house as this will not be as accurate. These can also be used to check other things on the farm such as pipes etc.

Other ways to measure RH

You can use a simple handheld tester of which there are many to choose from and they are not expensive and are all relatively accurate with a range of around +/-1-2%. You could also use a Kestrel (also measures others such as wind speed and air temperature) but unless you are going to use the wind speed feature etc it is not the cheapest of options at around £200+. The most important thing to remember when using a handheld device is that you need to let it get accustomed to the house conditions from being outside before you can expect a realistic reading. Give it a good 10 minutes to adjust. You will preserve the life of your handheld tester if you do not leave it in the houses for prolonged periods.

SMARTHY - measuring temperature and RH

I did also test an insert that you can use on your mobile phone to measure RH and temperature. It was only £25 and proved really useful and compact. It will also log the readings which most handhelds won't do. Though it was useful its fairly small (about the size of an in-ear mobile phone hands free kit) and easy to lose, and because you don't want to mess up the sensor with lots of dust etc, I would suggest finding a pouch to store it in whilst you carry it around. The other great part about this is the software with it which provides a useful tool when looking at the data.

Thermal Imaging Cameras

This is the exciting one. I was able to use a FLIR C2 camera which was quite expensive to buy but really useful. Again, FLIR is an American company but very well known in the industry. You can get an attachment for your mobile phone (either iPhone or android) called a FLIR one which is much more affordable. The Imaging is really useful for all sorts around the farm. It was great for checking the temperature of the floors, walls, and incoming air from inlets as well as locating draughts. The software provided free with the camera was really useful too. I used a company called Pass; they provide all the options for FLIR equipment and are really helpful. I did get chance to use The FLIR camera used by Mike Czarick of Georgia University but that one is several thousand Pounds!

FLIR C2 Camera I used

FLIR One iPhone / Android phone attachment

Smoke Emitters

Pellets are great; they are cheap and easy to use. I was advised that to smoke test you really need a decent temperature differential from inside to outside of about 20°c. It's therefore not so useful to try and smoke test in the summer. I used these pellets all over the houses and would highly recommend that you try them if you haven't already. The pellets are best for use inside the houses, to smoke test from outside the houses to check for leaks in the house etc, you are probably much better to use a smoke machine.

I used an online company called 'Peasoup' www.smokemachines.net for my pellets. They do everything you can think of including smoke machine hire... Since purchasing the pellets there has been an improvement to their design and you now get a plastic holder.

Static pressure

I used an American gauge called a Dwyer as this seems to be most commonly used. Most farms now have a meter installed in the house, but if you don't, then a Dwyer meter is compact and easy to use. Please see Chapter 4 for the more information on the use of this piece of kit.

Heating Zones

How many farms have their temperature sensor in the middle of the house? Did you know that is the worst place you can have it? The centre of the house will always tend to have the least heat demand of the whole house, meaning your sidewalls will probably always be a bit too cold.

Place your sensors around 3 metres / 10 feet from the sidewall for the best results but 6 metres/ 20 feet from end walls where applicable. The sensor should always be 12 to 18 inches above the floor and be moved upwards as the birds grow. Worthy of note is that the RH % sensor, however, should be in the middle of the house and about 3 feet / 914mm above the floor.

There should also be a minimum of three heating zones within each house which are the two end walls and then the section in the middle as shown in the image below.

Zone 1	Zone 2	Zone 3

More heating zones allows much more control over the house temperature and the heat each area needs are attended to within the zones rather than one sensor. This is because the end zones of the house are often the coolest. Also, this saves on heating costs as only the zone that requires the heat, gets the heat, thus saving you money.

Importance of Pre-Heating your houses and litter

Ventilation and heating costs are closely related. The way to reduce those heating costs is to understand what ventilation is and how to achieve it properly. The practical challenges of ventilating during cold weather are mostly related to the control of moisture. We must have as a major goal, control over the level of moisture in our houses.

Moisture has the most influence on what we need to do with our ventilation rates. We already know that too much moisture can lead to wet floors, condensation, FPD, leg issues, breast blisters and the formation of ammonia if allowed to take hold. You can get quite the opposite should your house be too dry; for one you will probably quite a nasty heating bill! Other factors are increase of respiratory issues and susceptibility to disease through excessive dust in dry houses.

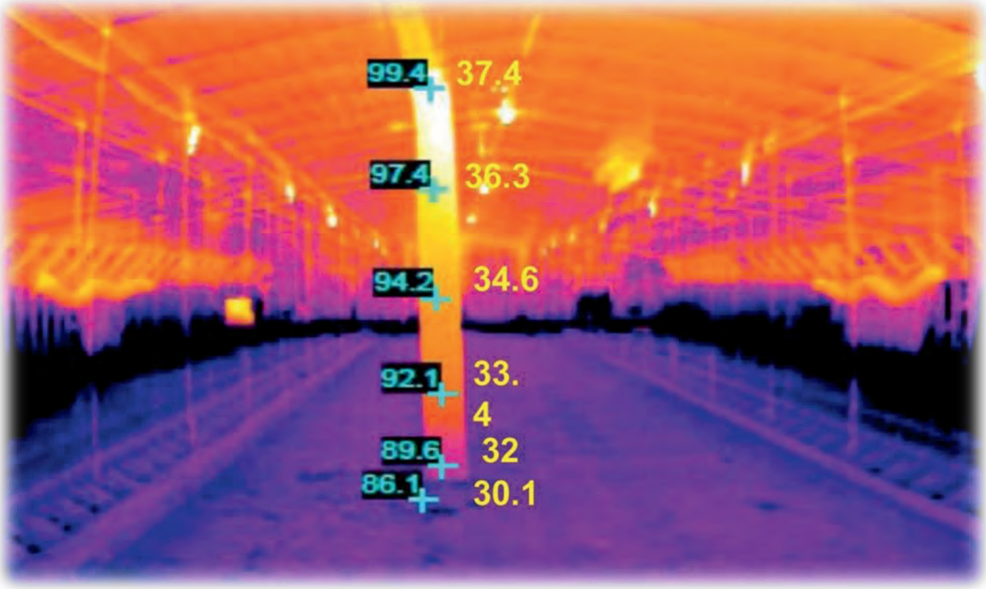


Figure 40 showing the temperature stratification between the floor and ceiling - Image courtesy of Cobb

So, when ventilating during cold weather the air you are bringing in is often a lot colder and often damp with a higher RH than the inside, meaning you have to work harder to condition (heat) it. We must remove the excess moisture from the houses by replacing it with outside air. This is where the importance of throw, airflow speed and heat come into play within our houses during the colder months in order to ensure that cold air doesn't end up falling on the floor making it wet, by ensuring it gets into the peak of the roof and mixes with the warm air already in the house before falling to the birds. And that, is about it. See... easy.

I had contact but no access to a farm that did not have time to pre-heat their floors before they placed their litter. I was not allowed to use equipment to test but they did tell me what happened; they were running their site on oil heating, combusted inside the house using in-house oil heaters. Because it was winter and at the time, and very wet weather, they had issues getting the bedding into the house completely dry, it was in fact damp upon spreading. Once the heating was switched on (after the bedding was placed), they still did not have sufficient time to dry the bedding. As a result, that farm had issues with litter for the whole crop duration. Extra bedding was placed in all houses on several occasions.

This same farm had problems with high FPD levels at the factory too, which was unusual but clearly linked to the problem of damp bedding, cold floors, very cold weather and no pre-heating. This proves to me that not only does pre-heating of the concrete matter, but the pre-heating and dryness of the *bedding* matters too. I learned that there is great importance in pre-heating your houses for at least, where possible, 48 hours.

I also learned from a conversation with another farmer who has biomass heating, a trick to pre-heating floors; he told me that he often struggled to get his floor temperatures up to scratch. So, he has found that if he heats his floors (prior to bedding placement) up to 37°c for 8 hours he achieves better floor temperature than if he heats to 33°c for 3 days!

The drying potential of recirculation / ceiling fans

Ceiling fans were originally designed to reduce the stratification of temperature from floor to ceiling, by pushing some of the hot air down to the litter and the birds. Recirculation fans were fitted to mix that air up, and, mostly this works well (we have these on our own farm) This was also to reduce the RH % stratification - remember that for every 10°c of temperature increase the RH is halved, i.e. the air can hold twice as much moisture, so we want that air where the birds are to dry up our litter and reduce the need for more heating. We also can use recirculation fans to reduce RH stratification. Your most valuable air is in the ceiling as its the warmest and the driest.

We also tend to find that the coldest areas of a house are around the sidewalls or at the ends, so recirculation fans deal with this issue too. It is also accepted that birds from the sidewalls tend to have a worse FCR than that of birds from the middle of the house since these areas are always cooler. Recirculation fans can help to reduce the difference in temperature throughout the house.

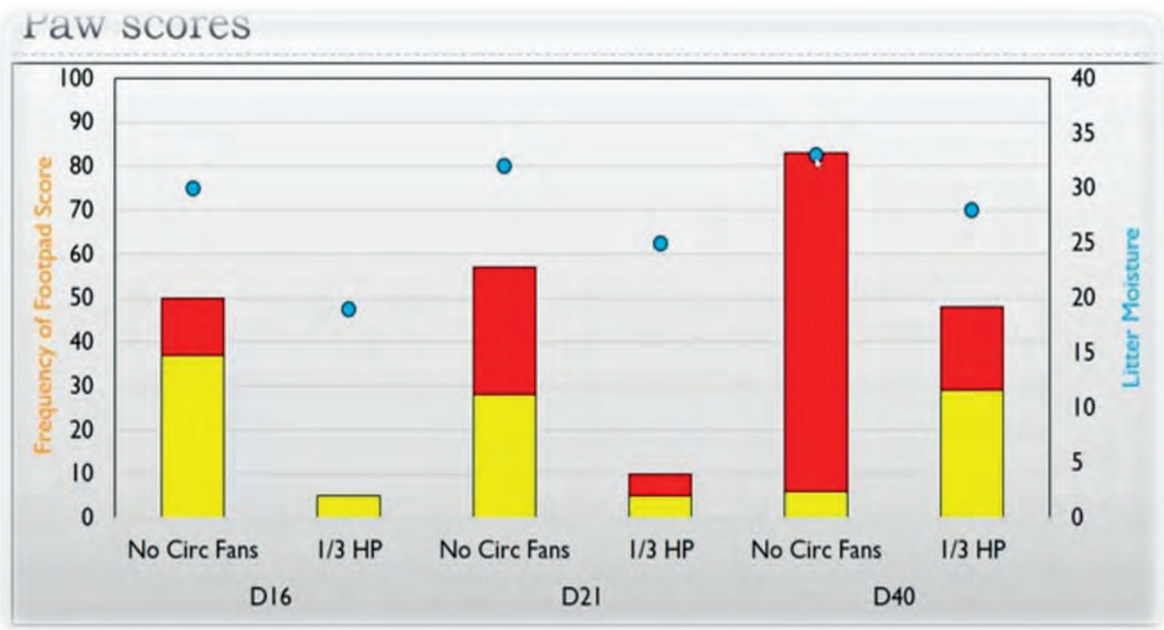


Figure 41 Courtesy of Brian Fairchild and Mike Czarick of Georgia University, USA

When talking about dry litter you can dry it either by keeping your RH low, or, if you use recirculation fans, you can use a slightly higher RH if you use the fans to move the air around the house and over the litter more effectively, which dries out the litter more, even if it is damp.

The circulation fans are meant to be of higher speed in the ceiling but of lower speed at floor level (less than 100ft/ minute) in order to avoid drafts. The University of Georgia (in the USA) found after their testing that using these fans really reduced the moisture in the litter across the whole floor, even at the sides where we tend to get the wetter litter. Not only that, but they found the incidences of FPD was a lot less when using such fans compared to not using any at all; 7-10% less moisture. See above graph in figure 41 of paw score for with and without recirculation fans. The temperature is also much more uniform across the whole house.

Over the page are two graphs taken from Mike Czarick's research at the University of Georgia where the first graph shows the house without recirculation fans and the second is the same house with recirculation fans - you can see that the temperature stratification of this house is minimal with the recirculation fans.

