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Monitoring Mechanical Ventilation Rates in Poultry Buildings



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**Rural Industries Research and
Development Corporation**

Monitoring mechanical ventilation rates in poultry buildings

For the application of odour and dust control technologies

by Mark Dunlop and David Duperouzel

January 2014

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Foreword

The Australian chicken meat industry grows approximately 565 million chickens producing 1,042,000 tonnes of meat annually. Meat chicken farms are often built close to feed supply and meat processing infrastructure, with associated markets and labour force. This is necessary in order to maximise transport and distribution efficiency and ensure supply of labour. Positioning poultry farms close to essential infrastructure usually means that the farms are located close to urban areas and rural residents. Close proximity of neighbours to poultry farms can result in adverse impacts, primarily due to odour. Odour impacts are recognised as an issue for intensive animal industries worldwide, including the Australian chicken meat industry. Technologies and techniques are being developed to minimise these impacts. While currently being prohibitively expensive, future adoption will be dependent on optimising these technologies to provide maximum control of odour impacts at an affordable cost. Optimal design of these technologies will require accurate information about the highly variable nature of ventilation in mechanically ventilated meat chicken production.

The data collected in this study will benefit producers who may be considering the installation of an odour or dust control technology. It will enable them to design the technology to suit the level of fan activity at the time when impacts are occurring, rather than simply the maximum ventilation rate. Reducing the size of the technology will lead to cost savings.

Producers considering the adoption of a technology to control farm emissions should consider the information included in this report. It will assist them to understand fan activity on their farm. By combining this information with an understanding of when impacts are occurring, they will be able to customise the technology to suit their needs.

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

This report, an addition to RIRDC's diverse range of over 2000 research publications, forms part of the Chicken Meat R&D program, which aims to stimulate and promote R&D that will deliver a profitable, productive and sustainable Australian chicken meat industry that provides quality wholesome food to the nation.

Most of RIRDC's publications are available for viewing, free downloading or purchasing online at www.rirdc.gov.au. Purchases can also be made by phoning 1300 634 313.

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Abbreviations

RIRDC	Rural Industries Research and Development Corporation, Australian Government
DPI&F	Department of Primary Industries and Fisheries, Queensland Government (currently—Department of Agriculture, Fisheries and Forestry, DAFF)

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Executive Summary

What the report is about

The chicken meat industry is under pressure to reduce odour impacts from broiler farms. Add-on technologies are being developed to control emissions and reduce impacts. It may be possible to optimise these technologies to match ventilation requirements during critical times when odour impacts are most likely. Mechanical ventilation in poultry buildings is automatically controlled to maintain a suitable environment for the chickens. There is currently a lack of information regarding the ventilation requirements in meat chicken sheds. This information needs to be collected to assist with optimising the designs of add-on technologies to reduce the size, running costs and maintenance of such systems. Improved understanding of ventilation rates will also be useful for estimating fan operating costs and improving prediction of ventilation rate in odour dispersion modelling for new or expanding farms.

Who is the report targeted at?

This report was written for:

- poultry producers, who may be considering installation of add-on technologies, and require knowledge of ventilation rates and fan activity;
- the chicken meat industry, which is under pressure to reduce odour and dust impacts and need to know actual ventilation rates and fan activity of modern poultry sheds to assess potential add-on technologies and whether they will be an appropriate odour reduction strategy;
- environmental regulators/government agencies, who require information when making decisions on how to resolve or prevent odour impacts; and
- consultants, who require greater knowledge of ventilation rates and fan activity when advising poultry producers, environmental regulators and community groups about odour and dust emission/dispersion and potential reduction strategies.

Background

Increasing pressure is being placed upon the chicken meat industry to reduce odour and dust emissions from poultry sheds. Recent research has identified that ventilation rate significantly influenced the odour emission rate from meat chicken sheds. Ventilation rate increases with live weight and with ambient temperature due to seasonal and diurnal fluctuations. Therefore, accurate monitoring of ventilation rate would assist industry and environmental regulators plan for future development of the poultry industry through improved understanding of fluctuations in odour emission rate, which in turn may also in turn improve odour dispersion modelling.

Technologies that may be useful for controlling odour and dust from chicken sheds are being developed and have recently been reviewed. It was found that ventilation rate would significantly influence the adoption of filter/scrubber style technologies. The extremely large volumes of ventilation air exhausted from a meat chicken shed during full tunnel ventilation would more than likely make these technologies too large and expensive to be practical or affordable. It has been suggested that it may be possible to treat smaller volumes of air at critical times to achieve cost effective odour and dust control. To evaluate the practicality of this suggestion, detailed examination of ventilation and fan activity records would be required, hence the primary reason for this study.

Aims/objectives

This project was designed to quantify the daily, seasonal, and batch-age trends in ventilation rates for mechanically ventilated poultry sheds across different climatic zones of eastern Australia to support improved strategic design of odour and dust reducing technologies at critical periods of ventilation. In addition, this project will identify a suitable method to monitor ventilation rates of poultry production sheds.

Methods used

Five mechanically ventilated poultry farms were selected in a range of climatic zones along the eastern coast of Australia. Farms qualified if they had modern, industry representative tunnel ventilated poultry sheds (as of 2006 when this project was conceived). These farms were located in sub-tropical (two farms) and temperate (three farms) regions.

To accurately monitor fan activity, mechanical tilt switches were installed on both the tunnel fan and minimum ventilation (or inlet/side) fan back-draft shutters. Sensors were also placed on the mini-vents located along the sides of the sheds to assist in determining when a shed was in tunnel operation mode. Internal temperature, ambient temperature, ambient humidity and solar radiation were monitored to determine the influence of these factors on fan activity. Batch information, including placement and pickup details, was obtained from the producers.

Statistical methods were also applied to the ventilation data to develop simple mathematical models to link the ventilation rate to production and weather conditions to enable prediction of ventilation rate.

Results/key findings

Ventilation rate was found to be dependent on ambient temperatures (both seasonally and diurnally), solar radiation and batch age (including chicken live mass). Fan activity decreased at night time and during periods of cooler weather. This result was not unexpected; however the data demonstrated that reduced fan activity commonly occurred during those critical periods. Consequently, control of odour impacts at these critical times, with an add-on technology, may only need to be undertaken at reduced levels of fan activity.

Models were developed for each of the monitoring sites enabling prediction of ventilation rate based on production and weather conditions.

Implications for relevant stakeholders

The information provided in this report will enable producers, consultants and regulators to improve their knowledge of ventilation requirements for tunnel ventilated poultry sheds. This in turn will lead to greater understanding and improved modelling of meat chicken odour emissions. It will also increase their awareness and highlight the variable nature of mechanical ventilation, which greatly influences the adoption of add-on technologies.

Recommendations

Proponents of add-on technologies should consider the information in this report as it will assist them to select and match their preferred technology with ventilation requirements during critical odour/dust impact periods. The data generated in this study should be made available to improve the modelling of new and expanding poultry farms during their development assessment process.

Introduction

Background

The Australian chicken meat industry is under constant pressure to reduce odour and dust impacts from broiler farms. Increasing community concern relating to odour impacts from these farms may restrict expansion of existing enterprises and prevent the establishment of new ones, thus restricting the development of the industry. Regulatory bodies impose operational conditions on poultry production facilities in an effort to minimise the potential for odour impacts on nearby receptors. To date, the most effective method to prevent odour impacts is through adequate planning, including the requirement for buffer distances between the poultry sheds and nearby residences (McGahan and Tucker 2003). These buffer distances provide an opportunity for odours to disperse and be diluted into the atmosphere ideally to the point that nearby receptors cannot detect the odour. However, due to the influences of highly variable odour emission rates, weather and uncertainties surrounding the techniques used to calculate buffer distances, this planning approach may not provide complete protection against odour impacts. In this case, it may be possible to reduce odour impacts by reducing odour emission rate through the use of an odour control technology.

Dunlop (2009) reviewed technologies with potential for controlling odour and dust from chicken sheds. It was found that ventilation rate would significantly influence the adoption of filter/scrubber style technologies. Extremely large ventilation rates required in meat chicken shed during full tunnel ventilation (maximum ventilation rate) would more than likely make these technologies too large and expensive to be practical or affordable. It was suggested, however, that it may be possible to treat smaller volumes of air at critical times to achieve an effective yet affordable level of odour and dust control. To evaluate the practicality of this suggestion, detailed examination of ventilation and fan activity records would be required, hence the primary reason for this study.

Odour emission rate is the product of the odour concentration and the ventilation rate exhausted from volume sources, such as a chicken shed. It is therefore necessary to measure or estimate the ventilation rate in order to calculate the emission rate of odour (Wood *et al.* 2001). The relationship between odour concentration and emissions rate is quite complicated, with some research showing that ventilation rate influences odour emission rate while other research has found no relationship between ventilation rate and odour emission rate (Watts 2000; Wang 2003).

Dunlop *et al.* (2007) identified that ventilation rate influenced the odour emission rate from meat chicken sheds. It was also observed that ventilation rate increased (on average) as the mass of chickens in the shed increased or the ambient temperature increased (due to seasonal and diurnal fluctuation). Consequently, accurate monitoring of ventilation rate will assist the industry and environmental regulators to plan for future development of the chicken meat industry through improved understanding of fluctuations in odour emission rate.

Meat chicken shed and ventilation system

Note: This description of the features of a meat chicken shed and operation of the ventilation system has previously been stated by Dunlop et al. (2011).

Measurement of ventilation rate in poultry sheds can be challenging due to building design features and dynamic nature of mechanical ventilation. The ventilation system installed in poultry sheds comprises a central control unit, primary fans, duty fans, mini-vent inlets, tunnel ventilation inlets, evaporative cooling pads and ceiling baffles (see Figure 1). Large diameter axial fans (1219–1397 mm diameter, called primary or tunnel ventilation fans) are installed on the narrow end of the shed and provide the majority of the ventilation. Maximum ventilation rate is approximately 8–12 m³/hour per bird. Additional fans (referred to as minimum ventilation or duty fans) are installed along the length of the shed, on the wall opposite the primary fans or on the roof to provide low levels of ventilation. All fans are fitted with back-draft shutters to prevent fresh air entering the shed through inactive fans. Mini-vent inlets are installed at equal spacing along the walls on each side of the shed. Air is drawn through these vents when low levels of ventilation are required. Tunnel ventilation inlets are positioned on the opposite end of the shed from the tunnel ventilation fans. Air is drawn through these large vents when the shed transitions into tunnel ventilation mode. Evaporative cooling pads are usually installed in front of the tunnel ventilation inlets. When the weather is hot and maximum cooling is required, water runs over these cooling pads, creating a cooling effect as the air passes through them.

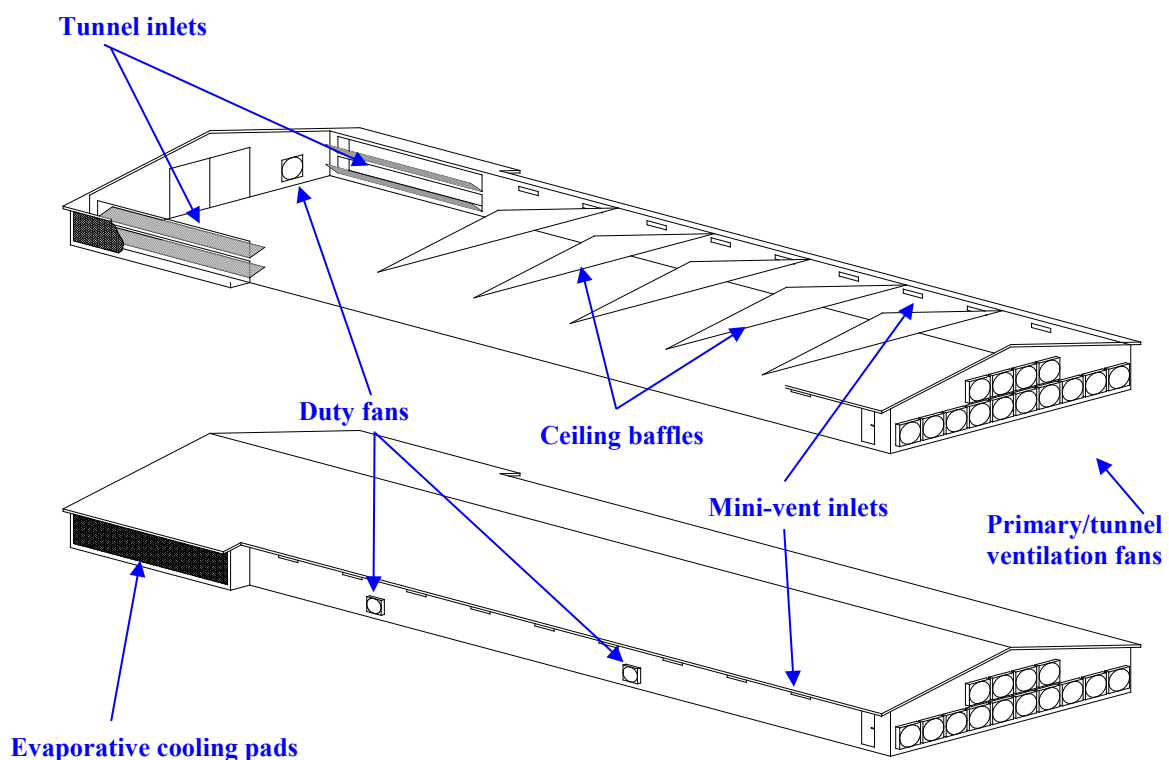


Figure 1 Components of the broiler shed ventilation system (top – inside shed with roof removed, bottom – outside shed)

The sheds are operated under negative pressure (ranging from 0–50 Pa) which draws fresh air into the shed through the inlets. Stale air is exhausted from the shed through the fans. There are primarily three modes of ventilation:

1. mini-vent ventilation;
2. tunnel ventilation without evaporative cooling; and
3. tunnel ventilation with evaporative cooling.

Mini-vent ventilation

Mini-vent ventilation is used when low levels of cooling are required or when no actual cooling is required. It allows stale, moisture laden air to be removed from the shed. Mini-vent ventilation is designed to exchange the air in the shed without creating airspeed or drafts. This is achieved by drawing fresh air into the shed through mini-vents. The amount of opening through the mini-vents is controlled to maintain a slight vacuum in the shed (approximately 20 Pa depending on shed width and inlet design). The negative pressure ensures that an even amount of fresh air is introduced along the entire length of the shed. It also aids the incoming air to be conditioned to increase its capacity to hold moisture.

At the lowest levels of mini-vent ventilation, duty fans will cycle on and off, removing stale air (containing moisture, dust and odour) while maintaining the internal shed environment. As the level of mini-vent ventilation increases, duty fan activity will increase and the primary fans will start to activate. Depending on the number and size of mini-vents and fan capacity, 50–75% of the primary fans can normally be activated before tunnel inlets need to be opened.

Tunnel ventilation with and without evaporative cooling

Tunnel ventilation is used when large amounts of cooling are required. During tunnel ventilation, mini-vent inlets are closed and tunnel inlets are opened. This creates airspeed along the length of the shed, introducing a wind chill effect for the birds. Wind chill is effective for improving bird comfort during warm weather by reducing the temperature experienced by the birds below the dry-bulb temperature of the air in the shed. Maximum airspeed through the shed may range from 1.8–3.5 m/s.

Ceiling baffles are installed in many sheds to reduce the cross-sectional area of the shed, increasing airspeed at a given ventilation rate.

When extra cooling is required during tunnel ventilation, water runs over the cooling pads, creating an evaporative cooling effect.

Techniques to monitor ventilation rate

Techniques used to measure ventilation rate include directly measuring shed airspeed, measuring the air flow through each active fan, using pitot tube (pressure) techniques or tracer gas techniques. These techniques are not suited to continuous, remote monitoring of ventilation rates because they either take ‘on-the-spot’ type readings or are very labour and equipment intensive.

Research investigations to continuously estimate the ventilation rate in mechanically ventilated animal sheds have been conducted. Typically, these investigations most commonly used air speed sensors to monitor air speeds (at inlets, fans or in the shed) or monitor fan activity. When fan activity is monitored, the performance of fans needs to be established either with manufacturer’s performance data (Wood *et al.* 2001) or by individually characterising the performance of each fan (Gates *et al.* 2004; Janni *et al.* 2005; Darr *et al.* 2007).

Demmers *et al.* (2001) found that tracer gas methods predicted ventilation rate to within 8% of the actual rate. This was conducted on a naturally ventilated animal shed. Hoff *et al.* (2004) concluded that the tracer gas method suffered from inaccuracies when there is incomplete mixing, and can be quite instrument intensive.

Measuring the difference in pressure between the inside and outside of a broiler shed (often referred to as the static pressure) is also required to determine fan performance and hence ventilation rate. As reported by Wheeler and Bottcher (1995), it is critical to install the sensors with great care, as exposing the tube openings to air velocities will give erroneous readings.