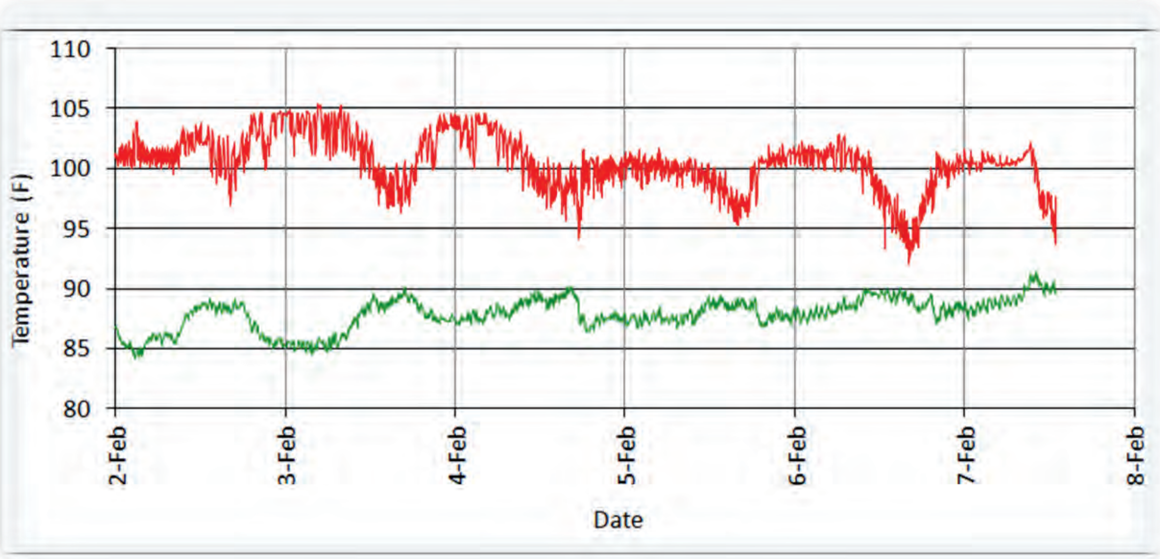


Figure 42 - House without circulation fan's - Image courtesy of Mike Czarick, University of Georgia, Department of Poultry Science, USA

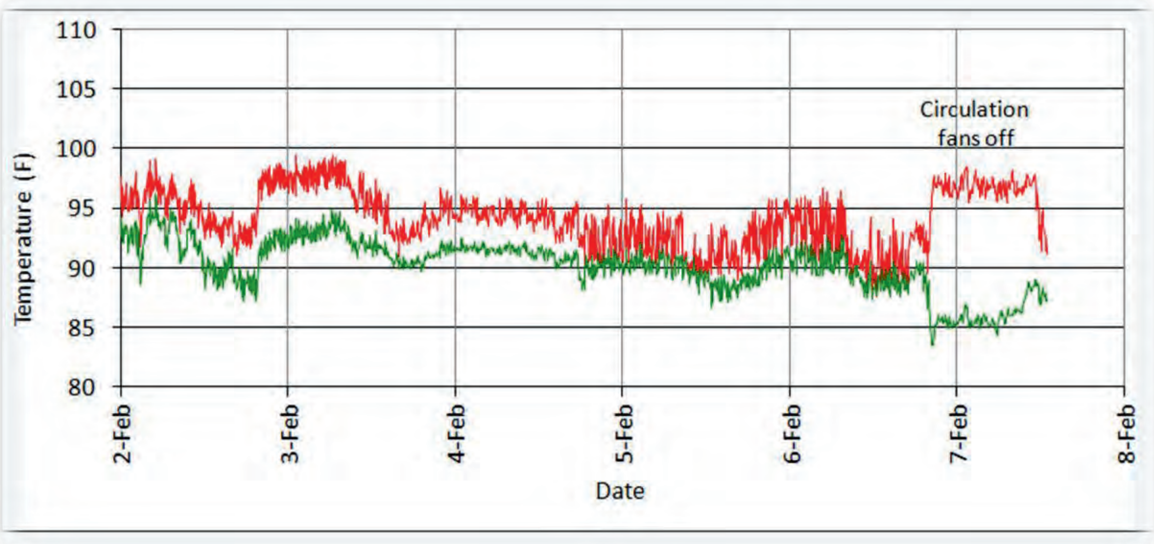


Figure 43 - The same house as above but WITH circulation fans - Image courtesy of Mike Czarick, University of Georgia, Department of Poultry Science, USA

Key Points from Chapter 4

- Wherever possible, always pre-heat your floors before placing bedding

- During cold weather it is important to ensure air speed along the floor is correct - too high and you create wind chill

- Moisture problems often happen during evenings and night times where the temperature is dropping, and the RH is increasing

- There are a huge number of affordable tools you can use to check house environment which will greatly help you improve conditions in your houses

- Test your inlets are directing the air along the roof by tying strips of ribbon every metre or so up the roof from the inlet - if the ribbon wafts around, then this is good!

- Thermal imaging is a superb way to check your house for leaks and ensure air is going in the correct places - there are mobile phone inserts that you buy for less than £100

- When using any handheld meter such as a RH or CO_2 meter, give it time (10 minutes+) to acclimatise to the house before taking a realistic reading, making sure any inspector on your farm does the same thing!

- Measuring temperature and RH is most useful if you use a logger, try Tempcon, a company based in the UK who supply Hobo's by Onset - very affordable and convenient to use equipment

- Use smoke emitter pellets to test out your ventilation as long as there is a 20°c difference in temperature from outside the house to the inside

- Consider using circulation fans to dry the house litter and reduce house temperature stratification

Chapter 5 | The Practical - Proving the Theories, Test Farms and Final Conclusions

Challenges of the project

When I started the project it was the winter that Avian Influenza (AI) really hit Europe and in the UK, we had the housing order as a result. This came about just as I was trying to visit and choose farms to test in. Obviously, no one wanted me to visit them, so things had to be put on hold. Other than AI having a full-time job at the family farm made it hard to fit everything in and there were things that had to give. However, I did get to test on three farms even if it was a year later than intended.

Test Farms

I was able to set up some basic test equipment at three farms in Devon, courtesy of Chris Chater at Hook2Sisters and some lovely farmers who agreed to help me.

It is very important to understand that a trial of this type has a certain leap of faith in that I hoped that out of the three farms, they would give me the data I required to confirm my theories. What would have been ideal is to have a famer under-ventilate their house and reduce the heat used in order for them to have wet floors and poor results at the end of the crop, and another farmer over-ventilate and use lots of heat (at great expense to the farmer), have super-dry floors and great results at the end of the crop, thus proving the theories. Obviously asking any farmer to do such a thing is unfair as either which way the test would be far too costly for them and no sane farmer would let me do this (so I didn't ask).

Also, I couldn't ask so much of the farmers by expecting them to take lots of measurements or record lots of data on a daily basis over what they would normally do. I tested at these farms for 4 weeks and collected data on temperature, RH, water consumption and temperature set points, litter moisture levels etc.

I did not get the extremes of differences between the test farms as I had hoped, but I did, with the help of **Bernard Green (Aviagen)**, learn to understand what the results of the tests told me about the farms and the people that ran them.

As a reminder, to give us the best chance of managing our minimum ventilation, RH levels in the house, and the condition of our litter, we must ensure the following:

1. **House Quality** - A well-sealed, airtight, well insulated house
2. **Minimum Ventilation Inlets** - A good minimum ventilation inlet system is of great benefit
3. **Inlet Management** - Knowing how to manage your inlets well
4. **Heating** - Houses must have adequate (and where possible, cost effective, cheaper), well distributed heat to be able to warm the house up whilst providing minimum ventilation, regardless of ambient conditions
5. **RH and Minimum Ventilation Rate** - We must run our minimum ventilation fans (preferably on a cycle timer) to control moisture in the house

I have tried to evaluate the test farms based on the above criteria.

1. **House Quality**

The houses I used at Farm A and C were both between 6 and 12 months old. When I pressure tested them, they gave good pressures; Farm A was 46Pa (good) and Farm C was 58 Pa (really good).

House B was a very old wooden house of ±30 years old. As the farmer himself admitted to me, "*it leaks like a sieve in places*". On pressure testing the house, it did indeed leak like at sieve, showing a pressure of only 15Pa (pretty bad).

When asked about the insulation of their houses, the only answers I got from the farmers was that House A is "very thick", and House B has "very little left".

2. **Minimum Ventilation Inlets**

Houses A and C have what may be considered among the better inlets on the market (in the opinion of Bernard Green). They are good at directing the incoming air up and along the ceiling with no air leakage along the bottom, and very little leakage at each side of the inlet door. The inlet doors are insulated. The doors are fitted with springs that pull it closed, ensuring that the seal is tight and so minimises air leakage on the inlets that are not used for minimum ventilation.

Over the page is a thermal image of Farm A's inlets during minimum ventilation - it shows that the inlets are working well.

Figure 44 Shows the inlets at Farm A (Farm C had the same inlets)

The House B inlets are very large and made of wood. Older inlets like this are not anywhere as good as those found on farms A and C. These inlets typically leak a lot of (cold) air around the hinges at the bottom of the door, and at each end.

This air leakage does not mix properly with the warm air in the house and falls down onto the birds and litter. This was shown by the areas of the floor near the inlets that were often greasy or capped.

The inlets are also very large and may allow too much air through each inlet, which isn't good.

Figure 45 Shows the inlets at Farm B

3. **Inlet Management**

In this area I had to rely on comments and thoughts from Bernard Green based on information and notes I had made during my farm visits.

When farmers comment that they opened the inlets more because "*the house didn't smell good*, Bernard says that it is clear that the farmer is not sure about how to manage inlets. One farmer sets his inlets with an opening of 5mm. This will not allow for ideal air flow into the house. Farmer B doesn't open his inlets at all for the first few day due to the amount of air leakage he has in his house.

None of the farmers seemed to be aware of what the operating pressure of their house should be.

From these and other comments, Bernard felt that in all 3 farms, there is room for improvement on how the farmers manage their inlets.

4. Heating

In trying to compare the heating capacity in each house, Bernard advised that I looked at kW of heat per m² of floor area. Using this method, it showed me that, in theory, all 3 houses had a fairly similar capacity.

House A has 0.15kW/M²
House B has 0.12kW/M²
House C has 0.13kW/M²

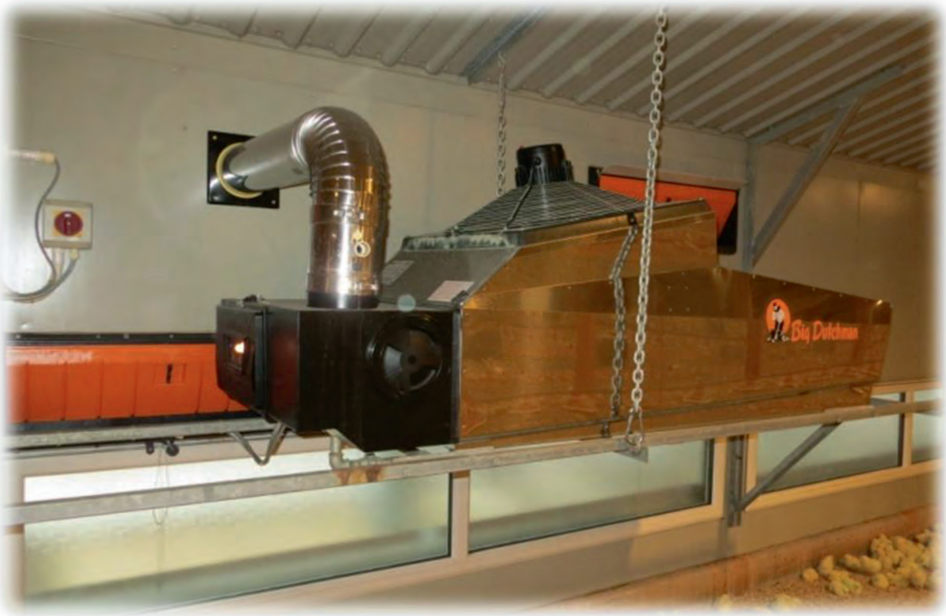


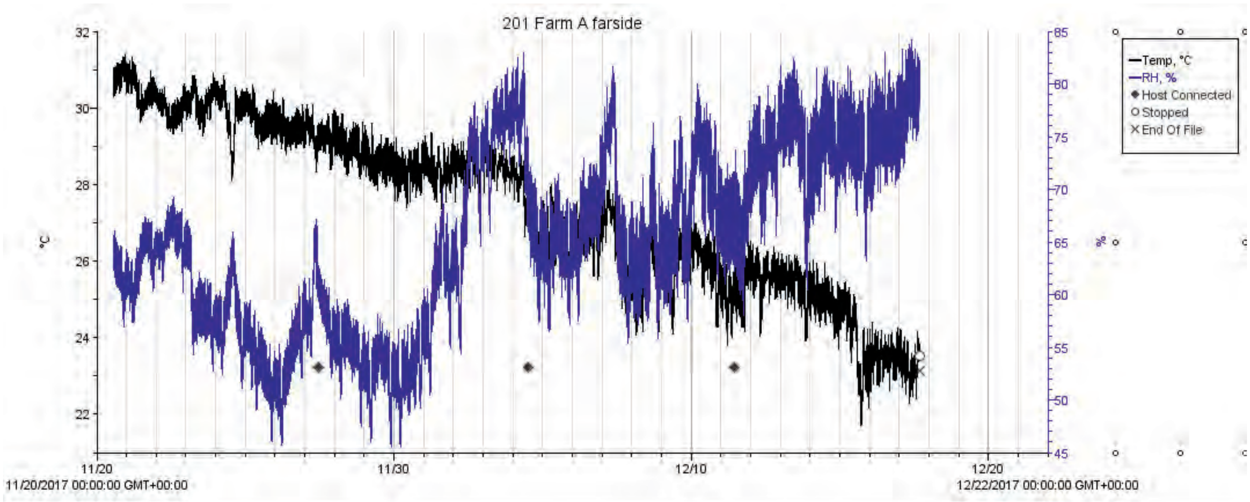
Figure 46 Shows the heaters used at both Farm A and C

If we take into consideration the age of each house, the air tightness/leakage of each house, and the current condition of the house insulation in each, it is probably fair to say that in real terms, house B has far less heating capacity when it comes to keeping the house environment and the birds warm. The heaters seemed evenly distributed in all houses.