Mechanical switches have been developed to enable monitoring of fan activity. Hoff *et al.* (2004) trialled whisker switches (limit switches), which are an electromechanical device requiring physical contact between a target object and switch activator to make the contacts change state. For successful operation of the switches, a sail was attached to the switch shaft, then tied to the fan shutters. Hence, when the fan turned on, the shutter would open and activate the switch. As a comparison to the sail switch, Hoff *et al.* (2004) also trialled magnetic pick up sensors (which were placed near fan blades or pulleys) to determine both fan activity and fan speed (in rpm), hence estimate ventilation rate. Ni *et al.* (2005) and Darr *et al.* (2007) utilised vibration sensors to determine ventilation rate. A vibration (or mini shock) sensor, using a weighted spring to make or break an internal circuit when the unit is vibrated, was installed on each fan housing to determine fan activity. A strong correlation ($R^2=1$) between measured activity (26589 readings) and controller recordings (26504 readings) was found. Ni concluded that these could be a low cost (<US\$4.00) option for measuring fan activity, compared to limit switches (~US\$40.00) or other devices, such as rpm meters. Anemometers have also been used, either internally or externally, to determine air flow rate, and hence ventilation rate. Difficulties arise when measuring at the fan face to ensure a representative profile is sampled, as air speed will change from fan centre to fan blade tip. Wheeler and Bottcher (1995) noted that recordings taken in this manner represent only a small area of the air flow rate, and obstructions and wind gusts will cause uneven air speed distribution across the fan face. Wilhelm and McKenney (2001) and Wilhelm *et al.* (2001) used mercury tilt switches, attached to the fan back-draft shutters, to monitor fan activity. The tilt switches, combined with simple electronic circuitry and a data logger, allowed the researchers to monitor fan activity and hence estimate ventilation rate. This system was found to be robust and reliable.

Understanding when odour impacts are more likely to occur

Odour impacts are extremely complex and are a function of the odour source (i.e. broiler shed), dispersion of odour plumes and receptor characteristics. Impacts from poultry exhaust plumes are more likely to occur when periods of high odour emission rate (typically around the time of the first pickup at 35 days) coincide with conditions when dispersion of these plumes is limited. Atmospheric stability class is a dominating factor affecting the dispersion of plumes because it determines the extent to which a pocket of air will resist vertical mixing. It is most commonly reported using Pasquill-Gifford stability classes: *stable*, *neutral* and *unstable* (USEPA 2000).

Stable atmospheric conditions generally occur on clear nights and in the early morning, and by definition occur from an hour before sunset to an hour after sunrise. Stable conditions are generally associated with minimal turbulence and minimal vertical plume dispersion. Exhaust plumes will therefore resist mixing, dispersion and dilution under stable conditions, allowing exhaust plumes to travel significant distances, largely undiluted.

Neutral atmospheric conditions will generally occur during overcast conditions as well as during the day when wind speeds are moderately high. Vertical mixing of air is moderate and plumes will tend to neither rise nor descend (neutral buoyancy).

Unstable atmospheric conditions will occur on sunny days when ground temperatures heat low level air, forcing it to rise. Unstable conditions will maximise vertical mixing, leading to high levels of dispersion.

Previous research has shown that odour impacts are much more likely during stable atmospheric conditions or during neutral conditions when winds are strong (Guo *et al.* 2003). Consequently, designing add-on technologies to match the conditions of a meat chicken shed during stable atmospheric conditions—including ventilation rate—is likely to be able to reduce the potential for odour impacts and may reduce the size of the technology.

Research objectives

Reducing odour impacts from ventilated poultry sheds has been identified as a key goal for the poultry industry to achieve. Ventilation rates from mechanically ventilated poultry sheds vary due to the dynamic environment within the shed, and also due to external drivers, such as weather conditions. Add-on technologies, such as biofilters, scrubbers, or filters, have been identified as techniques to reduce odour impacts. However, it has proven difficult to utilise these technologies due to the large volumes of air emitted from poultry buildings.

This project was designed to provide the poultry industry with information that will:

- Quantify the daily, seasonal, and batch-age trends in ventilation rates for mechanically ventilated poultry sheds.
- Relate ventilation rates to the strategic design of odour and dust reducing technologies at critical periods of ventilation (i.e. especially during stable atmospheric conditions when there is greater potential for odour impacts).

In addition, this project will:

- Identify a suitable method to monitor ventilation rates of poultry production sheds.
- To record actual ventilation rates for mechanically ventilated poultry sheds across different climatic zones of eastern Australia—data that may be useful for improving the prediction of odour emission rates during odour assessments of new or expanding meat chicken farms.

Methodology

Site locations

Five meat chicken farms were chosen that had tunnel ventilated sheds. These enterprises covered a range of climatic zones, from sub-tropical to cool temperate.

Farm A

Farm A was located in south-east Queensland, approximately 65 km NNE of the Brisbane CBD. The climate at this location was sub-tropical, with summer dominant rainfall (annual average 1064 mm), and an annual average minimum and maximum temperature of 16.5 °C and 25 °C respectively (http://www.bom.gov.au/climate/averages/tables/cw_040697.shtml).

This farm had five tunnel ventilated sheds, each with a footprint of approximately 1440 m² (dimensions were approximately 14.4 m wide by 100 m long, 2.7 m wall height and 4.5 m roof apex). This shed had an insulated metal roof and cement treated road-base floor. The walls were made using a 0.3 m high concrete base, curtains in the middle and cement-fibre sheeting at the top. Mini-vents (1150 mm wide by 350 mm high, 38 mini-vents per shed) were installed into the cement-fibre panels on the walls. Eight rows of fogging nozzles were installed across the ceiling and were evenly spaced along the length of the shed. Spray foam was used to insulate the eastern and western walls.

The shed was ventilated using seven primary (tunnel) ventilation fans fitted on the western wall, plus one extra fan (minimum ventilation) fitted at the opposite end. All fans on the sheds were Fanquip 54” belt driven fans (Fanquip Pty Ltd, Singleton Australia, model 18-14083, 1370 mm diameter), with a stated maximum flow rate of 47,500 m³/hour. Fans were controlled using a Rotem[®] environmental control system (Rotem[®] model AC-2000). Evaporative cooling pads were fitted on the side walls at the eastern end of the shed. Ceiling baffles were fitted to improve internal airflow characteristics. The height at the bottom of these baffles was approximately 2.4 m. Given the shed dimensions (including baffle height) and fan performance, a theoretical tunnel ventilation velocity of 2.5 m/s could be achieved under the baffles (with a static pressure of -20 Pa).

Each shed was stocked with 26,000–28,600 birds (Ross 308, mixed sex) during each batch.

Wood shavings were used as bedding material.

Farm B

Farm B was also located in south-east Queensland, approximately 60 km NNW of the Brisbane CBD. The climate was typically sub-tropical, with summer dominant rainfall (annual average 1064 mm), and an annual average annual minimum and maximum temperature of 16.5°C and 25°C respectively (http://www.bom.gov.au/climate/averages/tables/cw_040697.shtml).

This farm had seven sheds of various designs. Three of these sheds had been converted from being naturally ventilated, two of the sheds were tunnel ventilated sheds with curtain walls and the remaining two were new sheds with fully insulated walls.

The shed chosen for monitoring in this project was one of the curtain-sided, tunnel ventilated sheds. The materials used to construct this shed were very similar to those used at Farm A (steel framing, insulated metal roof and walls made with concrete base, curtain middle and cement-fibre sheeting top). The shed was 120 m long and 13.7 m wide (1656 m² total floor area). The walls were 2.7 m high and the roof apex was 4.5 m high. Ceiling baffles were installed, the bottom edge of these baffles were suspended 2.5 m above the floor.

The shed was fitted with 12 primary (tunnel) ventilation fans (10 on the eastern wall and two eastern end of the southern wall) and one additional fan fitted to the southern wall approximately $\frac{1}{4}$ the length of the shed away from the western wall. All fans were 1270 mm belt driven axial fans (Munters Euroemme EM50, 1.0 hp, Italy), which have a maximum design flow rate of approximately 35,900 m³/h. Fan activity was automatically controlled using an environmental control system (Hired Hand, USA). Given the shed dimensions, fan performance and assuming a static pressure of -50 Pa (based on data measured at the farm), the maximum airspeed during tunnel ventilation would be approximately 2.4 m/s.

This shed was stocked with 29,500–32,000 birds (Cobb 500, mixed sex) during each batch.

Wood shavings were used for bedding material.

Farm C

Farm C was located near Tamworth, New South Wales, on the northern NSW tablelands (elevation 400 m, approximately 580 km south-west of Brisbane, Queensland). It was located in a temperate climate but experiences a characteristic hot dry summer, cold winter, summer dominant rainfall (annual average 673 mm), an average annual maximum and minimum temperature of 24 °C and 10 °C respectively (http://www.bom.gov.au/climate/averages/tables/cw_055325.shtml).

Farm C had eight tunnel ventilated sheds. This chosen shed was 110 m long and 13.7 m wide (internal dimension), had 2.5 m high walls and had a roof apex 3.8 m high. No ceiling baffles were installed in this shed. The shed had an insulated roof and the walls had a concrete base, curtains (blackout style curtains) and sheet metal along the top where the mini-vents were installed. The floor was compacted road-base.

This shed was fitted with eight fans in total. Six fans were installed on the eastern wall for primary (tunnel) ventilation. Two additional fans were installed on the northern wall (equally spaced) for operation during low ventilation conditions. The tunnel ventilation fans were 1220 mm diameter (Titan 48", 1.5 kW, 6 blade, Titan Fan Products Australia Pty Ltd), which were rated for a maximum flow rate of 46 200 m³/h. The two side wall fans were 1000 mm diameter (Titan 39", 6 blade), which were rated for a maximum flow rate of approximately 41 000 m³/h. Given the shed dimensions and fan performance, a maximum tunnel ventilation air velocity of 1.8 m/s would be achievable (with a static pressure of -20 Pa).

The shed was stocked with 28 700–31 500 birds per batch (mixture of Ross and Cobb birds, mixed sex).

Rice hulls or wood shavings were used as bedding material.

Farm D

Farm D was located near Mangrove Mountain, approximately 80 km north of Sydney, NSW. It was located in a temperate climatic zone, receiving summer dominant rainfall (1319 mm average annual), and has an annual average maximum and minimum temperature of 23 °C and 11 °C respectively (http://www.bom.gov.au/climate/averages/tables/cw_061375.shtml). The farm consists of six production sheds, each having dimensions of approximately 120 m long by 14.7 m wide (internal), with 2.7 m high walls and 4.1 m to the roof apex.

The sheds have an insulated roof and the walls are constructed with a concrete base, curtains and sheet metal at the top where the minivents (Fancom® 1450) were installed. No ceiling baffles were installed in the shed.

A total of eight primary ventilation fans were located on the eastern end of the shed. The primary (tunnel) ventilation fans were 1220 mm diameter fans (Titan 48", WM 1220, 6 blade, 1.5 kW, Titan

Fan Products Australia Pty Ltd). Sidewall mounted ventilation fans were 1000 mm diameter fans (Titan 39", WM 1000, 5 blade, 1.1 kW, Titan Fan Products Australia Pty Ltd). Maximum theoretical air velocity in the shed during tunnel ventilation was 2.05 m/s (with a static pressure of -20 Pa).

Production sheds were stocked with up to 42,500 birds. A mixture of Ross 308 and Cobb 500 birds (mixed sex) were produced.

Farm E

Farm E was located on the Mornington Peninsula, approximately 50km south east of Melbourne, Victoria. It was located in a temperate climatic zone, receiving winter dominant rainfall (740 mm annual average), with an annual average maximum and minimum temperature of 19 °C and 10 °C respectively (http://www.bom.gov.au/climate/averages/tables/cw_086079.shtml). The farm consisted of five production sheds, varying in capacity from 14,300 to 37,200 birds. Total farm capacity was approximately 154,400 birds.

The production shed utilised for this project was 120 m long by 13.5 m wide with 2.7 m high walls and roof apex height of 4.5m. This shed had an insulated roof and insulated side walls.

This shed had a total of 12 primary (tunnel) ventilation fans, plus two side wall fans (one on each side of the shed). The tunnel ventilation fans were 1220 mm diameter (Euroemme 48" 6 blade, similar to Euroemme EM50, 1 hp) with a maximum rated flow of 34,800 m³/h. The side ventilation fans were 1000 mm diameter (Gigola[®] ES-120, 39", 1 hp) with a rated maximum flow rate of 26,200 m³/h. Given the shed dimensions and fan specifications, the theoretical maximum tunnel ventilation velocity in this shed was 2.1 m/s.

This shed was stocked with 33,000–35,000 birds (predominately Cobb 500, mixed sex).

Monitoring equipment

Monitoring stations

Monitoring stations were used to collect fan activity and environmental data at each farm. Each station included a data logger, power supply, remote communications device and specialised sensors to measure:

- fan activity;
- shed static pressure;
- internal shed temperature;
- ambient temperature;
- ambient humidity;
- solar radiation; and
- mini-vent opening.

Each monitoring station had a two metre tall steel pole, which was cemented into the ground. A lockable steel enclosure and a solar panel, radiation shield and solar radiation sensor were mounted to this pole (see Figure 2).

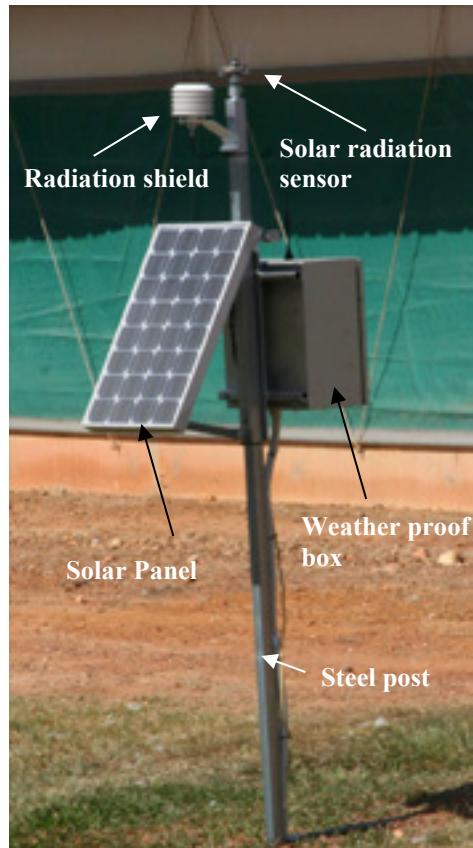


Figure 2 Monitoring station showing the solar panel, weather-proof box, radiation shield (for the ambient temperature and humidity sensors) and solar radiation sensor

The solar panel (12 V, 30 amp, BP[®] solar) supplied power to the data acquisition equipment via a 12 V, 24 AH sealed lead acid battery. Charging was controlled by a solar panel regulator.

A radiation shield (6 plate radiation shield, RM Young Company Meteorological Instruments, Michigan USA) was used to hold the ambient temperature and humidity sensor (Vaisala Intercap[™] HMP50Y, Vaisala[®]). The radiation shield was mounted near the top of the steel post so that the sensors would be 2 m above the ground. Specifications of the temperature and humidity sensor are given in Appendix 1.

A solar radiation sensor (LI200X Pyranometer, Li-Cor Inc.) was mounted at the top of the post to measure solar radiation. Specifications of the solar radiation sensor are given in Appendix 1.

The lockable enclosure (Figure 3) provided a weatherproof housing for the data acquisition equipment. This included a datalogger (dataTaker[®] DT500, dataTaker[®] Pty Ltd) and a GSM modem (Wavecom, various models, supplied by Intercel Pty Ltd, Victoria). Data was remotely accessed from the data logger via the digital GSM modem.

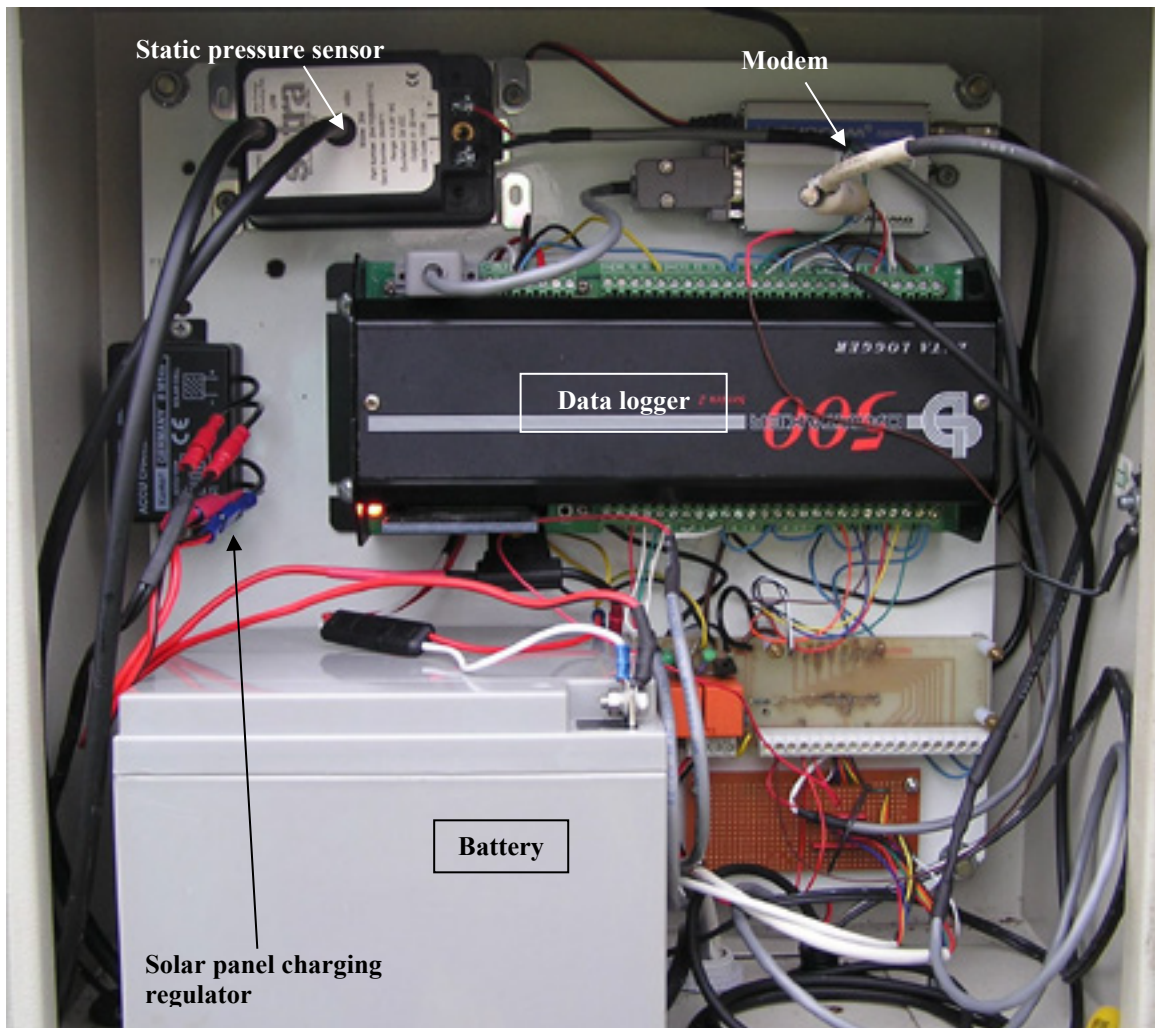


Figure 3 Internal view of the weather proof box showing data logger, battery, static pressure sensor, modem and electronic circuitry

Sensors

Fan activity

Fan activity data, combined with fan performance data, shed static pressure and inlet vent positions was used to estimate shed ventilation rate.