5. RH and Minimum Ventilation Rate

Below are three graphs, one taken from each test house. They are the graphed data from the Hobo's used to record temperature (black line) and RH% (blue line).

House A *(Please refer to **Appendix I** for a larger version of this graph)*

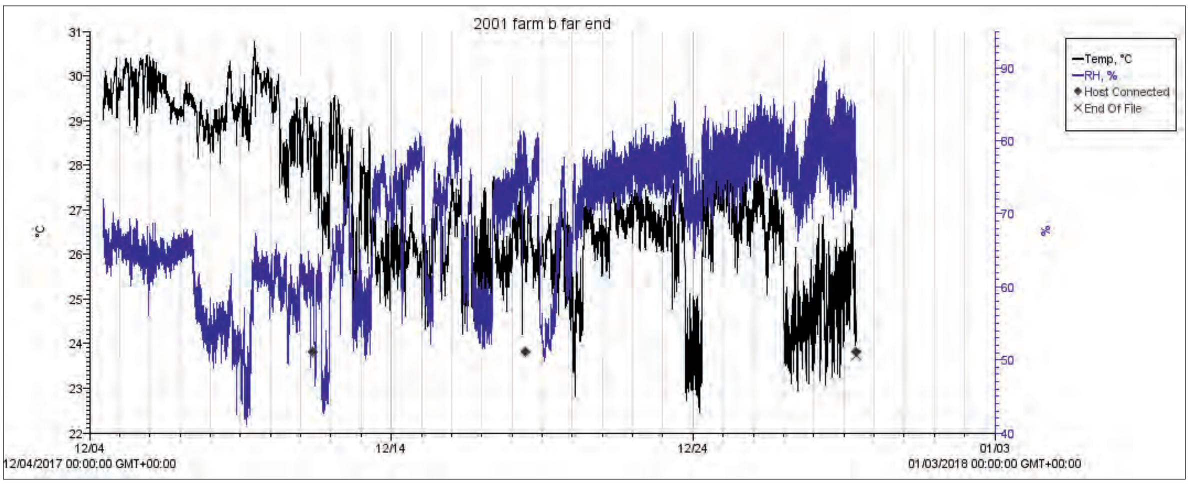


Looking at the initial 10 days of the crop, the RH is good and within a reasonable level. After about 10 days the RH increases into the 60's, 70's, and at times even into the 80's. These higher levels of RH would certainly contribute to wet litter problems.

During my visits to this house, my own evaluation of the "air quality" inside the house was that it was never terrible, but I felt that it could be better. My CO_2 measurements found levels as high as 3,000ppm. This, along with my air quality evaluation, would suggest that the minimum ventilation rate was not enough.

In support of some of the earlier conclusions made about the condition of House A and its inlets, take note of the temperature profile (black line). It shows good temperature control on a descending profile from when the chicks were placed through to near the end of the crop. This is what we would expect to see from a house that has the attributes mentioned earlier.

House B *(Please refer to **Appendix I** for a larger version of this graph)*



Bearing in mind the age of House B, the fact that it is not well sealed or insulated, and has very outdated inlets, these facts may all contribute to the erratic temperature graph above. It would be extremely difficult (almost impossible) to create a temperature profile such as that shown in house A, given house B's circumstances.

Figure 47 Shows inside House B

If it is difficult to control temperature, it will be very difficult to control RH. Typically in such houses, farmers may try to reduce the minimum ventilation rate in order to keep the birds more comfortable and warm. In doing so, RH levels will increase. This may have been the case above nearer the end of the crop where RH levels reach into the 80's.

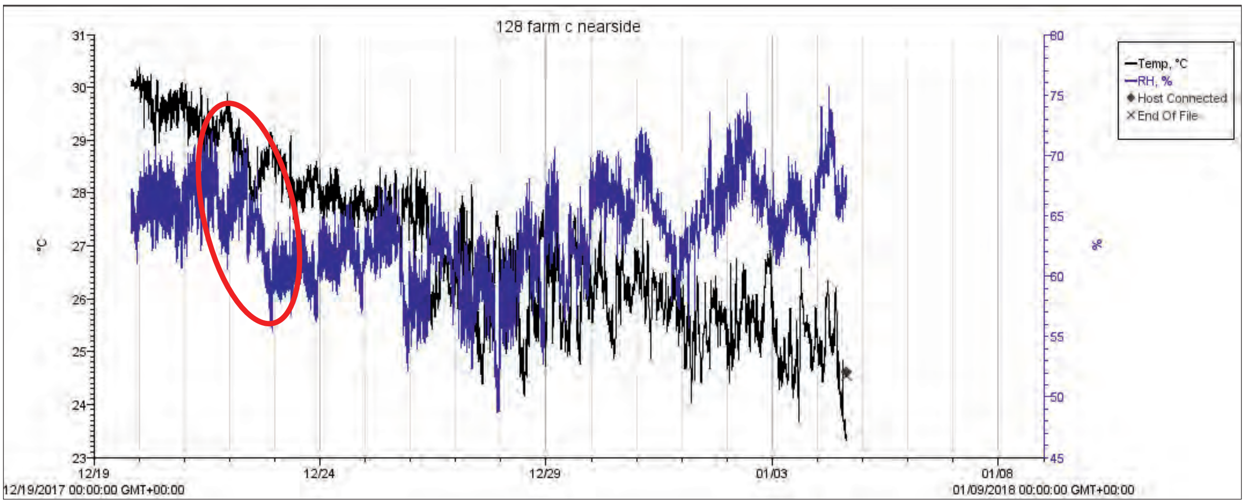
On my visits to this house I felt that the house was smelly, the air quality was definitely not as good as house A.

The litter in this house had areas where it was quite greasy and capped - especailly at the end and sidewalls though efforts to rebed were always made.

In this house I measured CO_2 levels as high as 3,900ppm.

The high CO_2 and RH levels, along with my evaluation of his air quality suggest that his minimum ventilation rates should be increased. But this may be easier said than done given the condition of his house and inlets.

House C *(Please refer to **Appendix I** for a larger version of this graph)*



The graph on the previous page shows a very good control of temperature descending through the period of testing, similar to House A. We can see that the control of RH is much better here than House A.

House C was a joy to be in - the floors were crispy dry and the air clear. The CO_2 level was never above 2400ppm on each visit. There was never any descernable smell in this house.

Figure 48 Shows inside House C - the air here was clear and the house a pleasure to work in

The RH and CO_2 levels along with my evaluation of the air quality would suggest that the minimum ventilation used in this house was higher than in the other two houses.

The table below is a summary of the minimum ventilation guideline from each house showing the minimum ventilation rates (M^3/hour per bird) for each house.

Bird Age	House A	House B	House C
0	0.07	0.04	0.08
7	0.27	0.15	0.25
14	0.53	0.32	0.53
21	0.89	0.66	0.89
28	1.30	1.05	1.31
35	1.53	1.48	1.53

It is clear to see that the (theoretical) ventilation program in House A is very similar to that used in House C. House B uses a program with a much lower ventilation rate.

If each house followed the program exactly (which is usually never the case), we would expect to see that the RH levels in Houses A and C are always lower than House B.

If Houses A and C have very similar minimum ventilation programs, then why is the RH maintained at a lower level in House C than in House A?

Well, in some ways, we think this was luck. Last cycle was the first winter cycle in the new House C. The farmer explained to me that things didn't go well, his ventilation was really poor, and as a result he had the worst litter condition he has ever had.

As a result of this disaster, and to ensure that it didn't happen again, the farmer from House C explained to me how, at certain ages, he exceeded the program by manually switching fans on to operate continuously. In doing so, he was far exceeding the rates shown in his minimum ventilation program.

According to Farmer C, at 3 days of age he switched on an additional fan to run continuously over and above his cycle timer. This meant an increase of 50% in the ventilation rate, and a clearly visible drop in RH (circled in red on the graph).

Again at 16 days he switched on another fan to run continuously over and above his cycle timer fans. This was the equivalent of a ±25-30% increase in his ventilation rate.

Conclusions

Farm C had the best litter, after C, Farm A was the next best, and then Farm B.

On paper, Farm A and C had very similar ventilation rates but Farm C clearly ventilated more and had much better floors and much less moisture.

A and B did not ventilate as much as C and this is evident through the higher RH readings on the graphs.

Both Farm A and C had more control over their houses and ventilation because they were well sealed houses with better inlets, Farm B we know isn't well sealed and this shows in the results.

Farm B ventilated the least of all. Its floors reflected this to a degree. Having to contend with a house that leaks a lot means it was very likely to struggle with wet litter.

It is worth saying that although Farm C ventilated more and had the better house conditions and litter, but it does not mean that operating fans continuously is the best way to go about it. The same results can be achieved by managing the number of fans on the cycle timer and managing the cycle timer (or M^3/hour/bird).

Summary

The testing and the research show that:

We must seal our houses as tight as possible and make sure we have adequate insulation levels in the ceilings and walls if we are to retain the heat.

We must have good quality minimum ventilation inlets (and overall system) and know how to manage them properly in order to get the best from them.

Have enough heat and don't be afraid to use it - well distributed heat that is available throughout allows us to carry out good minimum ventilation rates, removing stale air and moisture without chilling the birds.

We need to run our minimum ventilation fans on an on/off cycle timer and not on continuously in order to control moisture and RH in the house. If you do not have enough minimum ventilation in your house the RH will creep up and up until the moisture ends up being dumped back on the floor making your litter wet.

If we look back at the theoretical criteria that was highlighted as being necessary to operate minimum ventilation successfully, Farm C ticked the most boxes.

In looking at the data from Farm C, it showed that the minimum ventilation rate can be used to control the level of moisture (RH) in the house, and in doing so, can help us to improve the condition of our litter, proving my title of this scholarship.....

'How a Better Understanding of Ventilation can be used to Improve Litter Conditions in Broiler Houses'

Chapter 6 | Interesting Facts, Tips and Myth Busters

Below are statements I asked for from the professionals - things they felt were important when thinking about broiler house ventilation... a couple are ones I have lifted from publications too. Each statement is attributed to whomever donated it.

You cannot keep litter dry without air movement - *Mike Czarick, University of Georgia, Poultry Science Department, USA*

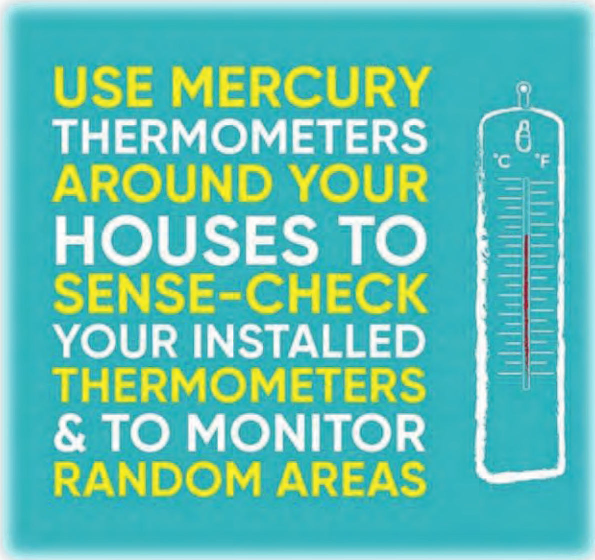
Newer houses are generally much tighter (few gaps and cracks) than older houses which means you have a lot less time to rectify ventilation before things go wrong in the house, and the floors cap over - *A vet I spoke to during an on-farm visit*

Have your heaters on the side walls, where its coldest, not in the middle of the house - Me - from my research

If your floors are not well insulated or not pre-heated it is better to use a thicker layer of bedding - *Source; Aviagen's 'Management tools to reduce FPD in broilers'*

High relative humidity outside is no excuse for wet litter - *Bernard Green, Aviagen (Asia)*

Using your senses to assess the house conditions is important. But don't hurry- wait until you have been in the house 5 minutes before judging it, especially if it's cold outside - *Justin Emery, Draper Ventilation UK*



Relative humidity should be monitored and used to make adjustments to the ventilation rate to keep it between 40-60%. This will help maintain floor conditions provided inlets, birds, drinker, etc. are managed correctly - *Brian Fairchild, UGA*

Use regular mercury thermometers hung up in your houses to sense-check your regular temperature sensors - *Me - from my research*