Mercury tilt switches were attached to the fan back-draft shutters to monitor fan activity, similar to the approach used by Wilhelm *et al.*(2001). Tilt switches were selected over other techniques due to low cost (sensors cost approximately \$3.00/fan), availability of components, expected reliability (when compared to more complex systems) and unobtrusiveness. The potential problems foreseen with the use of tilt switches included the possibility for false positive readings if the shutters did not close when the fan turned off or if the wire broke.

Mercury tilt switches were fitted onto an angled aluminium plate, which was then riveted onto the fan back draft shutters of every fan on the shed (see Figure 4 and Figure 5). The purpose of the angled plate was to avoid hysteresis issues associated with the switch only just (or just not) reaching a true horizontal position when the fan turned on and the shutter opened. The angle ensured the tilt switch passed through the horizontal position, whenever the louvers opened, so the switch would always activate.



Figure 4 Mercury tilt switch with fan turned off (shutters closed, switch closed)



Figure 5 Mercury tilt switch with fan turned on (shutters open, switch open)

Tilt switches were connected to the data logger, via a voltage dividing circuit (see Figure 6 for circuit diagram). The input voltage to the voltage dividing circuit was 5 V DC, and the maximum output voltage to each switch was restricted to 2.5 V DC (to match the data logger's specifications). Each switch was wired into an analogue channel on the data logger, with the voltages from each switch being read as an analogue voltage. The data logger was programmed so that when the shutters opened (resulting in the switch being open, and the voltage was high, *i.e.* 2.5 V DC), the logger would record that the fan was on. Conversely, when the shutters were closed (the switch would be closed and the voltage would be low, *i.e.* 0 V DC), the logger would record that the fan was off.

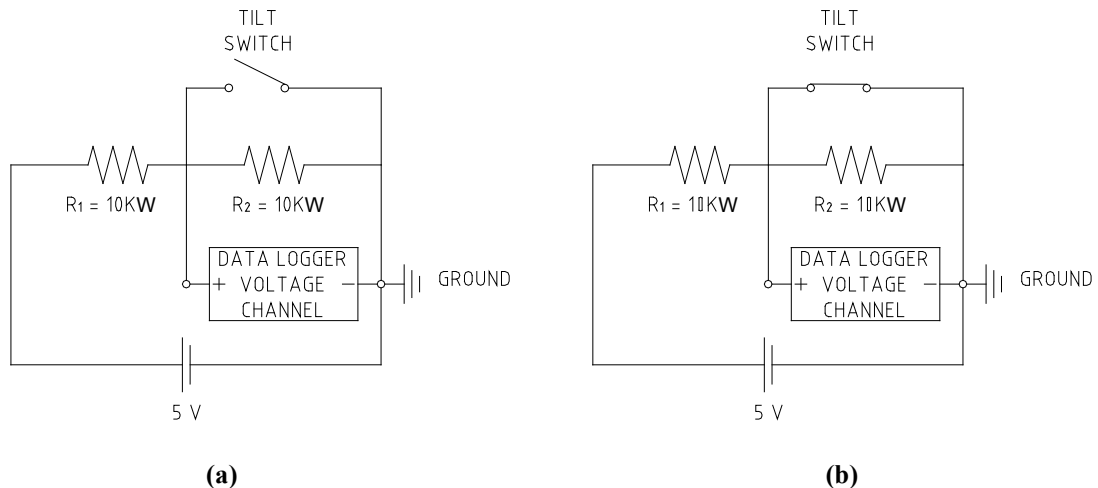


Figure 6 Voltage divider circuit used on the tilt switches. Configuration (a) occurs when the fan is on and the mercury tilt switch is open, in which case the data logger returns a reading of 2.5 V. Configuration (b) occurs when the fan is off and the mercury tilt switch is closed, in which case the data logger returns a reading of 0 V

The data logger recorded fan activity in two ways. Firstly, if the number of active fans changed, the logger recorded the date and time of the change, as well as the new number of active fans. Secondly, the data logger monitored the number of active fans every 6 s, then reported the average number of active fans every 15 min. When sheds were fitted with side wall fans, or any fans with different performance characteristics (e.g. different size or model of fan), the average of each type of fan was recorded separately.

Inlet vent opening

To detect when mini-vents along the sides of the shed were open or closed, a custom sensor was developed. This sensor comprised some mechanical linkage, a sensor to monitor the position or rotation of the linkage, and a housing to protect the sensor (see Figure 7). Initially a rotating potentiometer was trialed to monitor the position of the mechanical linkage. Unfortunately, following washing of the shed, this sensor failed due to water damage. A Hall-effect sensor was then used to replace the potentiometer as the sensor to monitor the position of the mechanical linkage. The rotating potentiometer was retained as a pivot point for the mechanical linkage, but was not connected to the data acquisition system.

A Hall-effect sensor is a digital semiconductor, which responds to the presence of a magnetic field. To create a magnetic field, a magnet was fastened to one of the mechanical linkage arms (see). The voltage output of the Hall-effect sensor changed as the strength of the magnet moved away from the sensor. This change in voltage was recorded by the data logger.

The Hall-effect sensor was powered by 5 V DC. As the magnet was moved away from the sensor by the opening mini-vent, the Hall-effect changed state from zero, to a positive voltage reading, up to a maximum of 2.5 V DC, which equates to a mini-vent being fully open. The data logger was programmed to scale these voltage readings into a percentage reading relating to how far open the mini-vent was.

Specifications of the Hall-effect sensor are given in Appendix 1.



Figure 7 Mini-vent position sensor following installation of a Hall-effect sensor and magnet

Internal shed temperature

Internal shed temperature was measured with a PT100 platinum resistance temperature detector (RTD) (Figure 9, and refer to Appendix 1 for sensor specifications). The temperature sensor was positioned approximately 5–10 m in front of the tunnel ventilation fans in the centre line of the shed and about 0.4–0.5 m above the litter surface (see Figure 8).

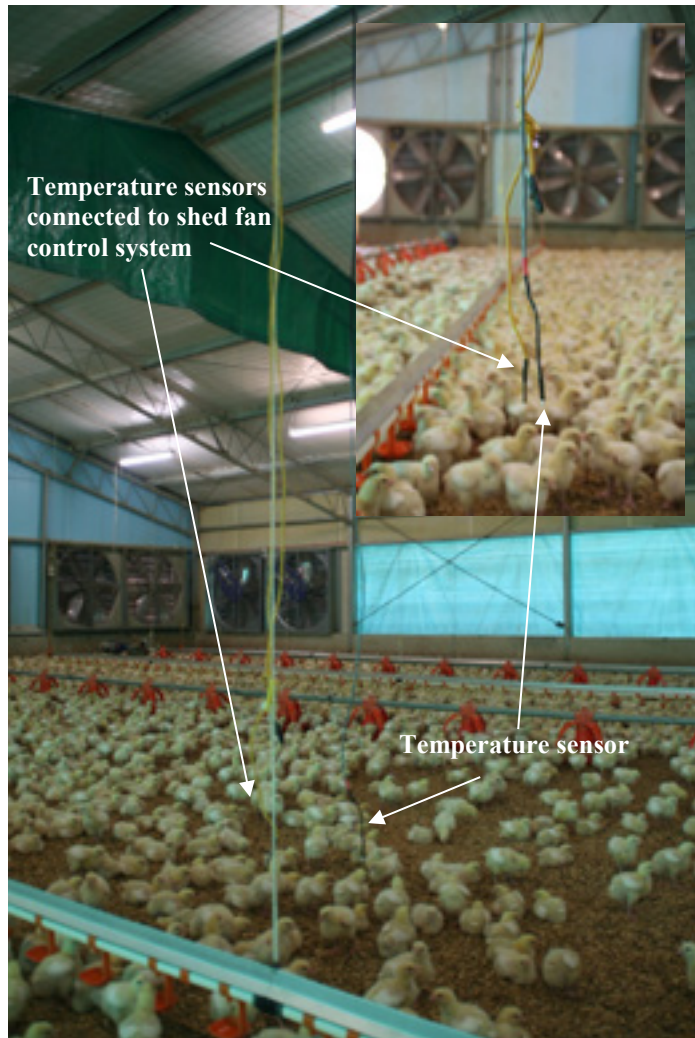


Figure 8 Internal temperature sensor in shed (*inset – position of the internal shed temperature sensor in relation to the chickens*)

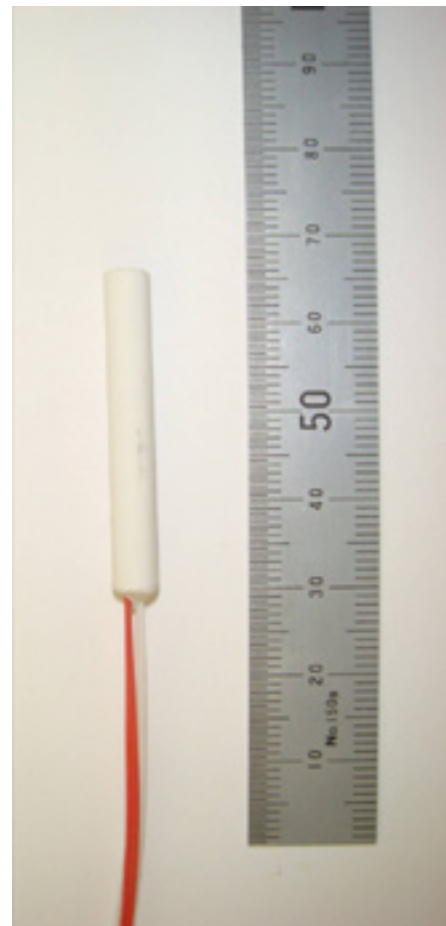


Figure 9 PT100 RTD sensor before installation

Shed static pressure

The differential pressure between the inside and outside of the chicken shed affects the performance of the ventilation fans (see Figure 13 for fan performance data for fans monitored in this project). Chicken sheds will normally have a differential pressure in the range of 0 Pa to -50 Pa relative to the outside. This differential pressure is often referred to as *static pressure*. The static pressure will vary due to the number of active fans, inlet vent position and by external forces such as wind. Consequently, the static pressure will fluctuate constantly. The ventilation controller monitors the static pressure and adjusts the inlet vents to maintain a suitable pressure. Because static pressure affects fan performance, it was essential to monitor the static pressure to allow calculation of ventilation rate with reasonable accuracy.

A differential pressure sensor (Setra brand model 264, refer to Appendix 1 for specifications) was used to measure the pressure difference between the ambient environment and the internal shed environment. A 4 mm diameter tube was installed into the chicken shed and extended into the weather proof box on the monitoring station and connected to the pressure sensor. The reference pressure for the pressure sensor was the pressure measured inside the weatherproof box (which was vented, but protected the sensor from strong wind pressures).

Ambient temperature and humidity

Ambient temperature and humidity were monitored using a Vaisala 50Y Humitter® combined temperature and humidity sensor (refer to Appendix 1 for specifications). This sensor was installed into a radiation shield and mounted on the monitoring station at a height of 2 m. The monitoring station was located external to the shed, typically at the primary tunnel fan end, and approximately half way between the monitored shed and the neighbouring shed.

Solar radiation

Solar radiation was monitored in this study because it was expected to influence the ventilation rate by increasing the heat loading on the shed through heating of the roof and walls. Solar radiation was measured using a LiCor radiation sensor (refer to Appendix 1 for specifications), which measures incoming solar radiation with a silicon photovoltaic detector.

Measurement frequency of each sensor

The data logger was programmed to monitor and record the output of each sensor at specified intervals. Table 1 lists the monitoring and recording frequency for each of the sensors.

Table 1 Frequency of monitoring and recording for each sensor

Sensor	Monitoring Frequency	Recording Frequency
Fan activity (Mercury tilt switches)	Six second	15 minute; on event
Internal temperature (PT100)	15 minute	15 minute
Minivent switches (Hall effect sensors)	Six second	15 minute; on change in fan activity
External temperature (Vaisala Humitter)	15 minute	15 minute
External humidity (Vaisala Humitter)	15 minute	15 minute
Solar radiation (Pyranometer)	15 minute	15 minute
Shed static pressure (differential pressure sensor)	Six second	15 minute; on change in fan activity

Monitoring and maintenance

During initial set-up, equipment was tested and calibrated for on-site conditions. Testing and calibration mainly focused on the Hall-effect switches and mercury switches, as the operation of these sensors was site dependent, due to variations in mini-vent and shutter design and opening mechanisms. Once installed, equipment was field tested on-site to ensure all sensors were providing accurate readings.

Following installation, equipment was monitored remotely by examining the data downloaded from the monitoring station via the digital GSM link. Aberrations in the data were investigated as soon as they were detected. If a sensor or the data acquisition system were thought to be faulty, research staff travelled to the site to service and repair the faulty equipment.

Estimating chicken live weight

Total chicken live weight was calculated by estimating the individual bodyweight of the chickens using data supplied by breeding companies and multiplying it by the number of birds in the shed.

Chicken individual bodyweight was estimated using published growth data for Ross 308 and Cobb 500 breeds (see Figure 10, mixed sex data <http://www.aviagen.com> and <http://www.cobb-vantress.com>). Polynomial equations were developed to enable estimation of bodyweight at all stages throughout the batch.

Equation 1 and Equation 2 were used to estimate body mass for Ross 308 and Cobb 500 chickens, respectively.

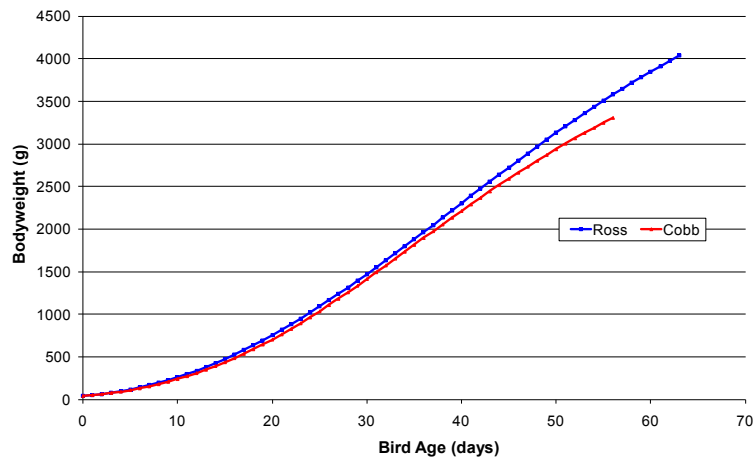


Figure 10 Estimations of individual chicken bodyweights through growth cycle

Equation 1 Ross 308 individual bodyweight (g) = $-0.0173 d^3 + 2.086 d^2 + .2317 d + 59.758$

Equation 2 Cobb 500 individual bodyweight (g) = $-0.0217 d^3 + 2.3616 d^2 - 6.5475 d + 75.376$

(Where d is the age of the birds in days.)

For Farm A, the Ross 308 equation was used. For all other farms, the Cobb 500 equation was used because Cobb 500 was either the only breed used, or was the majority of birds placed in the shed (with the balance being Ross 308).

To enable calculation of total shed live mass, the individual bird bodyweight was multiplied by the number of birds estimated to be in the shed. Placement and pickup bird numbers were supplied by the producer. Figure 11 displays typical total live mass data for one batch. This figure demonstrates how the total live mass drops following a pickup.

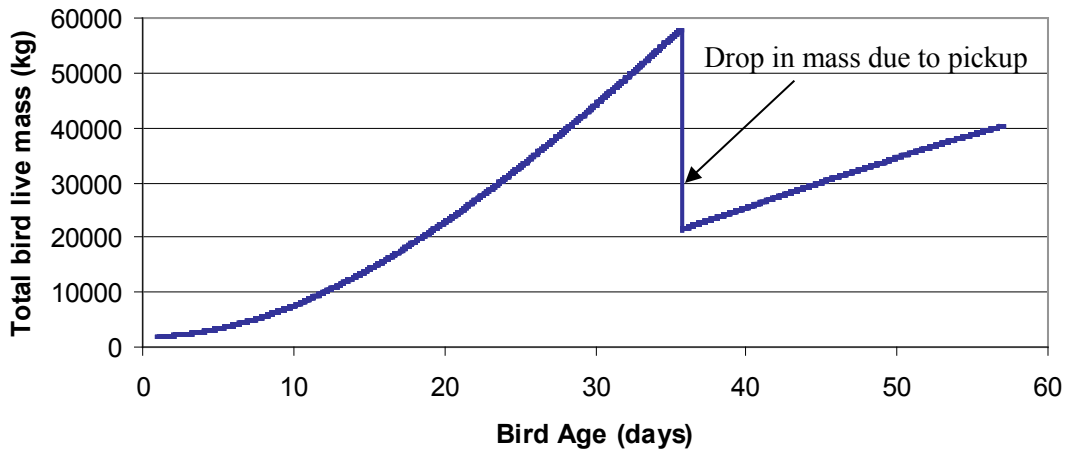


Figure 11 Estimated total bird live mass for Farm B, batch 2

Estimating shed target temperature

Target production temperatures were estimated using the values published for Ross 308 and Cobb 500 breeds (see Figure 12, <http://www.aviagen.com> and <http://www.cobb-vantress.com>). Polynomial equations were developed, refer to Equation 3 and Equation 4 for Ross 308 and Cobb 500 respectively. For Farm A, the Ross 308 equation was used. For all other farms, the Cobb 500 equation was used.

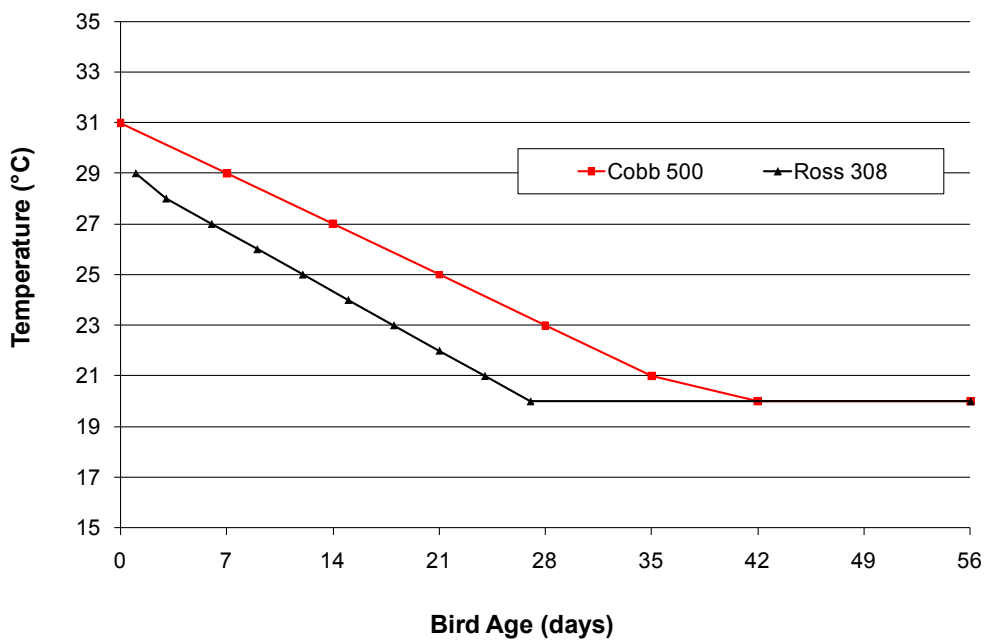


Figure 12 Estimations of target production temperatures through the growth cycle

Equation 3	Ross 308 target temperature	$= -0.5 d + 29.5$ (for $0 \leq d < 3$); $= -0.333 d + 29$ (for $3 \leq d < 27$); and $= 20$ (for $d \geq 27$)
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Equation 4	Cobb 500 target temperature	$= -0.2857 d + 31$ (for $0 \leq d < 35$); $= -0.1429 d + 26$ (for $35 \leq d < 42$); and $= 20$ (for $d \geq 42$)
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(Where d is the age of the birds in fractions of days—e.g. 8 days and 3 hours would be $d = 8.125$ —and Temperature is degrees Celsius, °C.)

Note that the target temperature is not dry bulb temperature, but the temperature ‘felt’ by the birds taking into account air humidity and air speed.

Calculating ventilation rate

Ventilation rate was calculated by multiplying the number of active fans by the estimated flow rate through each fan. As mentioned previously, the flow rate through the fans will be dependent on the static pressure of the shed. Other factors such as fan condition, drive belt tension/condition and cleanliness of fan blades, shutters and safety grills will all have an effect on fan performance (usually by reducing the flow rate).

Figure 13 displays the fan performance data for the fans monitored during this study. It can be seen that flow rate reduces as the magnitude of the static pressure increases (inside the shed is lower pressure than the outside). Calculating ventilation rate with this method assumes that the fan performance data is accurate and that the fans are clean and in good condition.

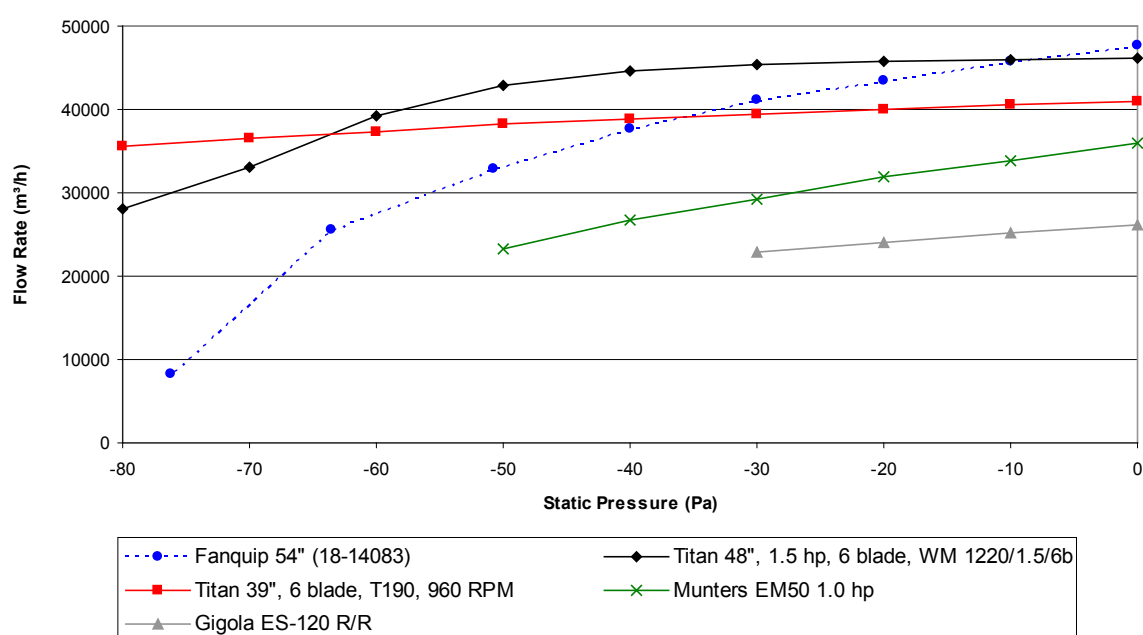


Figure 13 Manufacturer’s fan performance data for fans used in this project

Formulas for estimating fan performance

Formulas for estimating the flow rate from each fan were generated by plotting flow rate data supplied by each manufacturer, then using Microsoft Excel® to develop polynomial equations.

Equation 5 to Equation 9 were used to estimate flow rate through each of the fan types. In all of these equations, p is the static pressure of the shed (negative when the shed pressure is less than the external pressure, i.e. shed is in vacuum).

Flow rate for the Titan fan was estimated using three separate equations, depending on the static pressure of the shed at the time of calculation. For the other fans, only a single equation was required to adequately estimate the flow rate.

Equation 5, estimating flow rate from 48” Titan fans (1220 mm diameter)

if static pressure is >-20 Pa,

$$\text{Flow rate (m}^3/\text{h)} = -0.295 p^2 + 15.65 p + 46231$$

if static pressure is -20 Pa to -40 Pa,

$$\text{Flow rate (m}^3/\text{h)} = 0.1018 p^3 + 7.535 p^2 + 226.97 p + 48140$$

if static pressure is less than -40 Pa,

$$\text{Flow rate (m}^3/\text{h)} = -11.45 p^2 - 885.5 p + 27250$$

Equation 6, estimating flow rate from 39” Titan fans (1000 mm diameter)

$$\text{Flow rate (m}^3\text{/h)} = -0.0005 p^3 - 0.4229 p^2 + 35.287 p + 40928$$

Equation 7, estimating flow rate from 54” Fanquip fans

$$\text{Flow rate (m}^3\text{/h)} = -0.0029 p^4 - 0.3021 p^3 - 12.074 p^2 + 64.188 p + 47668$$

Equation 8, estimating flow rate from 50” Euroemme EM50 fans (1.0 hp)

$$\text{Flow rate (m}^3\text{/h)} = 0.0234 p^3 + 0.173 p^2 + 201.77 p + 35937$$

Equation 9, estimating flow rate from Gigola ES-120 fans

$$\text{Flow rate (m}^3\text{/h)} = 0.0117 p^3 + 0.45 p^2 + 115.33 p + 26220$$

Calculating percentage of maximum ventilation

Following collection of the fan activity data at the study farms, it was evident that the number of active fans very rarely exceeded the maximum number of tunnel fans. In other words, it was very uncommon for minimum ventilation fans to be operating whenever all of the tunnel fans were operating.

Consequently, the maximum level of fan activity has been assumed to be the maximum number of tunnel ventilation fans, not the maximum number of all fans. In this report, the terms ‘*percentage (%) of maximum tunnel ventilation*’ and ‘*percentage (%) of maximum fan activity*’ refer to the current level of fan activity compared to the maximum ventilation rate (m³/s, assuming all **tunnel** fans active and corresponding shed specific static pressure) or maximum number of active **tunnel** fans.

Development of models to estimate/predict ventilation rate

Statistical methods were applied to the data with the intention of developing models that could be used to predict fan activity on an hourly basis for each of the five monitoring sites. Such models could be useful during the design stage of an add-on technology or during the development of an odour emission model as required for odour impact assessments.

The data set of average hourly percentage of maximum fan activity (dependent variable) was highly autocorrelated, which violates the assumptions of linear regression analysis. The explanatory variables were also highly autocorrelated and often correlated with each other. To remove some of the autocorrelation every 9th hour was used and the rest of the data discarded. The every 9th hour was chosen as a balance between reducing the autocorrelation, the time of day changing across days and retaining a reasonable number of values.

To determine potential explanatory variables to include in a multiple regressions, each site was run through all possible subset selections and the best regressions identified based on highest adjusted R^2 and each term in the regression being significant at the 5% level. The list of trial explanatory variables were bird age, individual bird weight, total live weight, total solar radiation, production target temperature, humidity, ambient temperature (and its square), the product of ambient temperature and age, the product of ambient temperature and total live weight, and the difference between target temperature and ambient temperature. From this a shorter list of explanatory variables were compiled to trial for each of the sites.

Three models were developed for each of the farms using different combinations of explanatory variables.

Results

Summary of data collected

Almost ten million pieces of data were collected at the 5 meat chicken farms monitored in this study. The period of data collection and the number of chicken batches monitored in this study are summarised in Table 2. A Gantt chart showing the dates of each batch is provided in Appendix 2.

Table 2 Summary of data collection period at each farm

Farm ID	Record of data collection	Number of chicken batches monitored#	Number of production days monitored
Farm A	23/9/06 – 12/2/08	8	194
Farm B	24/10/06 – 10/2/08	7	297
Farm C	31/8/06 – 14/11/07	7	274
Farm D	17/10/06 – 19/12/07	7	223
Farm E	18/1/07 – 6/2/08	6	276

Note: some of these batches were only partly monitored due to the dates when logging equipment was installed, decommissioned or inactive due to equipment failure.

An example of the data collected during this study is shown in Figure 14. Charts showing data collected at each farm are provided in . These charts show how ventilation rate changes with batch age, chicken mass and temperature.

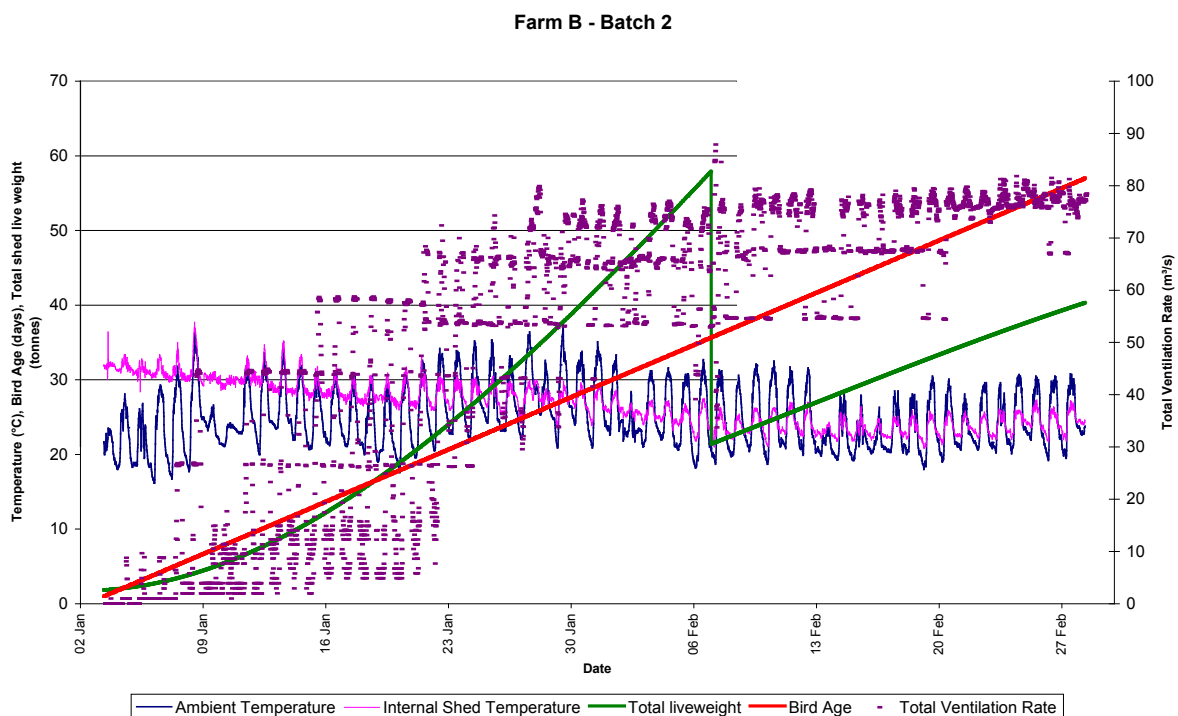


Figure 14 Example of data collected at Farm B (Batch 2)

Reliability of monitoring equipment

The equipment selected in this project proved to be very successful for collecting temperature, humidity, solar radiation, static pressure, mini-vent position and fan operation information at broiler farms.

Temperature, humidity and solar radiation sensors are very common, stable and reliable sensor types and no problems were experienced with the sensors. On two occasions, internal shed temperature sensors failed: at Farms C and E, the temperature sensor wires were snagged by moving winch cables and broke. Once repaired, no further problems were experienced.

The mini-vent position sensors worked reasonably well throughout the trial, however some problems were experienced. The research team have developed an improved method for using the Hall-effect sensors. Instead of attaching the magnet to metal linkages, the magnet can be adhered directly to the mini-vent shutter (see Figure 15). The choice of mini-vent sensor is dependent on the style and brand of mini-vent. Sometimes it is not possible to mount the Hall-effect sensor in a position where a magnet can be close to the sensor. In these cases linkages or mounting brackets may be required. If linkages are required, it is recommended to use waterproof potentiometers if possible because they provide a pivot point for the linkage as well as provide feedback over the full range of mini-vent opening. The Hall effect sensor is valuable for detecting when the mini-vent is closed, but once the vent is 25-50% open, the magnet is too far from the sensor to record a reading and the vent is assumed to be open.

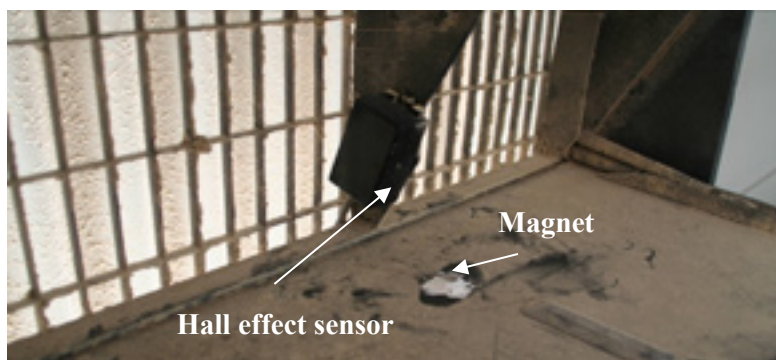


Figure 15 Hall-effect sensor installed on mini-vent

Mercury tilt switches were found to be very effective at indicating when fans were open and closed. The sensors themselves continued to work even after being tilted thousands of times. The only issue with these switches is the necessity to leave a loose loop of wire to enable the switch to move as the shutter opens and closes. During shed cleaning, this wire can be snagged by brushes or pressure cleaners and torn away from the sensor. Over the course of the year, seven of the fan switches were damaged in this way. Of these, four were broken at Farm C.

Apart from the broken wires, the tilt switches operated reliably over the course of the project and seemed to be a very good indicator of fan activity. It is recommended, wherever possible, to install tilt switches on all fans, even if multiple fans are operated simultaneously. That way, if a fan needs to be isolated for maintenance, or the switch fails, there is redundancy in the fan monitoring system.

Static pressure transducers operated in a stable manner and did not drift over the duration of the monitoring exercise. Some issues were encountered during periods of high wind, when the interference of the buildings on wind currents occasionally produced atypical pressure readings. Overall, the sensors provided reliable and important information. Careful consideration needs to be given to locating the sensor and connecting tubes in appropriate locations.