You don't feel heat and cold in the same way as the bird - *Justin Emery, Draper Ventilation UK*

Minimum ventilation rates should not be based on kilos of birds but rather house relative humidity - *Mike Czarick, University of Georgia, Poultry Science Department, USA*

What the computer says the temperature is and what the bird says it is may not be the same *- Justin Emery, Draper Ventilation UK*

Poultry lose 60% of their heat through evaporative (latent) heat loss and 40% to the air around them (Sensible heat loss) making them more sensitive to RH that humans - *Brian Fairchild, UGA*

Always allow for the wind-chill from air movement.... this varies with bird age, outside temperature, airspeed etc- *Justin Emery, Draper Ventilation UK*

Cold air is dry air - it can help dry out litter even if outside humidity is high - *Justin Emery, Draper Ventilation UK*

We must have good quality minimum ventilation inlets (and overall system) and know how to manage them properly in order to get the best from them *– Me, from my farm testing experience*
If you properly control RH levels 90% of the time your carbon dioxide and ammonia levels will be fine - *Mike Czarick, University of Georgia, Poultry Science Department, USA*

The same settings during both summer and winter may give different results - *Justin Emery, Draper Ventilation UK*

Adjust the temperature probe as the birds grow so it is always at bird-height - *Me, from my research*

The same inlet pressure can give very different results in different houses at different times of year *- Justin Emery, Draper Ventilation UK*

Most inlets need to be open to their 'minimum working gap' if they are to work well - *Justin Emery, Draper Ventilation UK*

Using minimum ventilation charts is dangerous because they often have little correlation to what is actually happening on a farm - *Mike Czarick, University of Georgia, Poultry Science Department, USA*

Higher pressure is usually better in wider houses in cold weather - *Justin Emery, Draper Ventilation UK*

Have enough heat and don't be afraid to use it - well distributed heat that is available throughout allows us to carry out good minimum ventilation rates, removing stale air and moisture without chilling the birds *– Me from my farm testing experience*

You can position fans anywhere in a house as inlet pressure should be the same. But if the fans are all at one end, low pressure can result in short circuiting of air flows - *Justin Emery, Draper Ventilation UK*

One of the best overall tools for determining minimum ventilation rates is a water meter. Minimum ventilation rates are proportional to water usage. If water usage increases 30% in a week then so do minimum ventilation rates
- Mike Czarick, University of Georgia, Poultry Science Department, USA

Use a smoke machine to test ventilation patterns *- Justin Emery, Draper Ventilation UK*

Cold concrete floors results in condensation and poor litter *- Justin Emery, Draper Ventilation UK*

But don't overheat the floors as chicks may need to cool themselves if house temperature is too high *- Justin Emery, Draper Ventilation UK*

Preferably use side wall exhaust fans rather than ceiling / chimney ones as these don't interfere with that nice bank of warm air you need to use from the peak of the house- if you already have ceiling exhaust fans then extend the chimney down further into the house to avoid exhausting the warm air from the peak. *- Bernard Green, Aviagen (Asia)*

We must have good quality minimum ventilation inlets (and overall system) and know how to manage them properly in order to get the best from them – *Me, from my farm testing experience*

Chapter 7 | Recommended Resources

Water quality and broiler chicken - search for **Dr Susan Watkins** on the internet (USA) - she's done a huge amount of research and is well worth looking into.

The **Aviagen website** where there loads of reference documents you can download and print including the **NEW** Ross 308 Broiler Management Handbook 2018 www.aviagen.com

University of Georgia, USA, Poultry Science Department Their Facebook page and website; www.poultryventilation.com - which is full of tips and guides and you can join their mailing list in order to receive relevant emails. Their Facebook page is brilliant and updated often. They use a lot of videos to show their work, most of which is relevant to the UK. Well worth joining.

The **Cobb website** where there are all sorts of publications and broiler manuals etc. www.cobb-vantress.com

www.poultryworld.net - there are lots of articles on here worth reading.

Chapter 8 | The People I Would Like to Thank

Without the sponsors below this would have been wholly impossible, so I would like to thank all of the companies who contributed finance to my project.

First and foremost, would be **Tesco** who awarded me the scholarship in the first place and who gave me the £5,500 to carry out the project; a huge thank you to **Tesco** and **Promar International** for this opportunity.

Next are the other companies who donated money to my cause. **Noble Foods**, who supply our farm with feed for our broilers gave me a lot of money towards the testing equipment etc which was fantastic and much appreciated, a massive thank you to **Dave Hopwood** and **Tim Goldsborough** for this.

All the other donors gave me large discounts on equipment; thank you to **Marc Paterson** at **Tempcon** who supplied most of my test equipment to me and helped me hugely throughout the process.

Pass - thank you for the discount on the thermal camera and to **Chris Measer of Pass** for the advice and guidance.

Thank you to **Chris Chater** at **Hook2sisters** for assistance with buying some of my equipment used on their farms for testing as well as letting me use and visit company and contract farms for interviews and testing.

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Personal Thank-You's

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A huge thank you to **Dr Fiona Roberts** for your help, guidance and advice regarding the report, the infographics as well as your help with the UFAW academic paper submission. You have been an immense help, thank you so much.

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Thank you to **Martin Jensen** at **SKOV** for taking me around SKOV and several farms in Denmark, I really appreciated the time you took out for me, thank you.

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Thank you to **Richard Bailey**, **Aviagen** for your time on the phone help with some of the details on health etc. Thank you this was really very helpful.

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Thank you to **Marc Paterson** of **Tempcon**, for the endless phone calls over the years, the genuine interest in my project and assistance with the choosing and use of equipment, you have been brilliant.

Test-farm farmers - Thank you for all letting me come to your farms and get in your way, as well as answering all my relentless questions ☺

A thank you to you **all listed below** for all your help in their various forms, this would not have been possible without you all, thank you

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John Kirkpatrick (Tesco)
Stuart Thomson (Aviagen)
Marc Paterson (Tempcon)
Martin Jensen (SKOV Denmark)
Tom Procter - (Cobb)
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Dave Hopwood (Noble Foods)
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Emma Main (Promar International)
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Gary Ford (NFU)
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Rebecca Lewis (Future Farmer Foundation / Promar International)
Sarah Jones (Hook2sisters)
Arriana Catania (Cobb)
Karena Boom (K Boom Creative)
Gary Radford and Dave Hutchings (Hedgerow Print)
Ben Crisp, Vet (St David's Vet Practice)
Mum, Dad and Rick; thank you for putting up with me ☺

Appendix A

A Photo Guide to Broiler Foot Health Classification


Class 0 – smooth, no lesion


Class 0 – small discolouration


Class 0 – almost healed lesion, scar


Class 1 – superficial lesion, discolouration


Class 1 – dark papillae, no ulceration


Class 1 – substantial discolouration


Class 2 – dark papillae and ulcer


Class 2 – ulcer covered by crust


Class 2 – abcess/bumble foot swollen

A Photo Guide to Broiler Foot Health Classification

Class 0 - no lesion

No lesions or very small and superficial lesions, slight discolouration on a limited area, mild hyperkeratosis, old scars.

Only the footpad should be evaluated.

Class 1 - mild lesion

Substantial discolouration of the footpad, superficial lesion, dark papillae.

Only the footpad should be evaluated.

Class 3 - severe lesion

Ulcers or scabs of significant size, signs of haemorrhages or severely swollen footpad.

Only the footpad should be evaluated.

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www.livestockresearch.wur.nl

This photo guide should only be used after (or in conjunction with) appropriate training.

Appendix B

European Chicken Commitment

To Whom It May Concern:

As you may know, we, the undersigned organisations, work individually with many food companies. In the course of that engagement, we're sometimes asked by companies if our groups can speak with one voice. That generally isn't possible— our groups don't necessarily work in tandem, and often disagree on issues, tactics, and more.

That said, you may be pleased to know that, while we often are not in agreement with one another, we have reached agreement on what the most pressing welfare concerns related to broiler production are, and how to best mitigate those concerns. Towards that end, we've reached a common agreement on baseline broiler welfare policy language—which we agree is the minimum that any European corporate policy must achieve and make publicly available. That language is outlined below. Thank you for your interest in this issue.

Sincerely,
Albert Schweitzer Stiftung für unsere Mitwelt (Germany)
Anima (Denmark)
Animal Equality (Germany, Italy, Spain, UK, global)
Center for the Ethical Attitude Towards Nature (Belarus)
Çiftlik Hayvanlarını Koruma Platformu (Turkey)
Compassion in World Farming (France, Italy, Ireland, Netherlands, Poland, UK)
Deutscher Tierschutzbund (Germany)
Djurens Rätt (Sweden)
Een DIER Een VRIEND (Netherlands)
Eurogroup for Animals (Pan-European)
Fundacja Alberta Schweitzera (Poland)
Humane Society International (global)
Irish Society for the Prevention of Cruelty to Animals (Ireland)
L214 (France)
Menschen für Tierrechte (Germany)
Oikeutta eläimille (Finland)
Otwarte Klatki / Open Cages (Poland, Ukraine)
OZ VEGÁNSKE HODY (Slovakia)
Pro iure animalis (Germany)
PROVIEH (Germany)
ProVeg International (Germany, global)
Royal Society for the Prevention of Cruelty to Animals (UK)
Slepice v Nouzi (Czech Republic)
The Humane League (UK, global)
VGT (Austria)
Vier Pfoten / Four Paws (Austria, Germany, UK, Bulgaria)
Welfarm (France)
World Animal Protection (UK, global)

***

By 2026, we will require our suppliers to meet the following requirements for 100% of the [fresh, frozen, and processed] chicken in our supply chain:

1. Comply with all EU animal welfare laws and regulations, regardless of the country of production.

2. Implement a maximum stocking density of 30kg/m^2 or less. Thinning is discouraged and if practiced must be limited to one thin per flock.

3. Adopt breeds that demonstrate higher welfare outcomes: either the following breeds, Hubbard JA757, 787, 957, or 987, Rambler Ranger, Ranger Classic, and Ranger Gold, or others that meet the criteria of the RSPCA Broiler Breed Welfare Assessment Protocol.

4. Meet improved environmental standards including:

- At least 50 lux of light, including natural light.
- At least two metres of usable perch space, and two pecking substrates, per 1,000 birds.
- On air quality, the maximum requirements of Annex 2.3 of the EU broiler directive, regardless of stocking density.
- No cages or multi-tier systems.

5. Adopt controlled atmospheric stunning using inert gas or multi-phase systems, or effective electrical stunning without live inversion.

6. Demonstrate compliance with the above standards via third-party auditing and annual public reporting on progress towards this commitment.

The above can be found at https://welfarecommitments.com/letters/europe/

Appendix C

AVIAGEN BRIEF

Aviagen®

February 2018

Minimum Ventilation Rates for Todays Broiler

Introduction
The next broiler handbook is due to be released in 2018. With continuing genetic progress in broiler performance one of the main updates is that of recommended minimum ventilation rates which have been increased to allow for improvements in daily growth rate and overall higher biomasses at younger ages.

Minimum Ventilation Rates for Todays Broiler
The table below gives a revised set of minimum ventilation rates for broilers. These have been updated to account for improvements in broiler performance in recent years and reflect the broilers need for higher ventilation rates as a result of this.

Table 1: Updated minimum ventilation rates.

Live weight (kg)	Live weight (lbs)	Minimum ventilation rates (m^3/hr)	Minimum ventilation rates (ft^3/min)
0.05	0.11	0.080	0.047
0.10	0.22	0.141	0.083
0.15	0.33	0.208	0.122
0.20	0.44	0.258	0.152
0.25	0.55	0.305	0.180
0.30	0.66	0.350	0.206
0.35	0.77	0.393	0.231
0.40	0.88	0.435	0.256
0.45	0.99	0.475	0.280
0.50	1.10	0.514	0.303
0.55	1.21	0.552	0.325
0.60	1.32	0.589	0.347
0.65	1.43	0.625	0.368
0.70	1.54	0.661	0.389
0.75	1.65	0.696	0.410
0.80	1.76	0.731	0.430
0.85	1.87	0.765	0.450
0.90	1.98	0.798	0.470
0.95	2.09	0.831	0.489
1.00	2.20	0.864	0.509
1.10	2.43	0.928	0.546
1.20	2.65	0.991	0.583
1.30	2.87	1.052	0.619
1.40	3.09	1.112	0.654
1.50	3.31	1.171	0.689
1.60	3.53	1.229	0.723
1.70	3.75	1.286	0.757
1.80	3.97	1.343	0.790
1.90	4.19	1.398	0.823

Live weight (kg)	Live weight (lbs)	Minimum ventilation rates (m^3/hr)	Minimum ventilation rates (ft^3/min)
2.00	4.41	1.453	0.855
2.20	4.85	1.561	0.919
2.40	5.29	1.666	0.981
2.60	5.73	1.769	1.041
2.80	6.17	1.870	1.101
3.00	6.61	1.969	1.159
3.20	7.05	2.067	1.217
3.40	7.50	2.163	1.273
3.60	7.94	2.258	1.329
3.80	8.38	2.352	1.384
4.00	8.82	2.444	1.438
4.20	9.26	2.535	1.492
4.40	9.70	2.625	1.545

The ventilation rates given in the table are for ambient temperatures between -1 and 16°C (30 and 61°F). Maximum levels of relative humidity, (60-70% for the first 3 days and 50-60% thereafter), carbon monoxide (< 10 ppm), carbon dioxide (< 3000 ppm) and ammonia (< 10 ppm) should never be exceeded. Bird behavior and distribution should be monitored as this can be an indicator of issues that need to be investigated. The table should be used as a guide only and actual rates may need to be adjusted according to environmental conditions, bird behavior, and bird biomass (total bird weight in the house).