The data loggers at Farms A, B and E functioned flawlessly. The logger at farm C failed on several occasions. One of these occasions occurred following a storm when a nearby lightning strike almost

certainly interfered with the sensitive equipment. Similar problems were encountered at Farm D, where the logger failed following a month of overcast and drizzly weather. It is thought that the battery probably went flat during this period. Also at Farm D, a lightning strike near the monitoring station created a terminal fault in the logger (and destroyed the ventilation control system at the farm). This problem was compounded by poor mobile telephone reception in the area, which made it difficult to diagnose the problem remotely.

If similar monitoring studies are conducted in the future, it is recommended that the same or similar equipment be used again. It is also recommended that a system be developed to monitor the operation of the tunnel ventilation inlets and cool pads, which were not monitored during this study.

Data

Inter-farm variability

Fan activity was observed to be different at each of the five study farms. Figure 16 is a chart summarising the annual average fan activity at each of the farms. All farms demonstrated an almost linear increase in fan activity for the first 21-25 days of the batch. From this point, fan activity at Farm A and Farm B (both located in south east Queensland) continued to rise linearly until the end of the batch. Farm C also continued to rise, but only until about day 45. Beyond this time, the fan activity at Farm C decreased as birds were harvested from the shed and the total live weight decreased. At Farms D and E, average fan activity appeared to remain fairly constant throughout the rest of the batch. The difference of this fan activity as opposed to that displayed by Farm A and B was most likely due to cooler weather conditions for a greater proportion of the year.

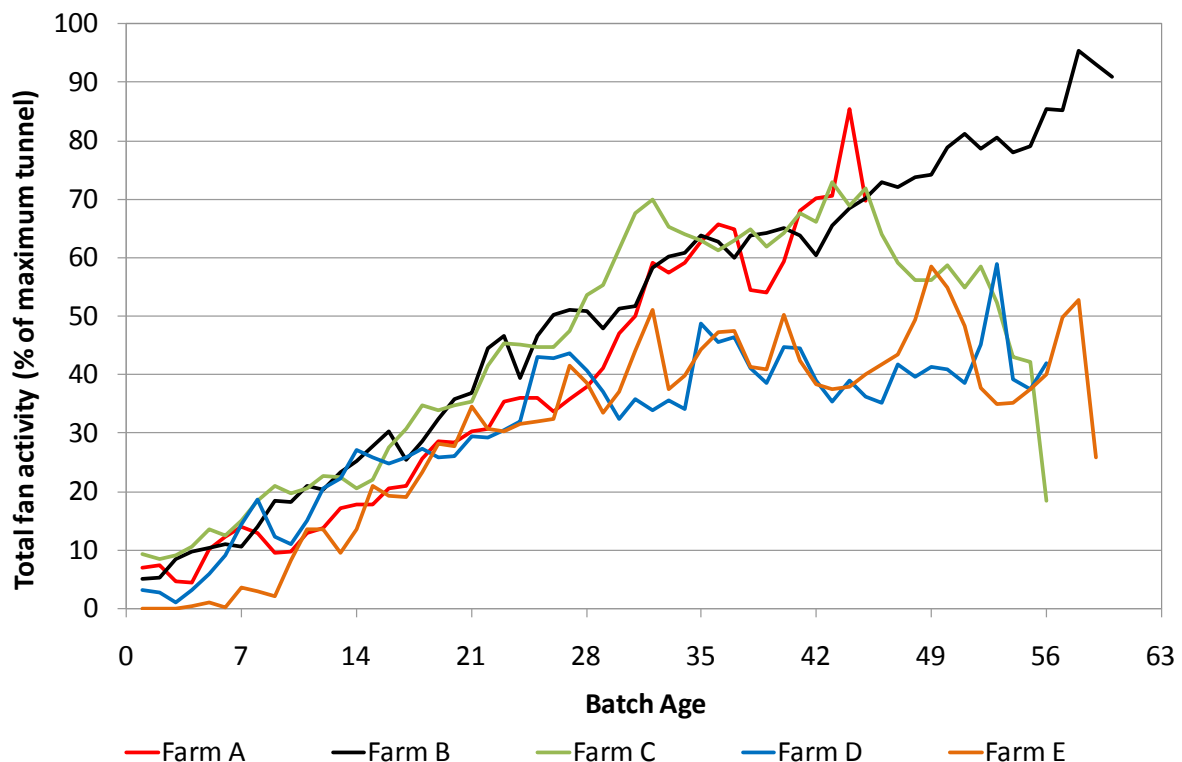


Figure 16 Summary of annual average total fan activity at the five study sites

Specific reasons for the variability are unknown but likely include differences in weather, bird placement and pickup programs, manager preference for ventilation rates, ventilation controller programming and operation, and shed dimensions and design (including the effect on maximum tunnel airspeed) (see Table 3 for summary of these values for reference).

Table 3 Summary of shed dimension and air flow rates for each of the five sheds

	Farm A	Farm B	Farm C	Farm D	Farm E
Shed Cross section area (m²)	51.8	49.3	43.2	49.98	48.6
Shed Cross section area under baffles (m²)	34.56	34.3	43.2	49.98	48.6
Shed length	100	121	110	130	120
Floor area (m²)	1440	1658	1507	1911	1620
Approximate number of bird places (@ 19.5 birds/m²)	28080	32331	29387	37265	31590
Annual average min temperature[#]	16.5	16.5	10	11	10
Annual average max temperature[#]	25	25	24	23	19
Total number of all fans	8	13	8	10	14
Number of tunnel fans	7	12	6	8	12
Number of duty fans	1	1	2	2	2
Pressure observed @ max tunnel	-35	-50	-35	-20	-40
Max tunnel airspeed (m/s) under baffle at observed tunnel pressure	2.2	2.4	1.7	2.0	1.8
Theoretical tunnel speed @ 25 Pa (m/s)	2.4	3.0	1.8	2.0	2.1
Max theoretical tunnel airflow @ 25Pa (m³/h)	294700	367600	273500	364700	367600

[#]data obtained from the Bureau of Meteorology <http://www.bom.gov.au/climate>

Daily average, minimum and maximum tunnel fan activity and ventilation rate

Tunnel fan activity varied greatly throughout each day and grow-out cycle. Figure 17 is one example of a chart showing the daily average, minimum and maximum fan activity at Farm B (Batch 2). The average daily fan activity generally increased throughout the batch cycle.

This style of chart is useful when considering add-on technologies because it identifies the range of fan activity rate experienced throughout the batch. These charts have been produced for all batches at all farms and are presented in Appendix 4.

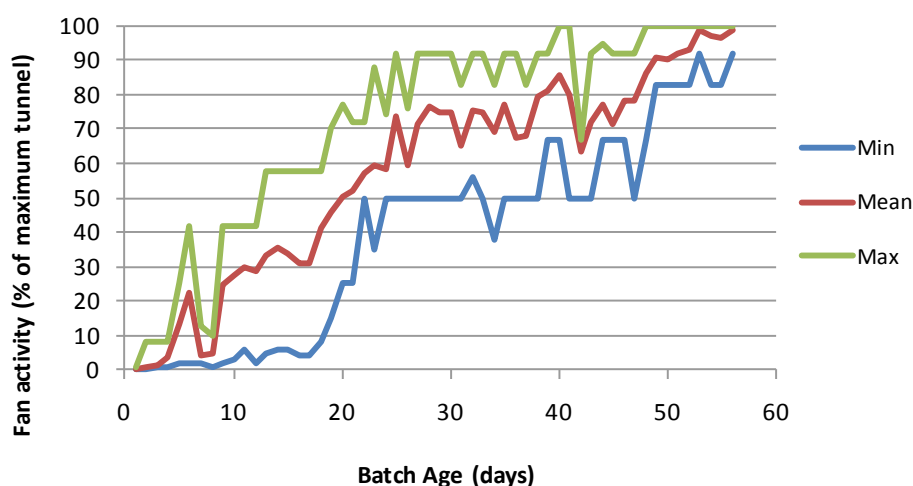


Figure 17 Example of a chart showing daily average, minimum and maximum fan activity during batch 2 at Farm B

Charts displaying the daily average, minimum and maximum ventilation rate have also been produced. An example of one of these charts is presented in Figure 18. These charts are very similar to the fan activity charts, however, they take account of the shed static pressure which will influence the actual ventilation rate. These charts have been produced for all batches at all farms and are presented in Appendix 5.

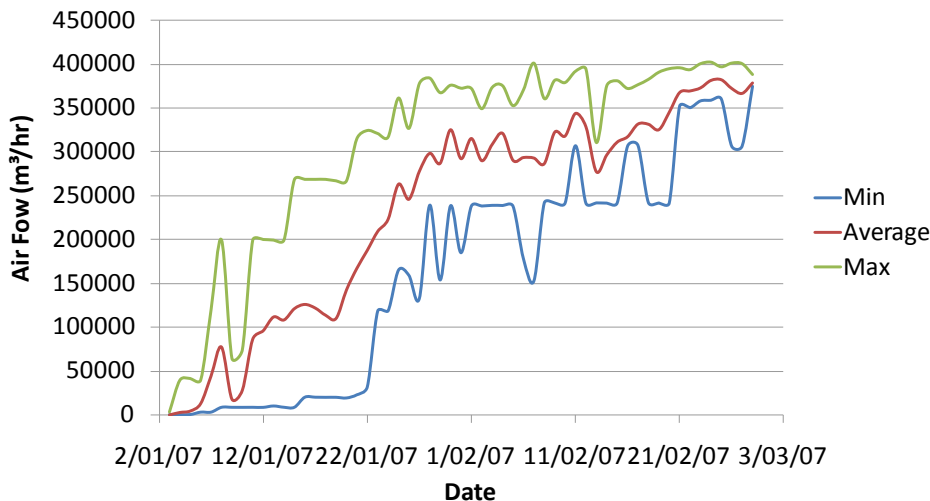


Figure 18 Example of a chart showing daily average, minimum and maximum ventilation rate during batch 2 at Farm B

Tunnel fan activity—daytime, evening and night time

The data used to generate the daily average, minimum and maximum fan activity (as shown in Figure 17) were further processed to display the level of ventilation experienced at certain times of the day. For the purpose of producing these charts, each 24 hour daily period was divided into ‘day’ (Appendix 6), ‘evening’ (Appendix 7) and ‘night’ (Appendix 8).

Day was considered to be from an hour after sunrise to an hour before sunset. Evening was considered to be the period from an hour before sunset to two hours after sunset. Night was considered to be the period from two hours after sunset to an hour after sunrise. (The usual practice for categorising day and night, for the purpose of analysing atmospheric stability, is to consider night to be an hour before sunset to an hour after sunrise, with the balance of the day considered daytime (USEPA 2000USEPA 2000)). We separated the night time period into evening and night due to anecdotal reports of odour complaints being commonly received during the early evening.

This combination of graphs is valuable when considering add-on technologies because it allows assessment of the ventilation rates at particular times of the day. If, for example, shed emissions only needed to be treated to relieve impacts occurring at night, the night-time graph reveals that only a relatively small percentage of the exhaust air needs to be treated—approximately 50% of maximum tunnel fan activity.

Cumulative fan activity

An alternative way to view the data is to plot what percentage of the batch was spent at or below each level of fan activity. These charts have been referred to as cumulative fan activity charts. Figure 19 is an example of a cumulative fan activity chart for Farm B (batch 2). The cumulative fan activity charts for all batches at each farm are presented in Appendix 9.

Level of fan activity was categorised into 5% intervals, and the duration of activity at each of these levels was summed to produce cumulative fan activity charts for each batch of chickens.

To interpret these charts, the vertical y-axis is the percentage of the total batch duration and the horizontal x-axis is the level of fan activity. As an example of how to read these charts, it can be seen in Figure 19 that for 75% of the time during batch 2 (summer), the ventilation rate was less than ~80% of the maximum ventilation rate. (75% is a value that has been arbitrarily chosen to represent a majority of the batch time. Any other value can be equally applied to these charts.)

These cumulative fan activity charts provide a good summary of the amount of time during each batch for which a maximum level of ventilation was achieved. If, for example, a producer planned to install a dust filter to their shed, and wished to filter air for 75% of the time throughout a batch, the filter would need to be designed to have the capacity for ~80% of the maximum fan activity if it were going to be used in summer (at this southeast Queensland farm).

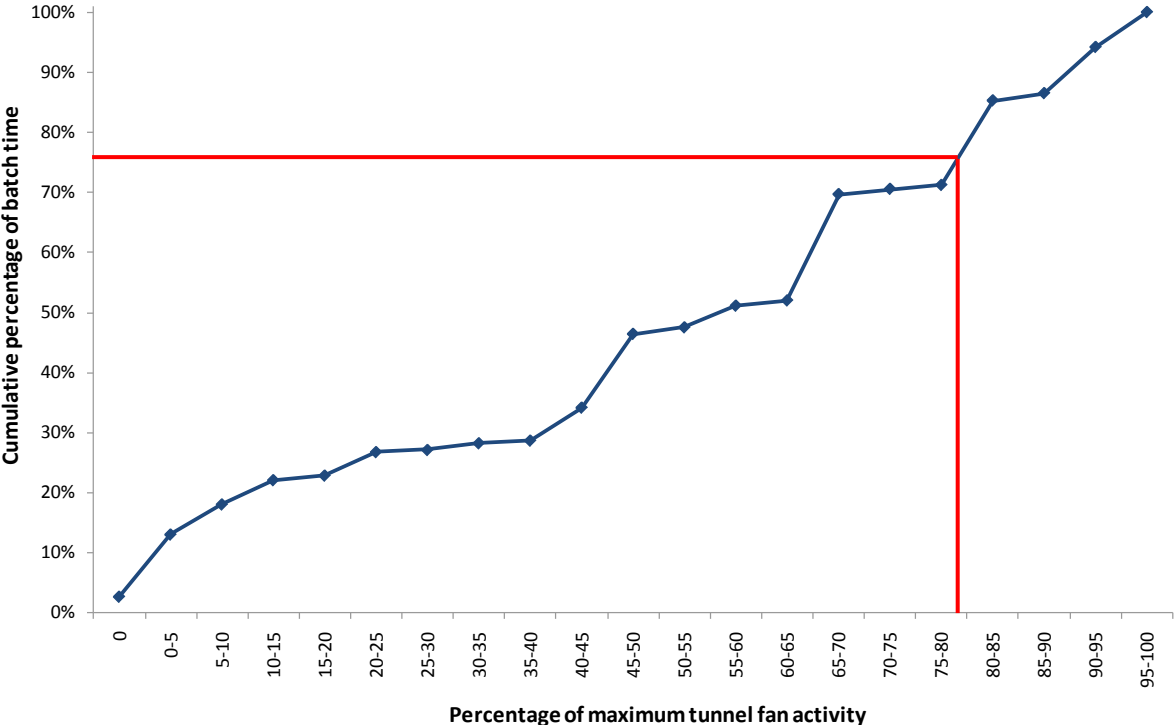


Figure 19 Example of a cumulative fan activity chart which displays the percentage of each batch spent at or below a particular level of ventilation rate

Side/duty fan activity

As with tunnel and total fan activity, side (and/or shed inlet end fan) activity was categorised according to day, evening and night. The side fans need to be considered as a source of odour emission, especially during cooler weather and night time, when they are commonly used. The method of determining day, evening, and night was identical to that used for total and tunnel fan activity. For each of the day, evening and night periods, side fan activity is presented as both a percentage of the period that the fan was active, and a total running time (in hours).

Figure 20 presents side fan activity charts for batch 2 at Farm B. With this batch being grown over summer, use of the side fans in the later stages of the batch is virtually non-existent.

Appendix 10 through to Appendix 12 contain side fan activity charts for all sites and all batches for day time, evening, and night time respectively.

These charts are useful if considering the installation of an add-on technology on the side fans because they display the percentage of the time that side fans are active, and show how often side fans are used and during which periods they are active during each batch and throughout the year.

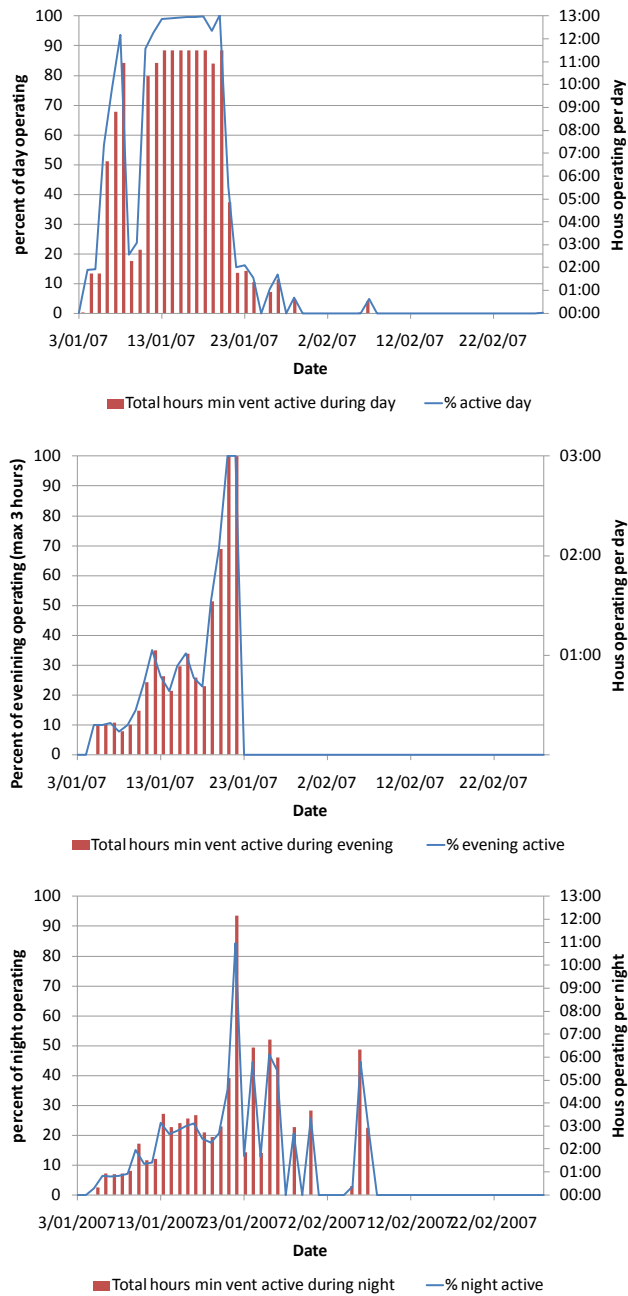


Figure 20 Percentage and sum of side fan activity during the day (top), evening (middle) and night (bottom) (Farm B, batch 2)

Analysis and discussion

Daily, seasonal and batch age trends in ventilation

Ventilation rate fluctuated diurnally, seasonally and throughout each batch cycle. Diurnal and seasonal variation demonstrates that ambient temperature is a dominant factor. Batch cycle variations in ventilation are related to increasing live weight and therefore heat generation within the shed. The combination of these three factors demonstrates that temperature, both ambient and internal, significantly influence ventilation requirements.

Fan activity varied throughout each day. Figure 21 and Figure 22 display fan activity over 24 hour periods during warm and cool weather respectively. In each case, it can be seen that during the night, ventilation activity is at its daily minimum (as indicated in the daily average, maximum and minimum charts in Appendix 4 and Appendix 5). Around sunrise, the fan activity steadily increases until it reaches the daily maximum value, before decreasing again. This general pattern was observed during each batch at all farms.

Fan activity was observed to be different on warm days (see Figure 21) than it was on cooler days (see Figure 22). On warmer days, fan activity increased shortly after sunrise and maintained a high level of ventilation (approaching the daily maximum) until well into the evening (approaching 8:00pm to 9:00pm). On cooler days, however, the fan activity didn't start to increase until a few hours following sunrise and decreased rapidly around sunset. Consequently, an elevated level of ventilation rate occurred for a much shorter portion of the day during cooler weather than it did during warmer weather.

The differences in daily ventilation are further reinforced through the comparison of *day*, *evening* and *night time* fan activity trends (as shown in the example in Appendix 6 for *day*, Appendix 7 for *evening* and Appendix 8 for *night time*). Comparison of the three types of charts reveals that during night, ventilation requirements were significantly less than they were during the day and evening.

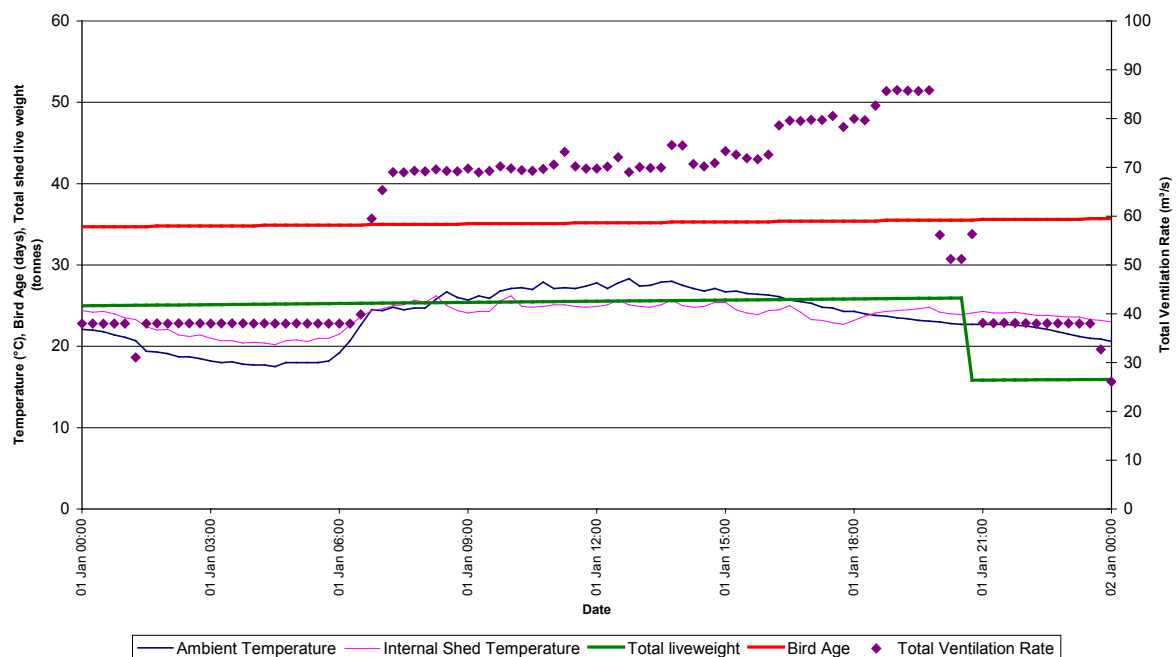


Figure 21 Daily variation in fan activity during warm weather (Farm A, batch 2, batch age 35 days)

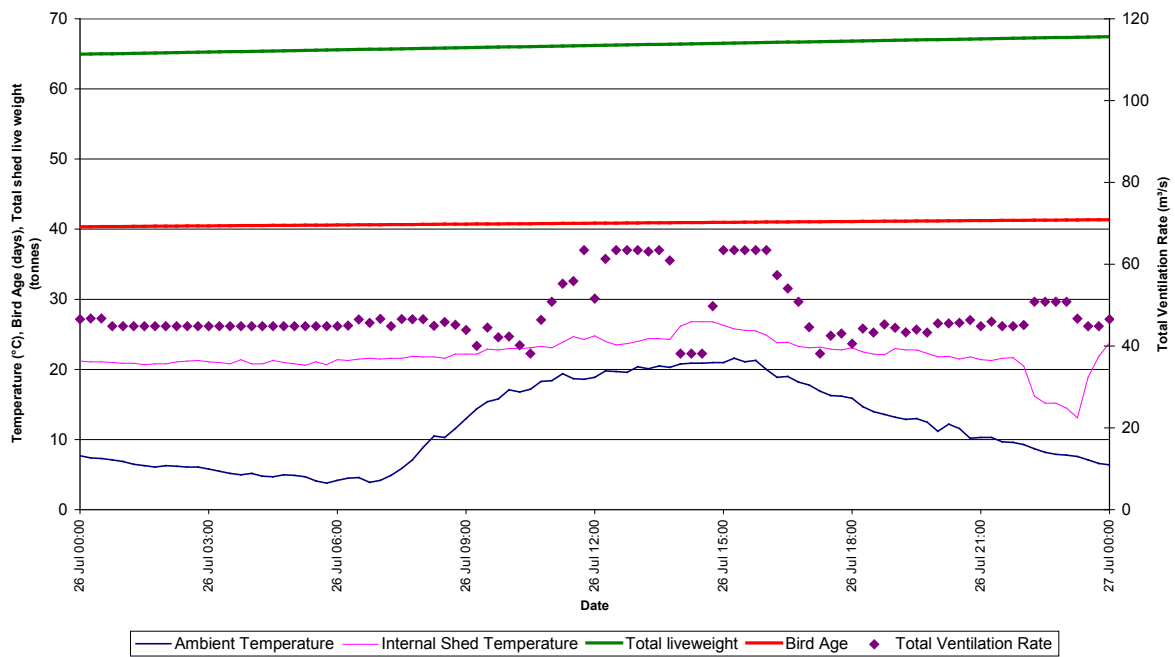


Figure 22 Daily variation in fan activity during cool weather (Farm C, batch 6, batch age 38 days)

Fan activity also varied throughout each batch. Figure 23 displays how the ventilation rate was low at the start of the batch and generally increased throughout the batch. When chickens were harvested around day 32-35, the ventilation rate decreased slightly, but certainly not to the same level as it was around day 19 when the total live weight in the shed was the same. This indicates that ventilation rate was not only related to the total live weight, but also to bird age.

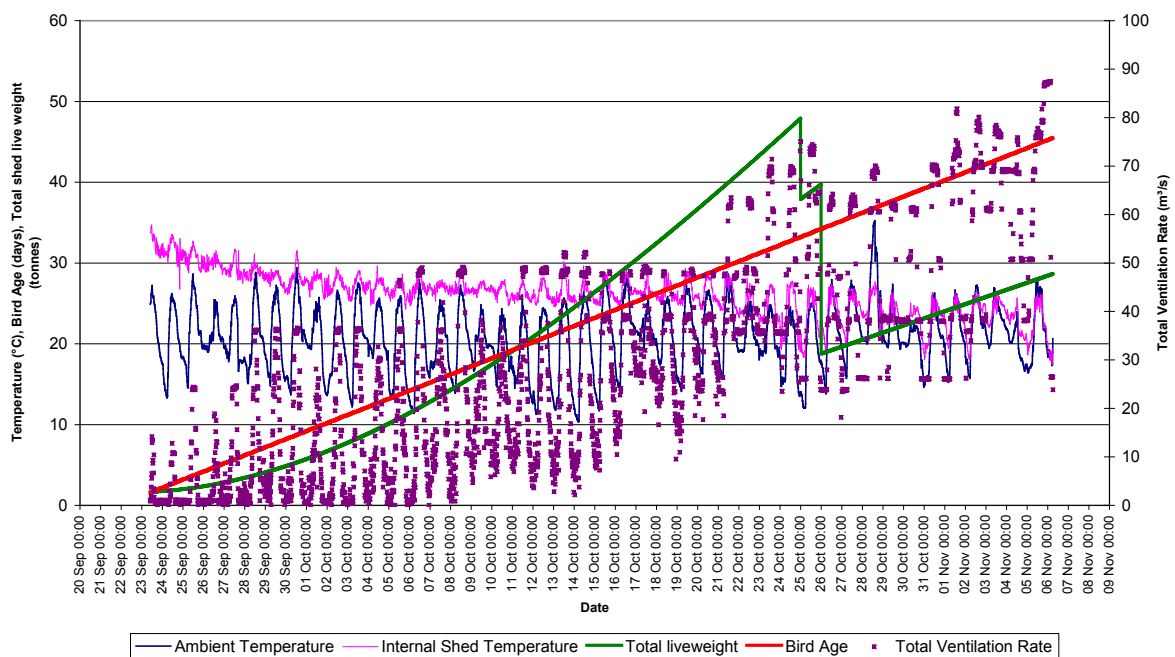


Figure 23 Ventilation rate, total live weight, ambient temperature and internal shed temperature throughout Batch 1 at Farm A.

Ventilation rate was observed to vary depending on season. Figure 24 to Figure 28 display daily average, minimum and maximum fan activity at each farm during a summer batch (*left*) and a winter batch (*right*). In all cases, it can be seen that greater amounts of ventilation were required in summer than in winter.

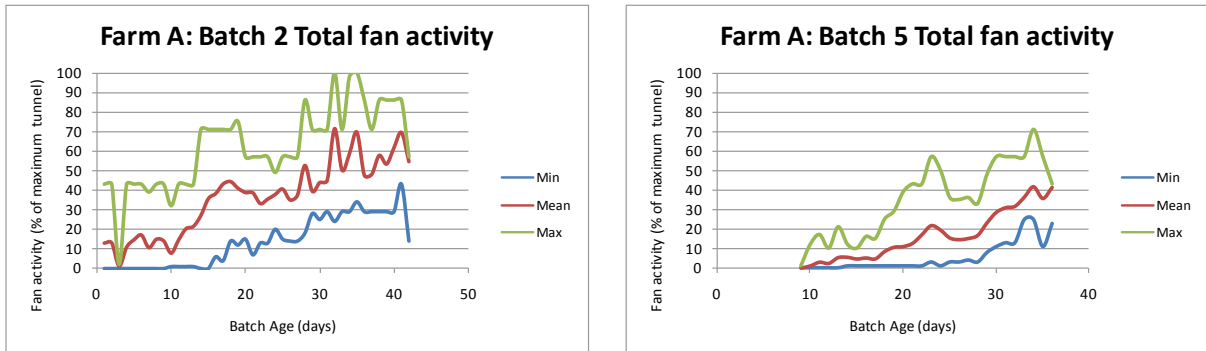


Figure 24 Farm A daily average fan activity during summer (*left*) and winter (*right*) (batches 2 and 5)

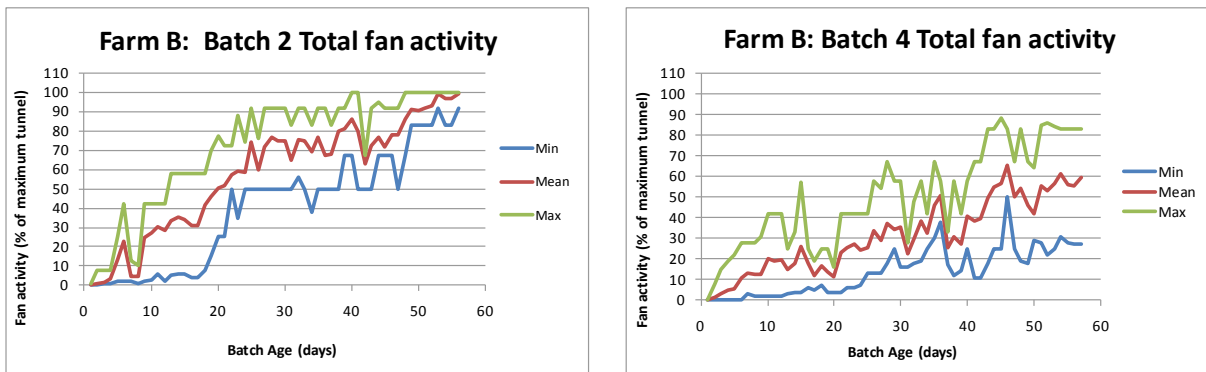


Figure 25 Farm B daily average fan activity during summer (*left*) and winter (*right*) (batches 2 and 4)

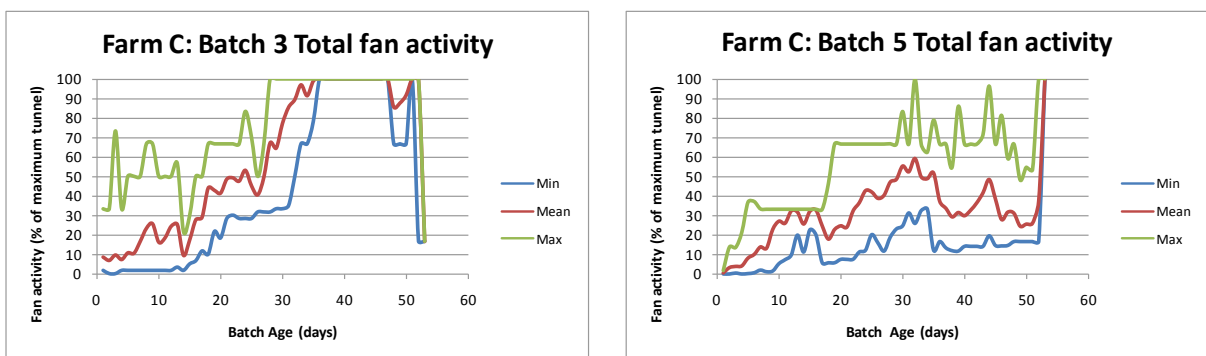


Figure 26 Farm C daily average fan activity during summer (*left*) and winter (*right*) (batches 3 and 5)

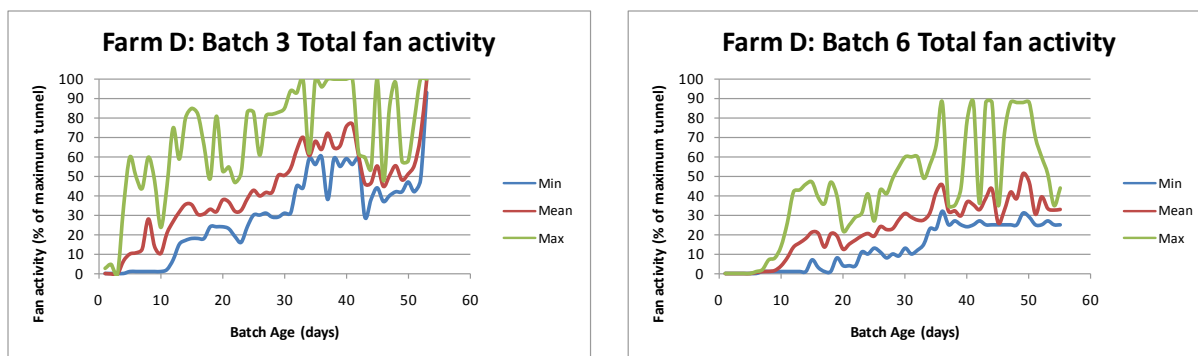


Figure 27 Farm D daily average fan activity during summer (*left*) and winter (*right*) (batches 3 and 6)

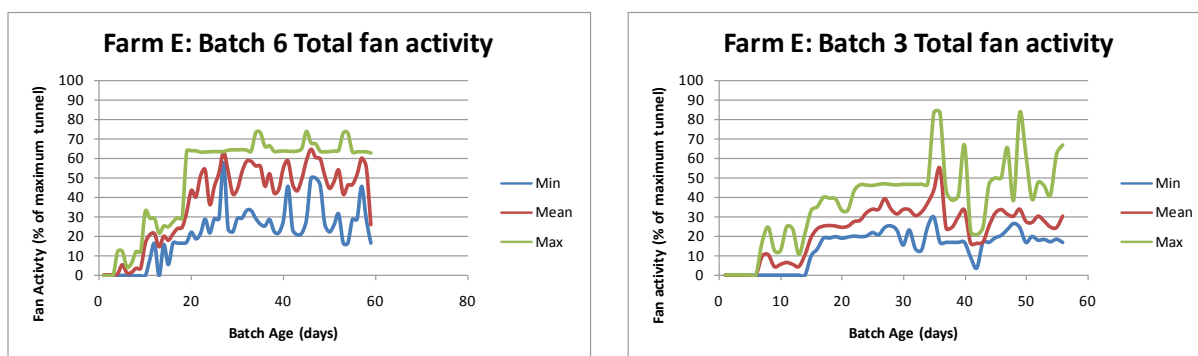


Figure 28 Farm E daily average fan activity during summer (*left*) and winter (*right*) (batches 6 and 3)

Side fan activity during summer and winter: day, evening and night

As with tunnel and total fan activity, side (and/or inlet) fan activity was categorised according to day, evening and night time. Figure 29 to Figure 31 display the side/inlet fan activity during the day time, evening, and night time for both a summer batch (batch 2 and 6) and a winter batch (4 and 3) for Farm B and Farm E, respectively.