Key Points for Minimum Ventilation

- **Some minimum amount of ventilation must be given at all times no matter what the external weather conditions are.**
- **Minimum ventilation is not adequate for cooling birds during high temperatures and will create very little air movement at bird level. For this reason, minimum ventilation is commonly used for young chicks during brooding, night time, or cool weather ventilation.**
- **Minimum ventilation is regulated by a timer. The fans operate according to a cycle timer and not according to temperature.**
- **It is critical to achieve the correct operating negative pressure to ensure incoming air is drawn at high speed up towards the apex of the roof.**
- **Evaluating bird behavior and house condition is the only real way to determine if minimum ventilation settings are correct.**

Appendix D

The importance of minimum ventilation and how to calculate it

by Richard Weatherley, Cobb broiler specialist for Europe, Middle East, Africa and Russia.

The importance of providing the birds with the correct environment is becoming overlooked due to the rapidly increasing cost in energy/heating costs. Trying to limit the amount of heat units used is in most cases false economy.

With more heat recovery units on the market, energy savings are possible, but trying to save equal energy amounts without a recovery unit is detrimental to final performance and therefore profit.

Fig. 1 shows what can happen if gas usage is reduced in the first week. It is possible for the flock to achieve, or possibly as in this case exceed, the targets set.

However, the damage made by this sub-standard environment did not show its effects until after 21 days of age as reduced air quality impaired cardiovascular development. When paying attention to the early ventilation rates, the outcome can be very different.

This article outlines the recommendations we find most beneficial for performance and also final cost.

Minimum ventilation

This is the minimum amount of ventilation (air volume) required to maintain full genetic potential by ensuring an adequate supply of oxygen while removing the waste products of growth and combustion from the environment.

This system should be independent of any temperature control system and works best if operated by a cycle timer and temperature override. The timer cycle should be a five minute period, with minimum run time of at least 20% of this time (five minutes = cycle of one minute on, four minutes off).

Whenever the air quality begins to deteriorate, there must be run time added to the 'on time' and the 'off time' reduced to maintain the same total cycle length, because to add 'off time' as well, the percentage of run time would not change and the air quality results will not be improved.

The minimum run time should be about

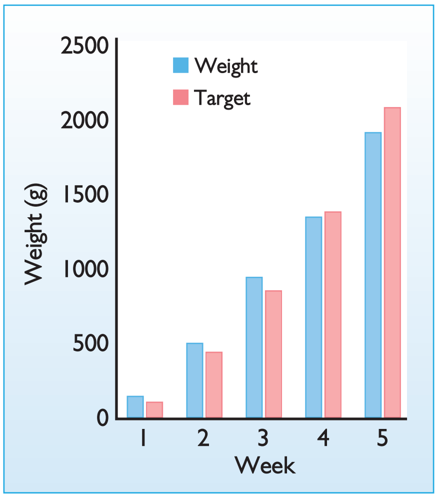


Fig. 1. Results of reducing gas usage in the first week.

one minute and this setting is dictated by the width of the house or the length of time needed to move the air from the inlet to the peak of the house where the incoming air is heated, expands and relative humidity reduced.

Then this air must fall to the floor bringing oxygen to the birds and removing waste gases and moisture produced from the litter, the birds and heating system.

This air needs to move from the middle of the house all the way back to the side walls, ensuring the house floor is correctly ventilated, before returning to the top of the house and being removed by the fans.

The minimum ventilation system should have a fan capacity equal to 12.5-20% of the capacity of the house (air exchange every eight to five minutes) and operate on a timer. The system runs whenever the house is at or below set point temperature.

Inlets

Important points about inlets:

- All minimum ventilation inlets should direct the air into the peak of the house and close when the fans are off, with no pressure drop inside the house.
- Baffle type minimum inlets with the ends open will direct cold air down to the floor and create chills on the birds and condensation on the litter when there is a pressure drop inside the house. The bottom of all minimum ventilation inlets should be sealed air tight to prevent the cold air being directed down to the floor.
- All inlets should open from the top – never from the bottom of the inlet except when cooling.
- In open truss constructed houses the angle of the inlet opening must be such that the air is not directed into a purlin and then redirected straight down to the floor.
- Inlets need to open enough to achieve the required static pressure and the airflow throw needed. For side wall inlets a minimum opening of 5cm is needed.
- Obstructions (electrical conduit/concrete or wooden beams) should be avoided because they interrupt the air flow, forcing air to the floor.
- Inlets driven with motors should be installed in the centre of the side wall to reduce inlet opening variation.
- When using a negative pressure ventilation system, it is not the placement of the fan which dictates uniformity of air distribution but the placement of the inlets. To achieve uniform air distribution in your house, inlets should be evenly spread throughout the house and open the same amount.
- Inlets with cables often stretch, giving different inlet openings through the house and poor airflow; aircraft cable stretches a lot more than high tensile fence wire. Solid rods of 8mm stretch even less and are the best option for long houses.
- A well-sealed house should, with the inlets closed and one 1.2m fan in operation, achieve a static pressure of at least 37.5 pascal (Pa). If the static pressure is less than 25Pa, the house is leaking too much and this must be addressed immediately.
- The inlet should be pressure controlled to maintain a constant air speed throughout the ventilation stages and not controlled by temperature.
- All air inlets must be wind proofed on the outside.
- Inlets should be installed at least 60cm from the house eves as long as there is no interruption to the air flow.
- Heaters should not be placed directly at the inlet because forced air heaters are not

able to heat the air when it is moving too fast; instead they should be placed where the air speed is less than one metre/second

- Inlet capacity should always match fan capacity at the actual working pressure.

Air should enter the building at a pressure drop that allows the air to get half way across the house before falling. This is the function of the inlet area combined with the fan capacity at the actual working pressure drop. The total inlet area must be adjusted to provide the correct pressure drop dependent on the house width. Table 1 gives guidelines on recommended pressure at different house widths.

- **How to work out the volume of a house:**

House volume (m^3) = Average height (side wall height + ridge height ÷ 2) x length x width.
Example: Width 23m, length 110m, side wall height 1.5m, ridge height 4m
1.5 + 4 ÷ 2 = 2.75m
2.75 x 23 x 110 = 6,958m^3

- **How to work out the heater capacity per m^3:**

We recommend that the heater capacity should be a minimum of 0.05Kw/m^3. As the heater capacity increases, the performance usually increases. New houses should be designed with a heater capacity of 0.07Kw/m^3. In countries such as Russia and Canada with a hard winter this should be raised to 0.1Kw/m^3.
Heater capacity per m^3 = number of heaters x heater output (Kw) ÷ house volume (m^3)
Example: 6 heaters at 80 Kw each
6 x 80 = 480 ÷ 6958 = 0.069Kw/m^3

- **How to work out how much a fan moves per minute:**

Fan capacity in hours ÷ 60 = fan capacity in minutes.
Example: 18,000 m^3/hr ÷ 60 = 300m^3/min

- **How many fans to put on for minimum ventilation:**

Volume m^3 ÷ air exchange time ÷ fan capacity m^3/min.
Example: 6,958 m^3 ÷ 8 min ÷ 300 m^3/min = 2.9 fans. Always round fans up = 3 fans.

- **How much inlet to open with the minimum ventilation:**

We need to work out the fan volume per second.
Number of fans turned on for minimum ventilation x volume of fan per hour (m^3) ÷ seconds in a hour (3,600)
Example: 3 x 18,000 ÷ 3,600 = 15
Next you need to work out the air speed required through the inlets, so that the air will reach the ridge of the house before dropping to the floor. The width in this example is 23 metres, so the air speed required through the inlet is 8m/sec.
Fan volume ÷ air speed = amount of ventilation required to run with the fans for minimum ventilation (m^2).
Example: 15 ÷ 8 = 1.875m^2.

Summary

- Heater capacity per m^3 = 0.069m^3.
- Number of fans required for minimum ventilation = 3.
- Amount of inlet to work with fans = 1.875m^2.

All figures should be adjusted to suit an individual house but the calculations remain the same.

These figures are our recommendations in the field, based on unlocking the genetic potential while balancing the costs to achieve high performance, high welfare and the best financial reward.

Ventilation figures are always a topic of conversation, with different experts giving different answers. However, this point-by-point guide has been practised in all parts of the world giving excellent results. ■

House width (m)	Pascal unit (Pa)	Air speed (m/sec)	Distance before air drops (m)
10	8	3.5	5.0
12	10	4.0	6.0
15	17	5.0	7.5
18	26	6.3	9.0
21	37	7.5	10.5
24	42	8.0	12.0

Table 1. Calculations for minimum ventilation.

Appendix E

Why measure house air tightness?

02

- In-house pressure can be used as an indication of house air tightness and must be at a certain level if air is to be drawn into the house at the correct speed to adequately ventilate the house and direct the incoming air where it is to go.
- Ventilation only works effectively if the house is adequately sealed / air tight and there are no air leaks present.
- In-house pressure should be monitored routinely and regularly over time to ensure the correct pressure is maintained and to identify the presence of any air leaks that may impair ventilation.

The procedure for measuring house air tightness using an in-house pressure meter

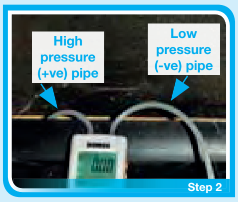
Equipment

1. An in-house or portable hand held pressure meter.

Procedure

House air tightness is measured by recording in-house pressure. During minimum ventilation, pressure can be measured anywhere in the house and should be consistent throughout the house. Measure in-house pressure before a flock is placed or when suspected issues with ventilation occur (e.g if condensation is seen, litter quality deteriorates or bird behavior is not as expected).

Step 1 Close all doors and inlets and have all fans switched off.



Step 2 If using a hand held pressure meter place the high pressure pipe (+ve) outside the house through an air inlet (being careful not to leave inlet open too much or to squash the pipe) and leave the low (-ve) pressure pipe inside the house.

Note *If using a mounted in-house pressure meter it should have been calibrated at the beginning of the flock (see How To... Calibrate an In-House Fluid Filled Pressure Meter).*

Step 3 Ensure the pressure meter is zero'd.

Step 4 Switch off the side wall inlet winch so that the inlets do not open automatically.

Step 5 Turn on either 2 minimum ventilation (91 cm / 36 in) fans or 1 tunnel ventilation (122 cm / 48 in) fan.

Step 6 Allow pressure reading to stabilize and then record the reading on the pressure meter.

Interpreting results

The pressure within the house should ideally not measure less than 37.5 Pa (0.15 inches of water column). The pressures indicated below are **not** operating pressures. They are to determine whether the house is sealed effectively. Higher operating pressures may need to be used during minimum ventilation.

Pressure Reading	In-House Pressure	Effect	Action
< 37.5 Pa (0.15 inches of water column).	Inadequate.	Ventilation will be effected, air speed will be low and birds will not be ventilated adequately.	ACTION REQUIRED: Check for presence of cracks in the walls of the house, poorly fitting doors and inlets, damage to curtains or inefficient fans. Complete restorative maintenance.
37.5 - 42.0 Pa (0.15 – 0.17 inches of water column).	Adequate.	Ventilation will be ok but beware of wet patches developing in the litter, condensation, birds huddling and drafts.	ACTION REQUIRED: Check for presence of cracks in the walls of the house, poorly fitting doors and inlets, damage to curtains or inefficient fans. Complete restorative maintenance.
42.0 (0.17 inches of water column).	Ideal.		NO ACTION REQUIRED.

Appendix F

Poultry House Leakage Estimator - 2016

The University of Georgia - Department of Poultry Science
Michael Czarick (mczarick@uga.edu)

Enter Green Values (do not leave blank)

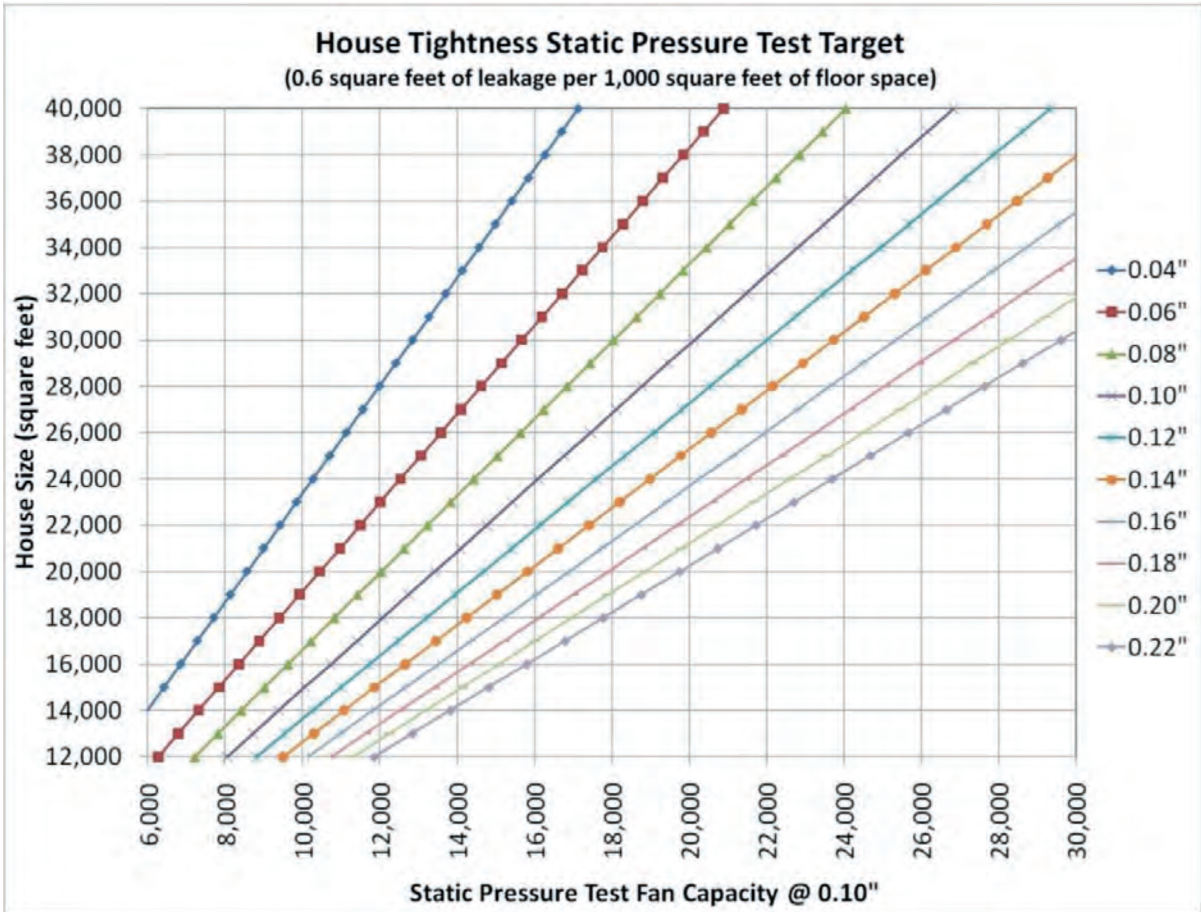
This spreadsheet is intended to illustrate how poultry house tightness can be estimated though the use of a static pressure test. The spreadsheet will also illustrate how poultry house tightness will determine the amount of fresh air brought in by minimum ventilation fans(s) that will enter through a houses inlets relative to that entering through cracks (unplanned openings). The spreadsheet will not provide precise values, but rather estimates

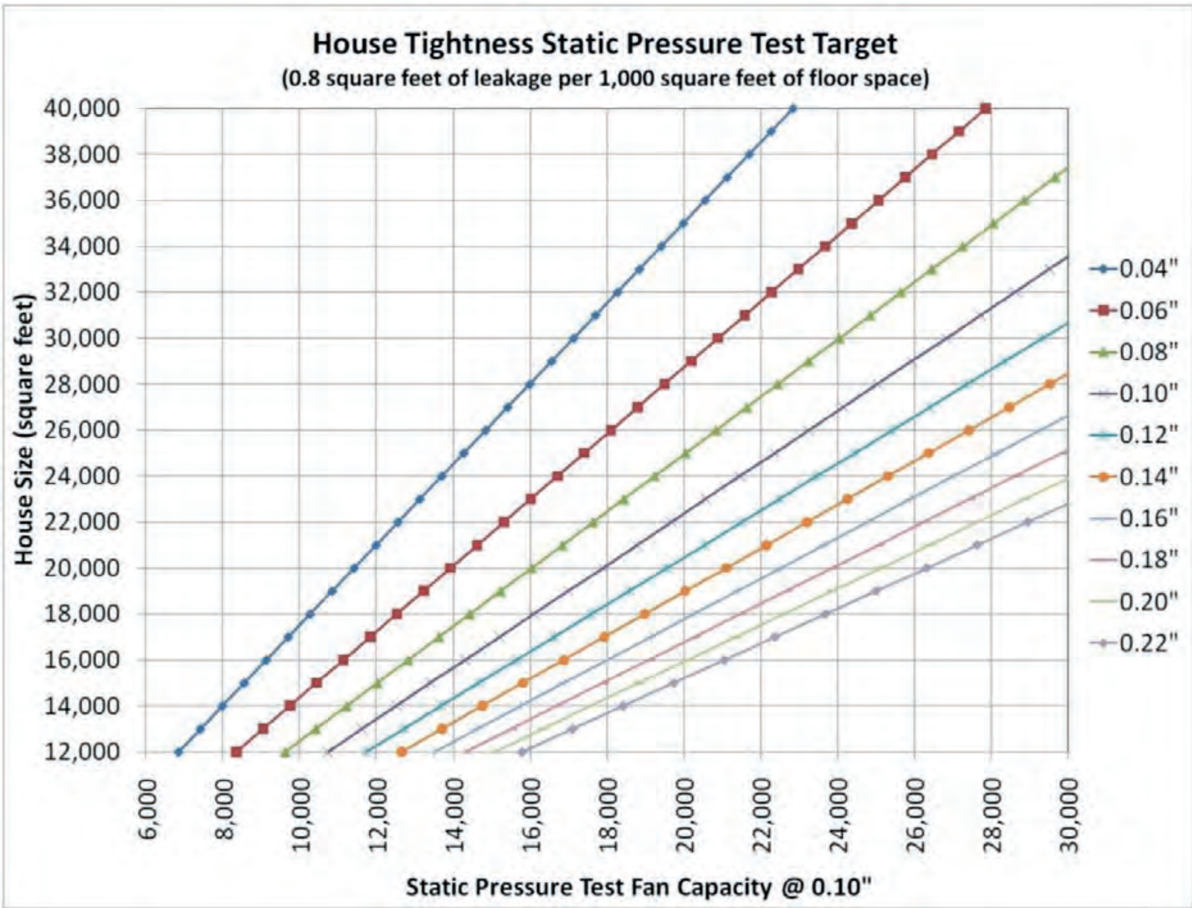
Poultry House Leakage Test:	
House length (ft)	500
House width (ft)	40
Total fan capacity used in leakage test (cfm @ 0.10")	20000
Static pressure measured (")	0.25
Relative leakage area (ft2 per 1,000 ft2 of house floor space)	0.35
Total house leakage area (ft2)	7.1

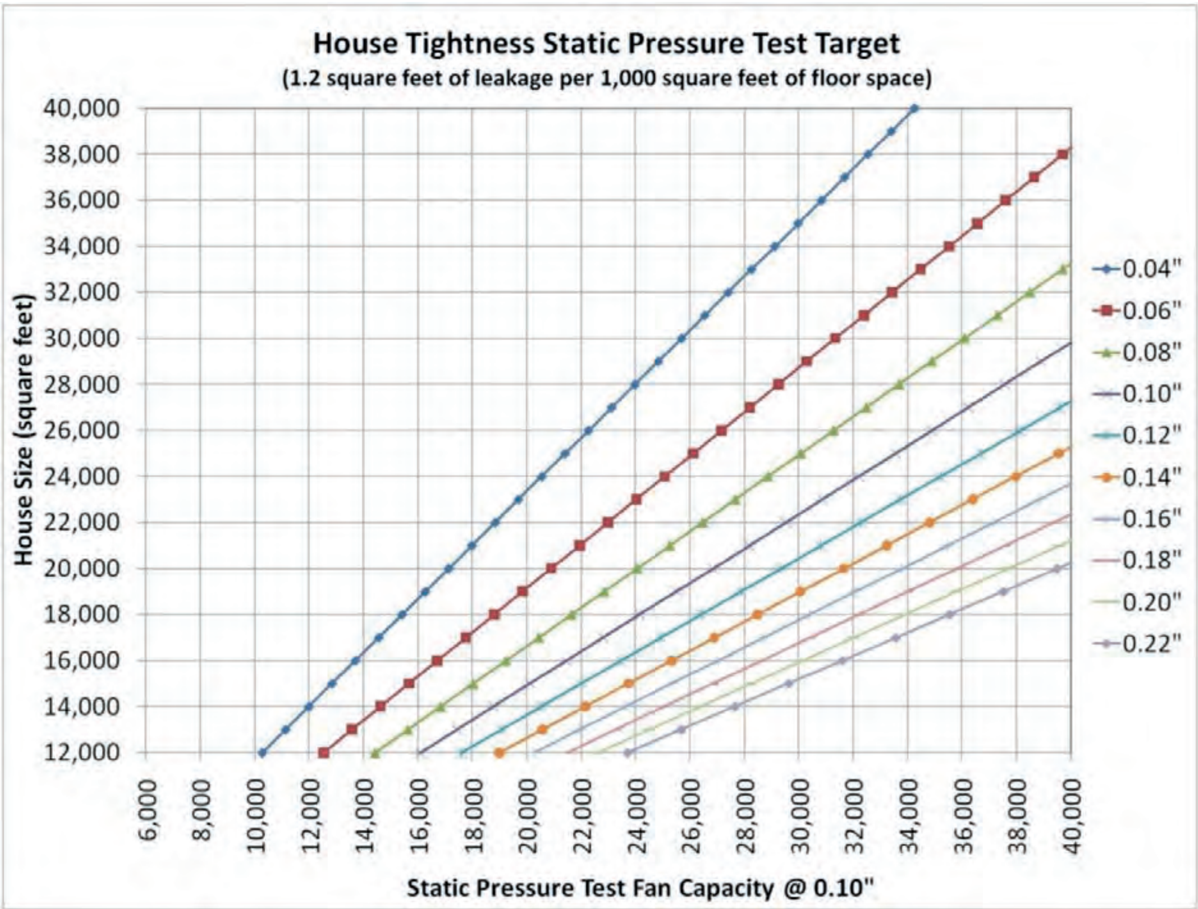
(For the best accuracy if the static pressure obtained during house testing exceeds 0.25", consider using fewer or a lower capacity test fans.)

Minimum Ventilation Inlet Opening Requirements:	
Minimum ventilation fan capacity (cfm)	20000
Number of air inlets to be used	40
Maximum air inlet height/opening (inches)	6.0
Air inlet length (inches)	48.0
Total side wall air inlet area (ft2)	80.0
Total required opening area for specified fan(s) @ 0.10" (ft2)	26.7
Total house leakage area (ft2)	7.1
Total required inlet area @ 0.10" (ft2)	19.6
Percentage of air that will entering through inlets	73%
Approximate required air inlet opening size/height (inches)	1.47

Appendix G


House Tightness Static Pressure Test Target
(0.6 square feet of leakage per 1,000 square feet of floor space)
House Size (square feet)
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
22,000
24,000
26,000
28,000
30,000
Static Pressure Test Fan Capacity @ 0.10"
0.04"
0.06"
0.08"
0.10"
0.12"
0.14"
0.16"
0.18"
0.20"
0.22"


House Tightness Static Pressure Test Target
(0.8 square feet of leakage per 1,000 square feet of floor space)
House Size (square feet)
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
22,000
24,000
26,000
28,000
30,000
Static Pressure Test Fan Capacity @ 0.10"
0.04"
0.06"
0.08"
0.10"
0.12"
0.14"
0.16"
0.18"
0.20"
0.22"



House Tightness Static Pressure Test Target
(1.2 square feet of leakage per 1,000 square feet of floor space)
House Size (square feet)
40,000
38,000
36,000
34,000
32,000
30,000
28,000
26,000
24,000
22,000
20,000
18,000
16,000
14,000
12,000
6,000
8,000
10,000
12,000
14,000
16,000
18,000
20,000
22,000
24,000
26,000
28,000
30,000
32,000
34,000
36,000
38,000
40,000
Static Pressure Test Fan Capacity @ 0.10"
0.04"
0.06"
0.08"
0.10"
0.12"
0.14"
0.16"
0.18"
0.20"
0.22"