The charts for Farm B (see Figure 29 to Figure 31) show that during summer months, side ventilation is quite active in the early weeks of the batch, up until approximately the first collection. After this time, side fan activity is reduced, presumably due to the greater reliance on tunnel ventilation as the total live weight of chickens increases. This trend is seen for all periods of the day during summer months. Conversely, during winter months, side ventilation is quite active for the duration of the batch. Both day and evening activity levels gradually rise as the batch progresses, however, near the end of the batch, ventilation rates decrease and remain low. Night ventilation rates, however, gradually rise and remain high until the batch is completed, indicating a heavy reliance on side ventilation fans for night time periods during winter.

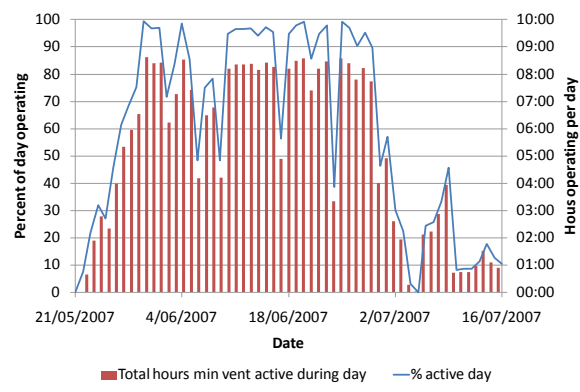
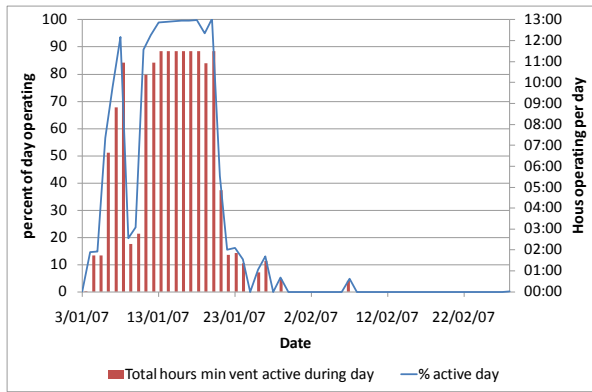


Figure 29 Farm B side fan activity during the *day* time, summer (*left*) and winter (*right*) (batches 2 and 4)

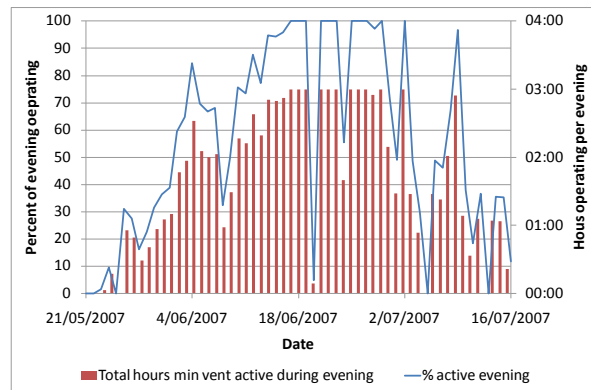
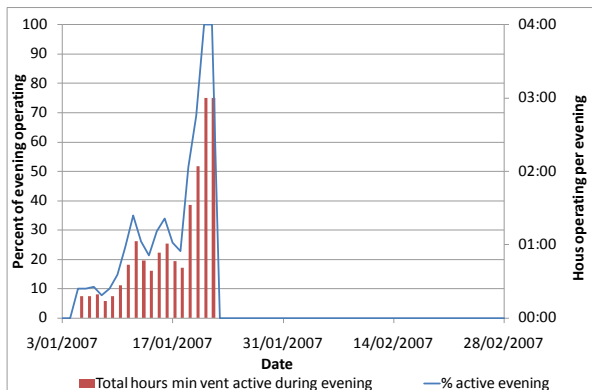


Figure 30 Farm B side fan activity during the *evening*, summer (*left*) and winter (*right*) (batches 2 and 4)

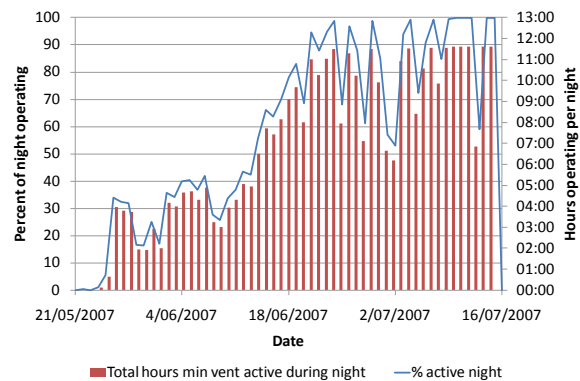
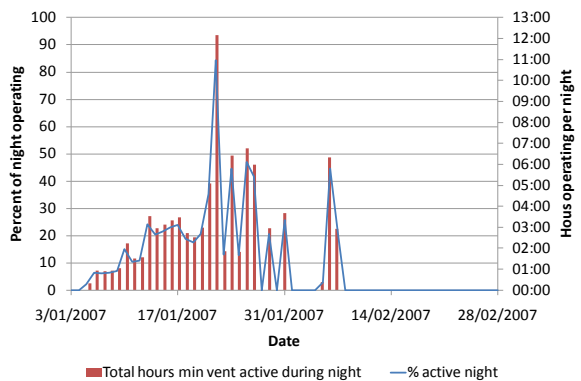


Figure 31 Farm B side fan activity during the *night* time, summer (*left*) and winter (*right*) (batches 2 and 4)

Cumulative fan activity—seasonal differences

Cumulative fan activity charts (see Figure 32 to Figure 36 for Farms A to E) displayed noticeable differences between summer and winter fan activity. During winter, fan activity was less than approximately 35% of the maximum fan activity for 75% of the batch time (with the exception of Farm C where fan activity was less than 45%). In summer, however, fan activity was less than approximately 65% of the maximum fan activity for 75% of the batch time (exceptions with Farm B, 80%, and Farm C, 95%).

The implication of this observation is that the ventilation rate for the majority of the batch is considerably less than the maximum ventilation rate, especially during cooler weather. Consequently, an add-on technology that has the capacity to treat only a portion of the maximum ventilation rate will

be sufficient to treat the exhausted air for a majority of the time. (Consideration will still need to be given to the actual fan activity at times when impacts may be likely.)

The remainder of these charts are provided in Appendix 9.

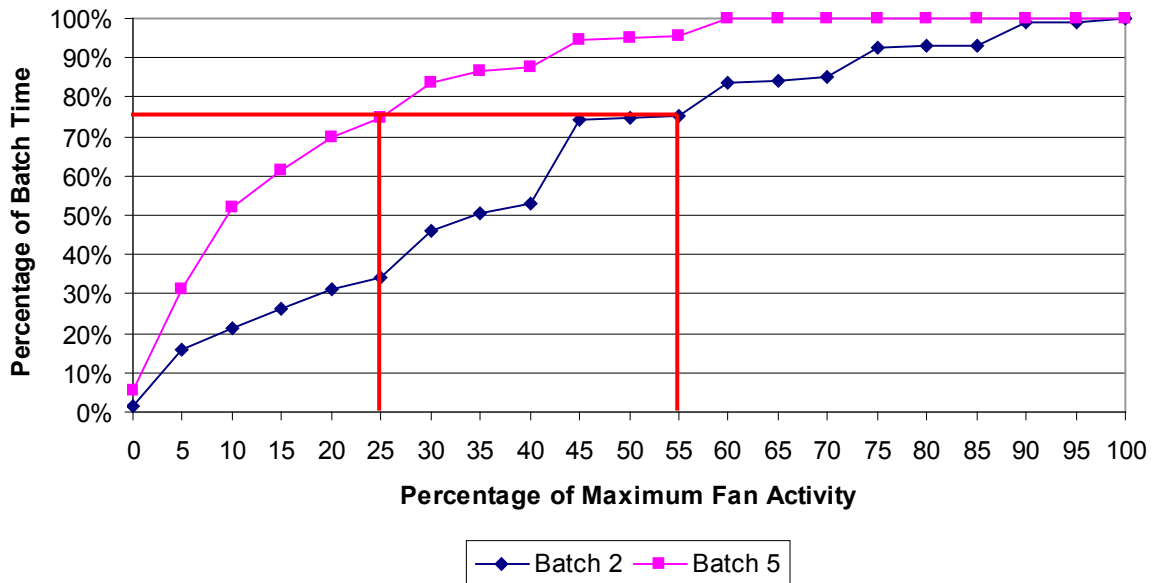


Figure 32 Farm A combined cumulative chart for summer (batch 2) and winter (batch 5)

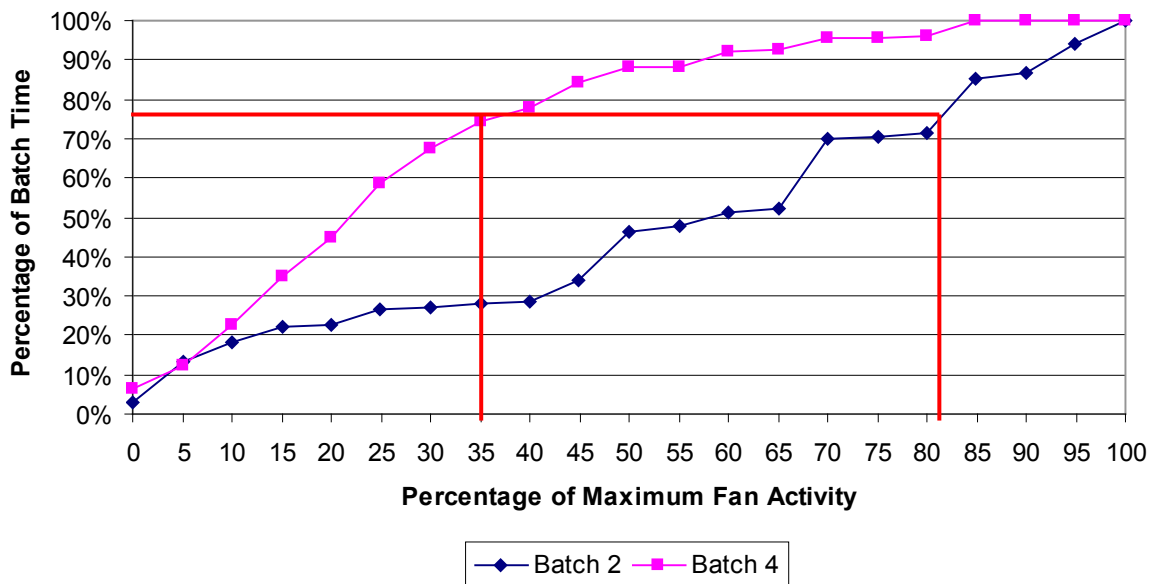


Figure 33 Farm B combined cumulative chart for summer (batch 2) and winter (batch 4)

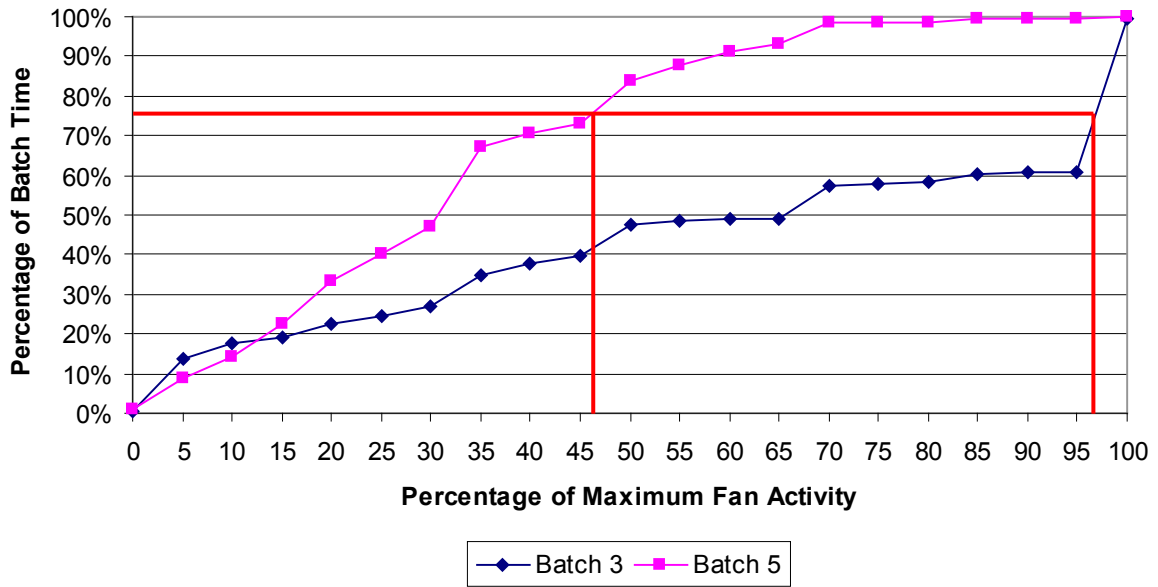


Figure 34 Farm C combined cumulative chart for summer (batch 3) and winter (batch 5)

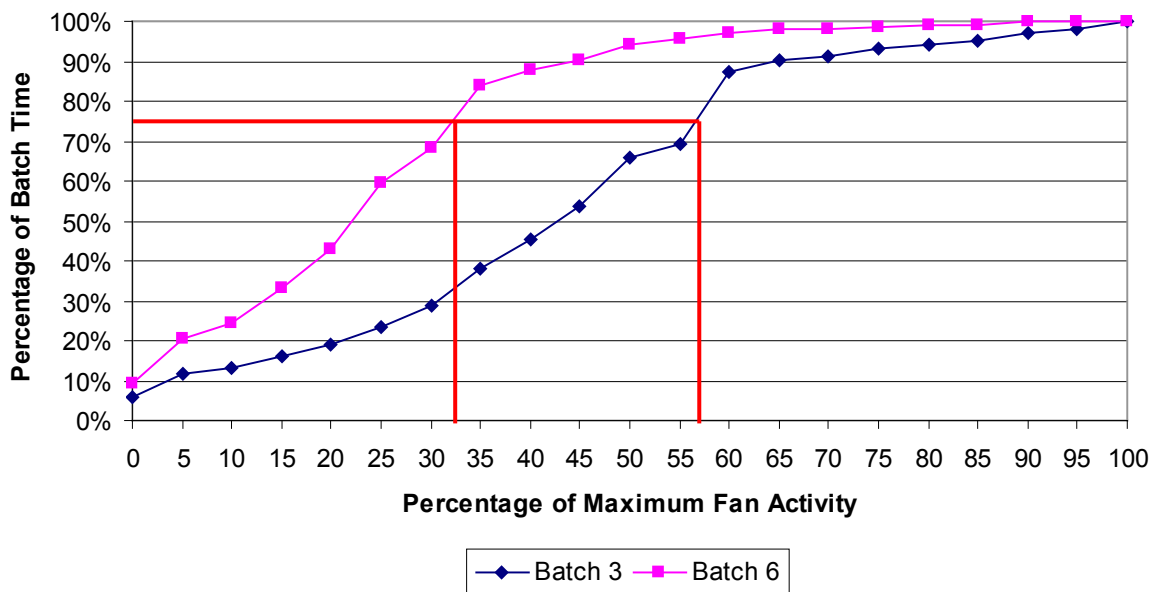


Figure 35 Farm D combined cumulative chart for summer (batch 3) and winter (batch 6)

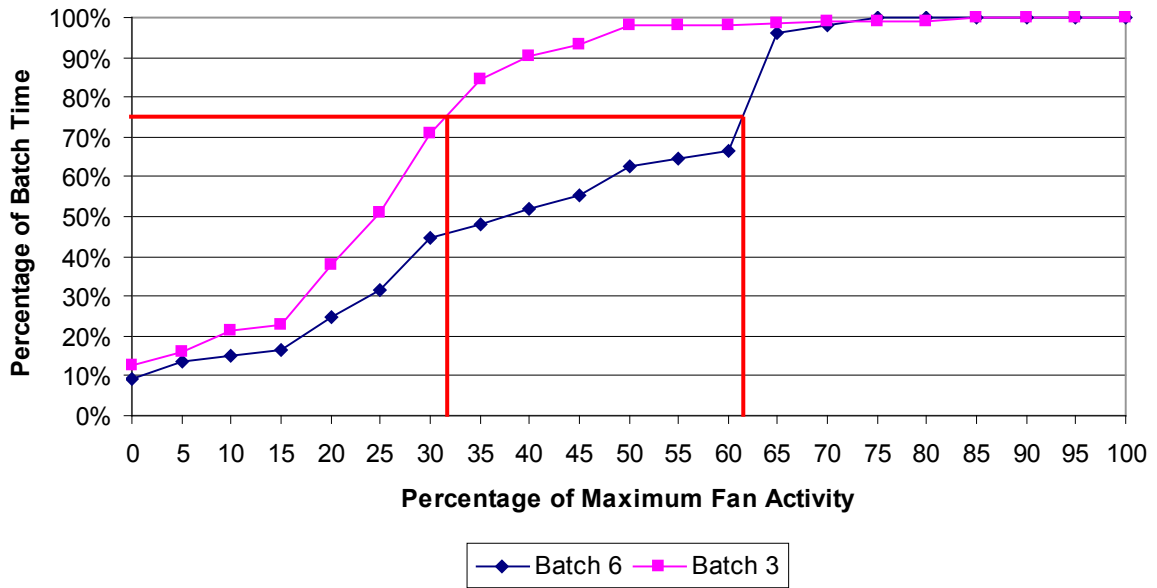


Figure 36 Farm E combined cumulative chart for summer (batch 6) and winter (batch 3)

Influence of static pressure on ventilation rate

Add-on technologies such as filters and scrubbers will increase pressure on the ventilation system. For these types of technologies, it will be important to consider the pressure already experienced by the fans due to the operating pressure of the shed. The additional back pressure produced by the technology will be added to the shed static pressure. Figure 37 to Figure 41 display the relationship between static pressure and fan activity as recorded at Farms A to E, respectively.