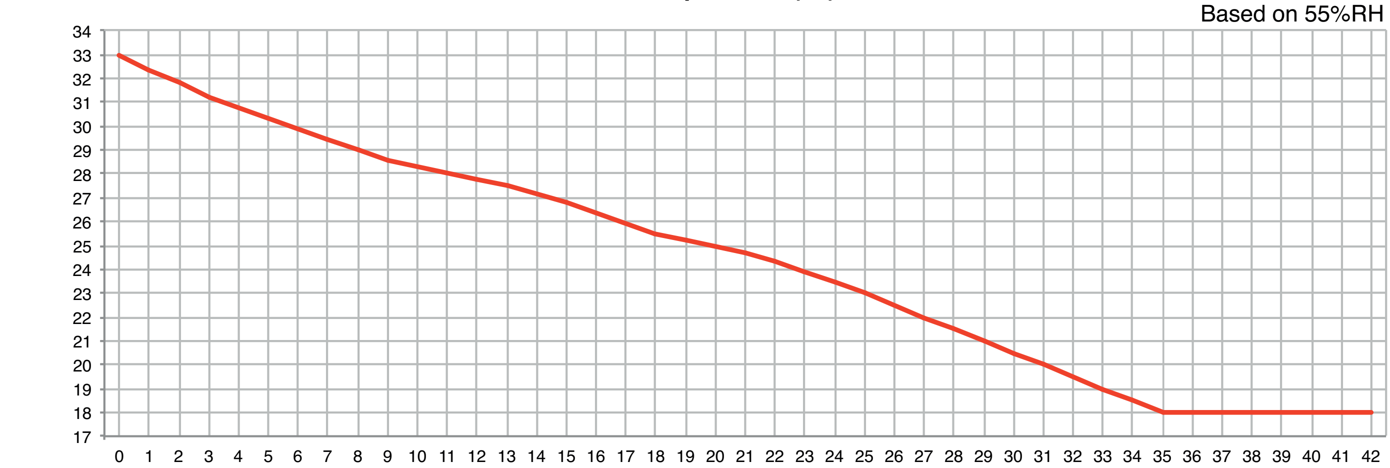
Appendix H

Hook2Sisters LIMITED

Aviagen | ROSS

Temperature (°C)

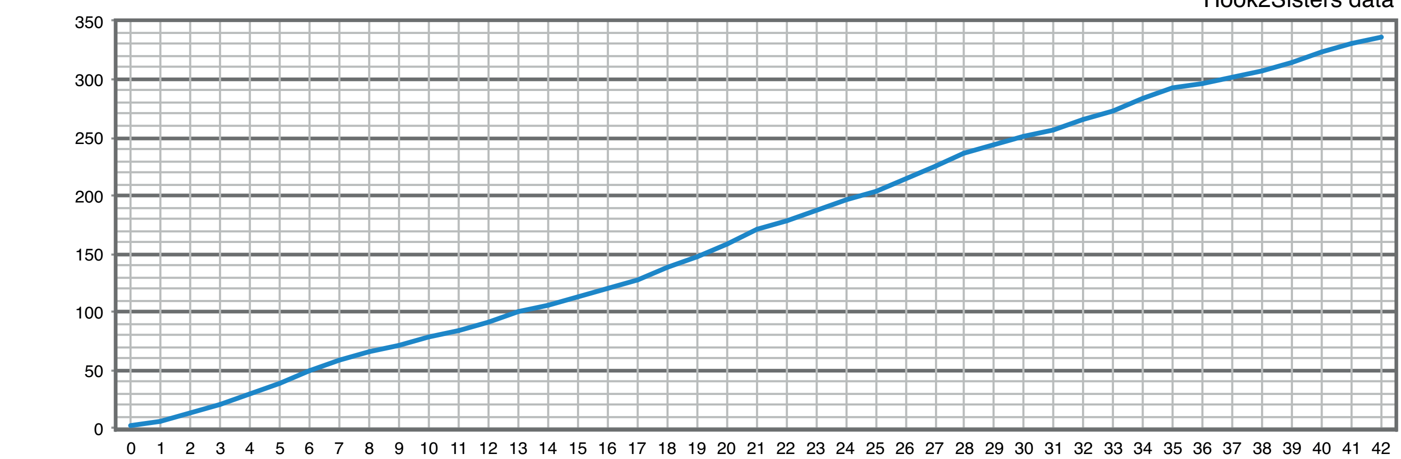
Based on 55%RH



Days	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Temperature - Guide	33	32.4	31.8	31.2	30.77	30.34	29.9	29.47	29.04	28.6	28.34	28.08	27.8	27.47	27.14	26.8	26.37	25.94	25.5	25.24	24.98	24.7	24.3	23.9	23.5	23	22.5	22	21.5	21	20.5	20	19.5	19	18.5	18	18	18	18	18	18	18	18
Temperature - Actual																																											

Water (Litres/1000 birds)

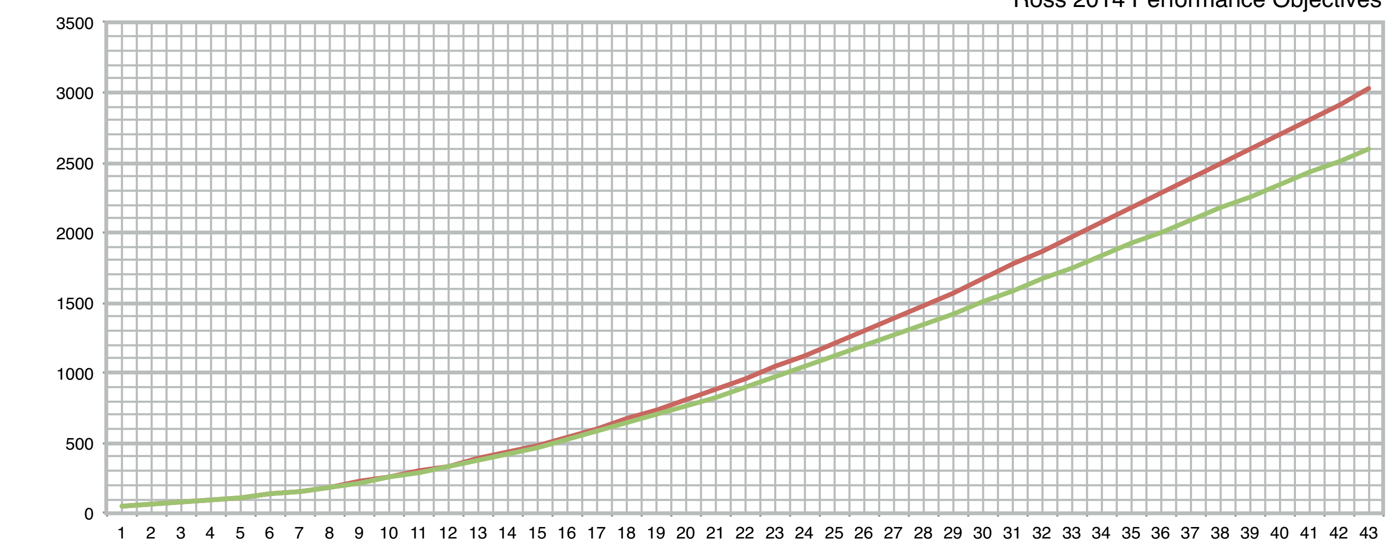
Hook2Sisters data



Days	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Water - Guide	2	6	13	21	30	39	49	59	66	1	78	84	91	100	106	113	121	128	138	148	159	171	179	188	196	204	214	225	236	244	251	256	265	272	283	292	297	302	308	314	323	330	336
Water - Actual																																											

Growth (g)

Ross 2014 Performance Objectives

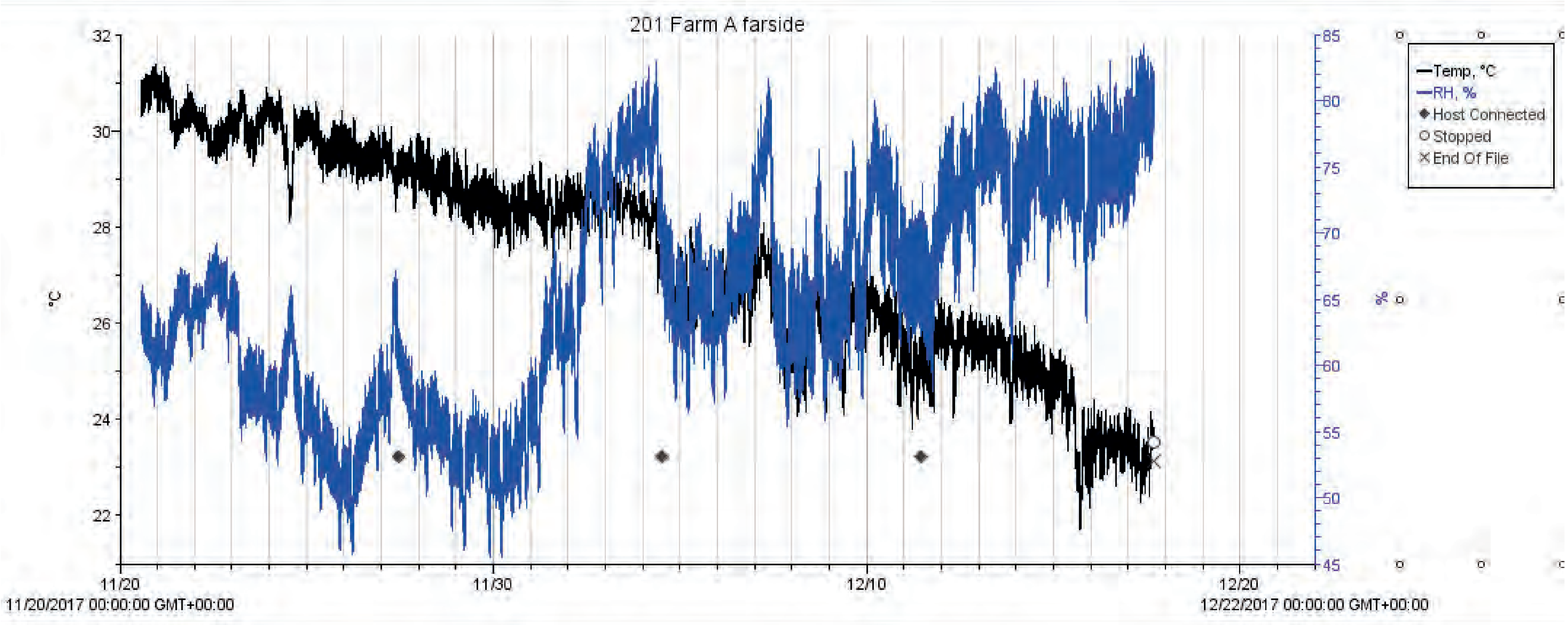


Days	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Growth - Male	42	57	73	91	111	134	160	189	221	257	296	339	385	434	488	545	605	669	737	808	882	959	1040	1123	1209	1297	1388	1481	1576	1673	1771	1871	1973	2075	2179	2283	2388	2493	2599	2705	2811	2917	3023
Growth - Actual																																											
Growth - Female	42	57	73	91	111	134	160	188	220	254	292	333	376	423	473	526	582	640	701	765	831	899	969	1042	1116	1191	1268	1347	1427	1507	1589	1671	1754	1838	1922	2006	2090	2175	2259	2344	2428	2512	2595
Growth - Actual																																											

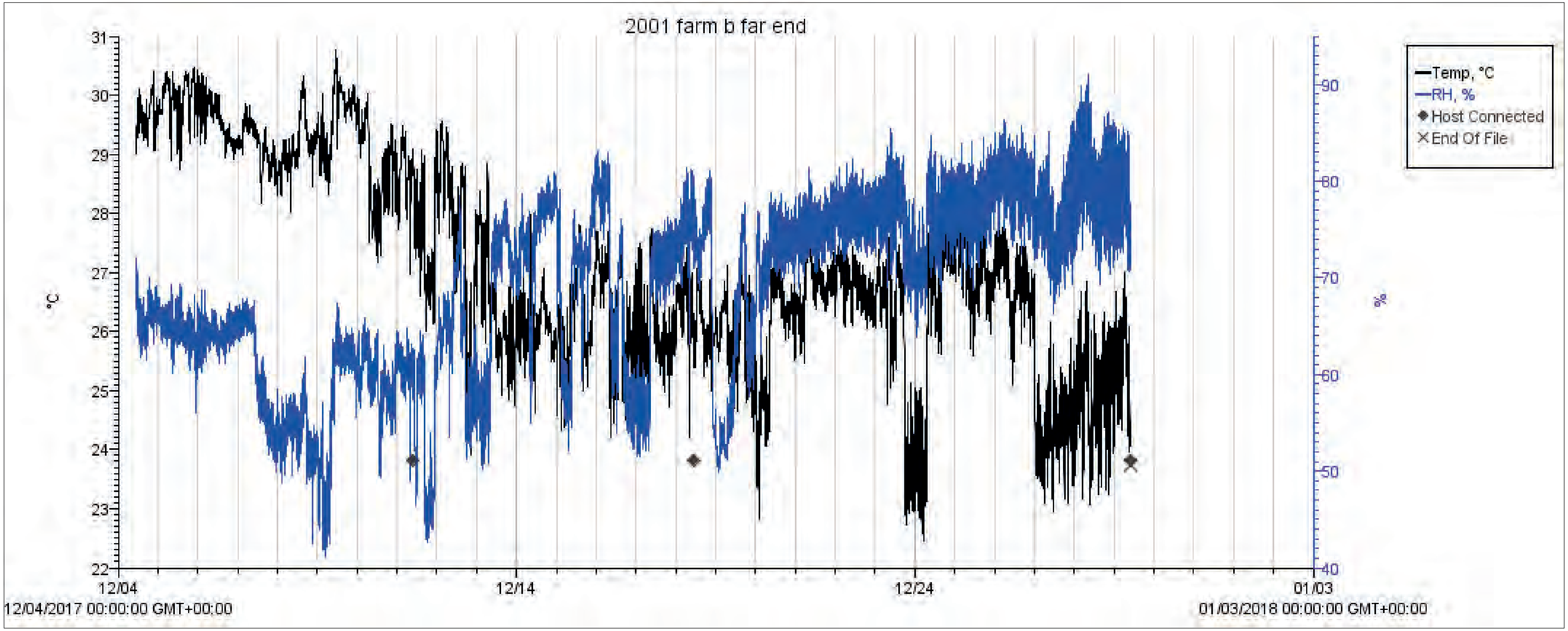
Appendix I

Appendix I

Farm A

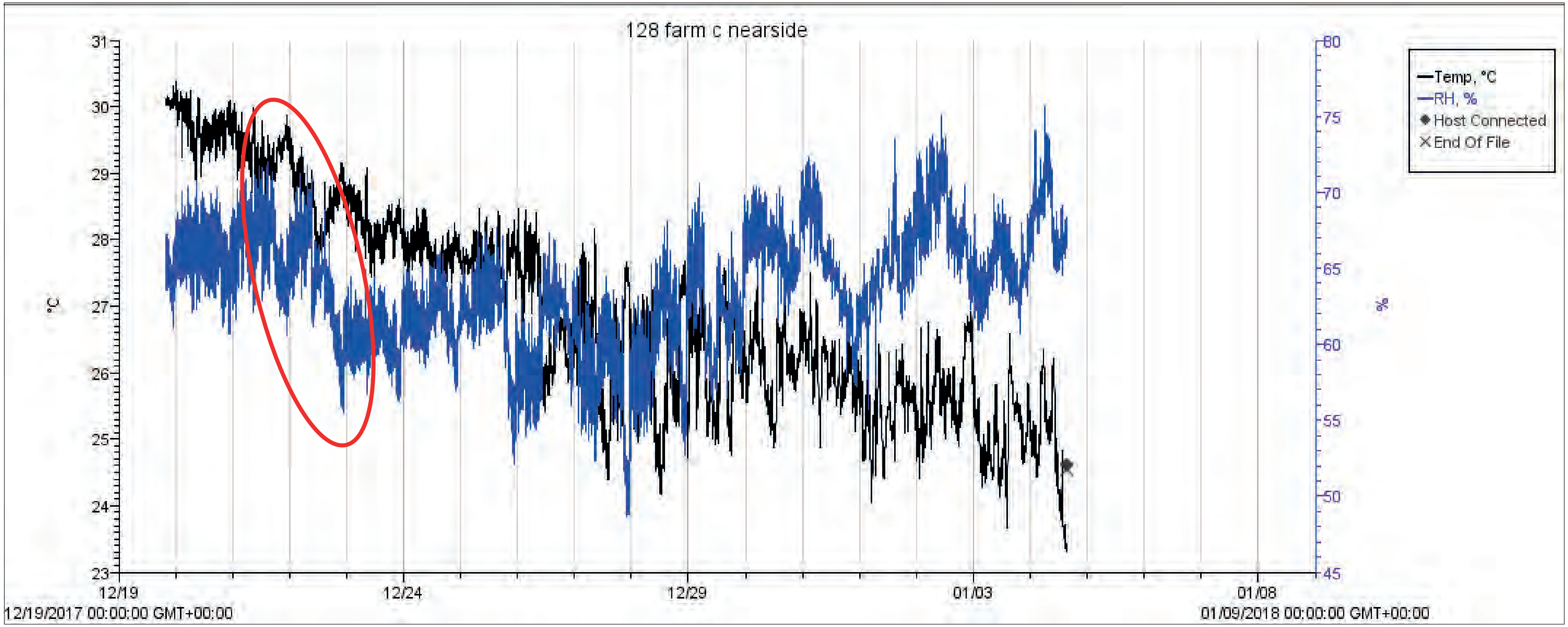


Farm B



2001 farm b far end
°C
31
30
29
28
27
26
25
24
23
22
%
90
80
70
60
50
40
12/04
12/14
12/24
01/03
12/04/2017 00:00:00 GMT+00:00
01/03/2018 00:00:00 GMT+00:00
Temp, °C
RH, %
Host Connected
End Of File

Farm C


128 farm c nearside
°C
31
30
29
28
27
26
25
24
23
%
80
75
70
65
60
55
50
45
12/19
12/24
12/29
01/03
01/08
12/19/2017 00:00:00 GMT+00:00
01/09/2018 00:00:00 GMT+00:00
Temp, °C
RH, %
Host Connected
End Of File

Appendix J


BROILER CHICKS
THE EARLY DAYS
CHICKS FEEL TEMPERATURE THROUGH THEIR FEET; ENSURE YOUR LITTER IS WARM ENOUGH AT 30-32°C
ALWAYS HAVE MORE (WELL-DISTRIBUTED) HEAT AVAILABLE THAN YOU NEED
COLD STRESS STUNTS GROWTH
XL
L
M
S
XS
KEEP RELATIVE HUMIDITY RATES BETWEEN 60-70%
AVOID COLD DRAUGHTS OVER CHICKS
A CHICK IN THE OPTIMUM ENVIRONMENT CAN QUADRUPLE ITS SIZE IN THE FIRST 7 DAYS ONLY
GROWTH WEIGHT (g)
200
160
120
80
40
0
1
2
3
4
5
6
7
NUMBER OF DAYS
ALWAYS PREHEAT CONCRETE FLOORS TO 28°C BEFORE PLACING THE BEDDING
USE A THICKER LAYER OF BEDDING IF YOUR FLOORS ARE NOT PRE-HEATED OR WELL INSULATED
CHICKS CANNOT REGULATE THEIR OWN BODY TEMPERATURE FOR THE FIRST
14 DAYS
Written by
Christina Hutchings
Sponsored by
TESCO

TIPS ON HOW TO KEEP YOUR BROILER-LITTER DRY & YOUR CHICKENS HAPPY

DURING MINIMUM VENTILATION AIR SPEED AT CHICK LEVEL SHOULD BE LESS THAN 0.25M/S

PROLONGED COLD LITTER MEANS GREASY, WET FLOORS

DON'T OVER-VENTILATE, YOU MAY CHILL YOUR BIRDS

BIG GAPS ON THE FLOOR WITHOUT CHICKENS MAY INDICATE COLD AIR IS DROPPING, FIND OUT WHY & STOP IT

CIRCULATION FANS CAN MOVE WARM AIR FROM THE PEAK OF THE ROOF

AN AVERAGE BIRD OF 2.3KG WILL CONSUME AROUND 6.3 LITRES IN ITS LIFETIME, EXCRETING 80% OF IT BACK INTO THE HOUSE...

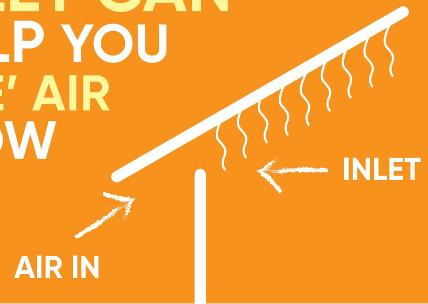
PRE-HEATING CONCRETE REDUCES RISING DAMP IN THE LITTER FROM CONDENSATION

MIN MAX

KEEP YOUR HOUSES WELL-SEALED TO MAINTAIN CONTROL OVER INCOMING AIR DURING MINIMUM VENTILATION

COLD INCOMING AIR MUST BE DIRECTED TO THE PEAK OF THE ROOF TO MIX WITH THE WARM AIR

STRIPS OF RIBBON HANGING IN FRONT OF THE INLET CAN HELP YOU 'SEE' AIR FLOW



AIR EXCHANGE MEANS DRIER LITTER

Written by Christina Hutchings

Sponsored by TESCO

TIPS ON HOW TO KEEP YOUR BROILER-LITTER DRY & YOUR CHICKENS HAPPY

PAY CLOSE ATTENTION TO DRINKER MANAGEMENT; (HEIGHTS & WATER PRESSURE) TO KEEP FLOORS DRY

LAG INCOMING WATER PIPES TO REDUCE CONDENSATION DRIPPING ONTO LITTER

KEEP MORE RECORDS, INCLUDING OBSERVATIONS & LEARNINGS

RELATIVE HUMIDITY (RH) RATES CONSISTENTLY OVER 70% WILL RESULT IN WET FLOORS; MONITOR RH CONTINUOUSLY

USE THE HANDHELD TOOLS AVAILABLE TO CHECK TEMPERATURE RH% & WIND-SPEED THROUGHOUT YOUR HOUSES

THE PURPOSE OF MINIMUM VENTILATION IS TO MAINTAIN AIR QUALITY & REMOVE EXCESS MOISTURE

MANAGE THE MINIMUM VENTILATION RATE (CYCLE TIMER) TO CONTROL RH%

USE A SMOKE MACHINE OR SMOKE PELLETS TO TEST VENTILATION PATTERNS

ADJUST THE TEMPERATURE SENSOR'S HEIGHT AS THE CHICKENS GROW SO IT'S ALWAYS JUST ABOVE BIRD HEIGHT

USE MERCURY THERMOMETERS AROUND YOUR HOUSES TO SENSE-CHECK YOUR INSTALLED THERMOMETERS & TO MONITOR RANDOM AREAS

FOR EVERY 10°C WE HEAT INCOMING AIR, THE RH REDUCES BY 50%

Written by Christina Hutchings
Sponsored by
TESCO

Appendix K

POSTER

VENTILATION ATTRIBUTES: IMPACT ON LITTER QUALITY AND ASSOCIATED BIRD WELFARE OUTCOME MEASURES.

Hutchings, C[1]; Green, B.[2]; Kirkpatrick, J[3] and Roberts, F.G[4]

[1] West Henstill Farm, Sandford, Crediton, Devon, EX174ES
[2] 403 Clare Park, 14 Brooke Street, Claremont, Cape Town, 7708, South Africa
[3]Tesco (UK) Ltd. Shire Park, Kestrel Way, Welwyn Garden City AL7 1GA
[4] PIC UK, Alpha Building, London Road, Nantwich, Cheshire CW5 7JW

Christina.h@live.co.uk

The incidence of hockburn and pododermatitis remains a challenge across global broiler production. The mean incidence of each across the Tesco supply base for the 2018 reporting period was 27% and 9% for pododermatitis and hockburn respectively. However, there is substantial variation between suppliers based on geography, production method and bird slaughter weight. Litter quality is a significant factor in the development of lesions and irrespective of litter substrate the objective is to maintain a dry, friable condition throughout the crop cycle (litter score 1 -2) and limit the rate at which it deteriorates to a damp, capped (score 3) or wet, greasy (score 4) contact surface. Factors affecting litter management include: substrate type, bird health, ventilation and temperature. However, ventilation and its effect on temperature and relative humidity, has the potential to have the most immediate impact on bird environment. Typically, poultry integrations will specify a company-wide approach to litter management. Although, the inter flock variations seen in pododermatitis and hockburn levels at slaughter may be indicative of inconsistent implementation. In the current study, three indoor sites in the same integration, producing birds to the same production requirements were evaluated to determine the practical limitations of ventilation policies and the subsequent impact on bird welfare.

	A	B	C
House negative pressure test (Pa)	-46	-15	-58
Ventilation rate (m^3/hour/bird) at day 0	0.07	0.04	0.08
Ventilation rate (m^3/hour/bird) at day 21	0.89	0.66	0.89*
Ventilation rate (m^3/hour/bird) at day 35	1.53	1.48	1.53*
House RH at day 21	65	74	60
House RH at depletion	80	78	67
Litter Score @day 21	2	3	1
Litter Score @day 35	2/3	3	1
Pododermatitis (%) at depletion	12	21	9
Hockburn (%) at depletion	44	24	13

* In addition, Unit C had two **extra** fans running continuously, resulting in a higher ventilation rate than 1.53

Results indicate a trend relationship between integrity of housing structure (as indicated by air pressure), relative ventilation rates, humidity and subsequent litter score. Early deterioration of litter is likely to be associated with an increase in pododermatitis (unit B) while later deterioration (and increase in relative humidity) may be associated with increased levels of hockburn (unit A). In turn reflecting differences in bird motility and behaviour with age. This case study confirms that early attention to ventilation has lifetime implications for bird welfare.

This work was funded by a Tesco Future Farming Foundation Scholarship.