For Farm A (see Figure 37) the static pressure of the shed ranged from 0 Pa down to approximately -35 Pa. The narrow tail on the right hand side of the graph was the static pressure during tunnel ventilation. The data to the left of the chart was collected while the shed was in minimum ventilation mode.

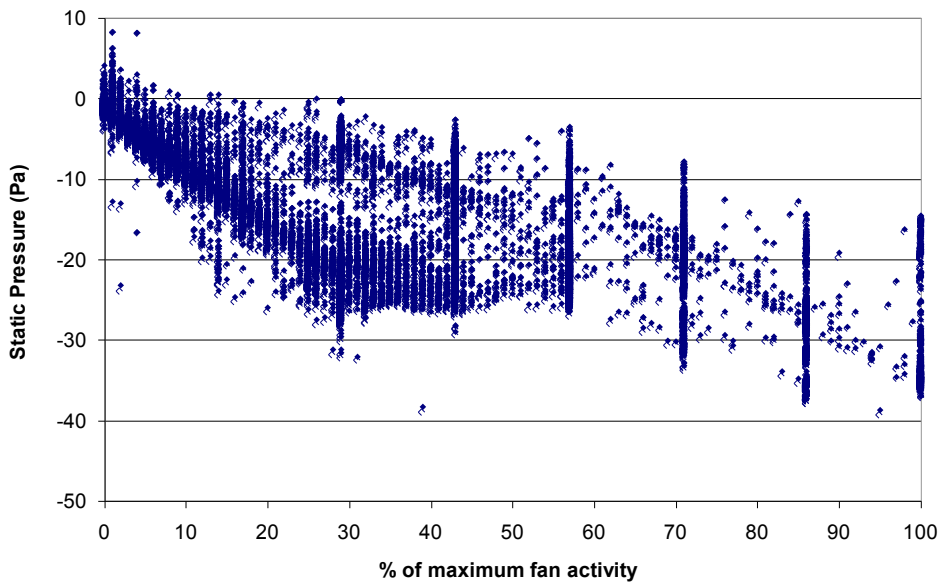


Figure 37 Farm A – Static pressure with different amounts of ventilation

For Farm B (see Figure 38), Static pressure ranged from 0 Pa to -50 Pa while in full tunnel ventilation mode. While ventilation transitioned from minimum ventilation to tunnel ventilation (approximately 25-65% of maximum fan activity), static pressure was reasonably constant at approximately -20 Pa. At the higher end of fan activity, special consideration would be necessary if considering the installation of an add-on technology. Any additional pressure on the ventilation system would cause a significant decrease in fan performance, almost certainly requiring additional fans, replacement of fans with one of higher performance or modifications to the shed to reduce the static pressure.

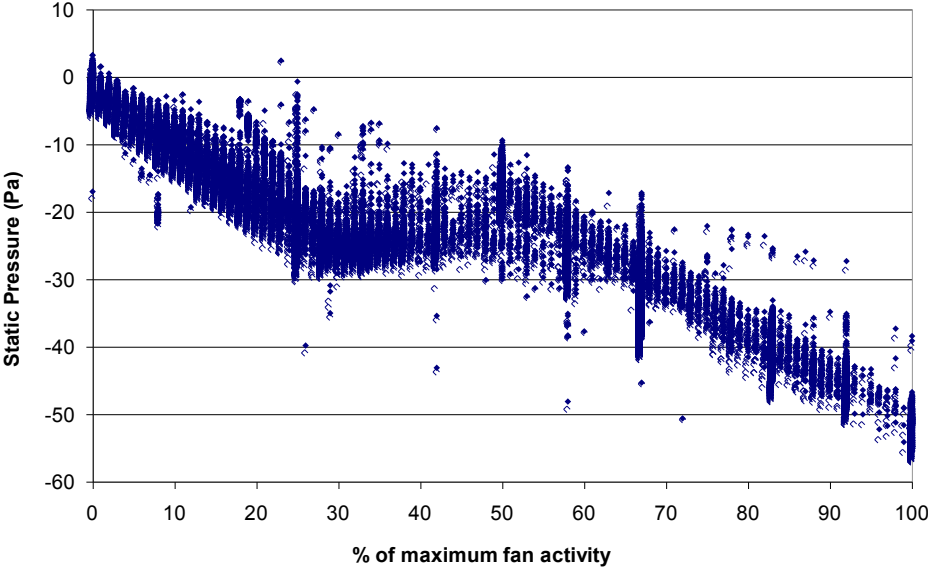


Figure 38 Farm B – Static pressure with different amounts of ventilation

Figure 39 displays the static pressure data collected at Farm C. At this farm, static pressure appeared to increase up to approximately 30% fan activity and then stabilised at approximately -20 Pa. There was considerable variation in the static pressure measured throughout the range of fan activity. This may have been due to the influences of wind on the shed and the pressure sensor.

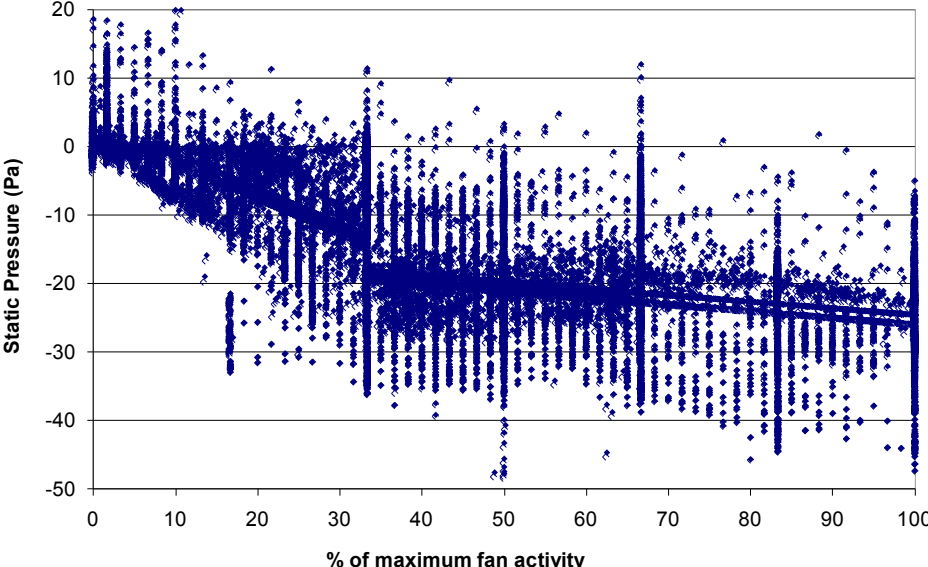


Figure 39 Farm C – Static pressure with different amounts of ventilation

The static pressure measured at Farm D (see Figure 40) showed an interesting trend. During tunnel ventilation, the magnitude of the static pressure increased until it reached approximately -25 Pa (this is the long tail on the right hand side of the figure). The two tails in the centre of the chart extending down to -50 Pa occurred during minimum ventilation. As with Farm B, if installation of an add-on technology was being considered at this farm, it would be necessary to consider the reasons why this high static pressure is occurring and how the ventilation system will be affected if additional pressure is added by the technology.

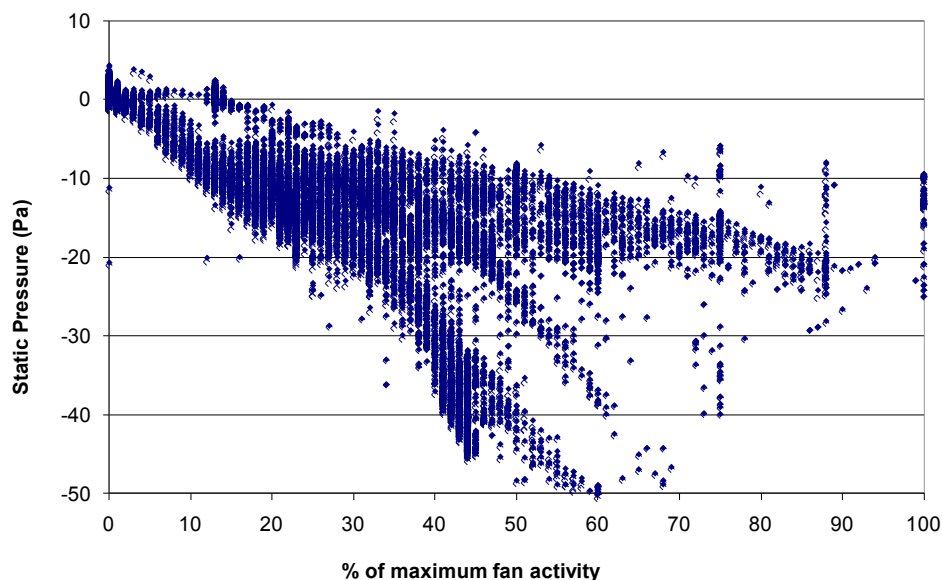


Figure 40 Farm D – Static pressure with different amounts of ventilation

The static pressure recorded at Farm E was highly variable. The majority of the pressure recordings were between -35 Pa and -10 Pa.

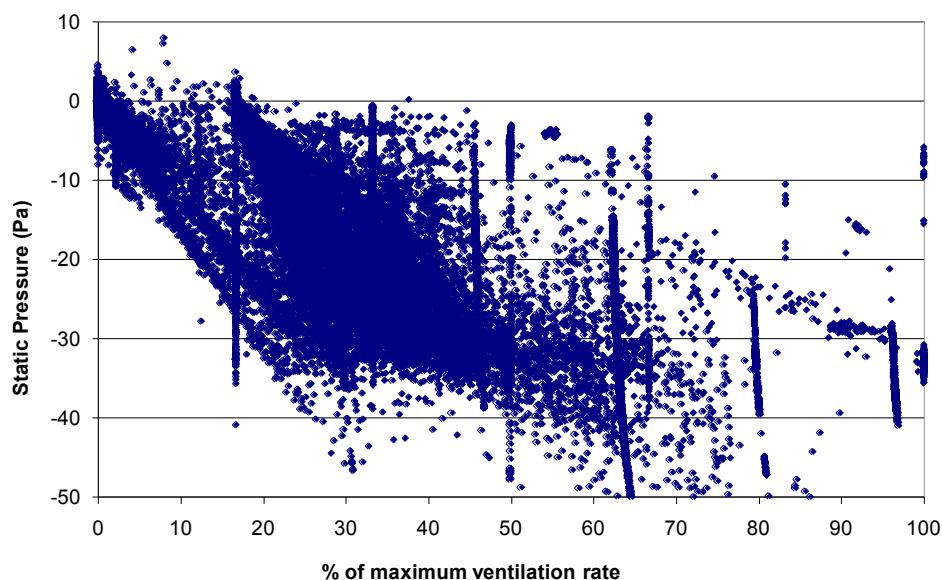


Figure 41 Farm E – Static pressure with different amounts of ventilation

Each farm displayed different trends in static pressure. The static pressure is controlled by the automated ventilation management system, and will be influenced by configuration of the mini-vents and tunnel ventilation inlets (and cool pads). The importance of this information is to demonstrate that as the amount of ventilation increases, so does the static pressure. If an add-on technology such as a filter or biofilter is to be installed, it will be crucial to consider the influence of this device and the shed

static pressure on the ventilation system. If static pressure increases to the point where ventilation performance is significantly decreased, additional fans may need to be installed, the fans may need to be replaced by more powerful ones or the shed inlets may need to be re-designed in order to reduce the static pressure on the fans.

Models for estimating/predicting fan activity

Three fan activity prediction models were developed for each of the monitoring farms (see Equation 10, Equation 11 and Equation 12). These were found to have good correlation to the hourly average fan activity data that was collected. Each model uses slightly different input variables, and therefore model selection will depend on what data is available.

Fan Activity Prediction Model 1

$$\text{Fan activity} = A \times \text{Bird age} + B \times \text{Target Temperature} + C \times \text{Ambient Temperature} + D \times \text{Ambient Temperature}^2 + E \times \text{Ambient Temperature} \times \text{Bird Age} + F \quad \text{Equation 10}$$

Where: *Fan activity* is the percentage of maximum tunnel fan activity (%)
A, B, C, D, E and *F* are coefficients
Bird age is in days
Target Temperature is in °C (see Equation 3 for Farm A; and Equation 4 for all other farms)
Ambient Temperature is in °C

Table 4 Coefficients and R² for Fan Activity Prediction Model 1 (Equation 10)

	Farm A	Farm B	Farm C	Farm D	Farm E
<i>A</i>	0.927	0.448	-1.365	-0.318	-1.544
<i>B</i>	0.675	-2.569	-8.282	-4.84	-7.863
<i>C</i>	-2.185	2.986	1.877	1.221	0.457
<i>D</i>	0.1007	-0.01229	-0.01731	0.0172	0.0135
<i>E</i>	0.04623	0.02273	0.04759	0.00105	0.05163
<i>F</i>	-25.3	17.4	223.4	127.7	227.6
Adjusted R²	85.2	89.2	82.6	66.7	74.3

Fan Activity Prediction Model 2

$$\text{Fan activity} = A \times \text{Total Live Weight} + B \times \text{Target Temperature} + C \times \text{Ambient Temperature} + D \times \text{Ambient Temperature}^2 + E \times \text{Ambient Temperature} \times \text{Total Live Weight} + F \quad \text{Equation 11}$$

Where: *Fan activity* is the percentage of maximum tunnel fan activity (%)
A, B, C, D, E and *F* are coefficients
Total Live Weight is the total mass of birds in the shed, expressed in kg
Target Temperature is in °C (see Equation 3 for Farm A; and Equation 4 for all other farms)
Ambient Temperature is in °C

Table 5 Coefficients and R² for Fan Activity Prediction Model 2 (Equation 11)

	Farm A	Farm B	Farm C	Farm D	Farm E
<i>A</i>	0.000156	-0.0002637	-0.000466	-0.000286	-0.0007203
<i>B</i>	-3.458	-6.015	-4.902	-4.874	-3.077
<i>C</i>	-0.69	3.279	2.16	0.759	0.053
<i>D</i>	0.076	-0.01793	-0.02378	0.0246	0.00634
<i>E</i>	0.00002512	0.00002076	0.0000417	0.00000424	0.00006222
<i>F</i>	75.6	116.85	117.8	134	93.23
Adjusted R²	77.9	87.5	82.9	67.2	76.6

Fan Activity Prediction Model 3

$$\text{Fan activity} = A \times \text{Solar Radiation} + B \times \text{Total Live Weight} + C \times \text{Individual Bird Weight} + D \times \text{Target Temperature} + E \times \text{Ambient Temperature} + F \quad \text{Equation 12}$$

Where: *Fan activity* is the percentage of maximum tunnel fan activity (%)
A, B, C, D, E and *F* are coefficients
Solar Radiation is the total solar radiation in W/m²
Total Live Weight is the total mass of birds in the shed, expressed in kg
Individual Bird Mass is the mass of an individual bird in grams
Target Temperature is in °C (see Equation 1 for Farm A; and Equation 2 for all other farms)
Ambient Temperature is in °C

Table 6 Coefficients and R² for Fan Activity Prediction Model 3 (Equation 12)

	Farm A	Farm B	Farm C	Farm D	Farm E
<i>A</i>	0.01195	-0.00681	0.00189	-0.00257	0.00617
<i>B</i>	0.0003724	0.0002181	0.000312	-0.0002117	0.0000782
<i>C</i>	0.0208	0.009694	-0.00572	-0.00532	-0.0079
<i>D</i>	-0.34	-2.882	-6.993	-6.463	-6.734
<i>E</i>	2.343	3.399	2.598	1.879	2.396
<i>F</i>	-39.41	16.42	156.9	160.3	168.6
Adjusted R²	84.4	89.1	80.5	68.0	72.1

Following application of the above models, any value less than zero (0) should be set to zero and any value greater than 100% should be set to 100%.

Figure 42 displays the modelled tunnel fan activity compared to measured values at Farm B (as an example). It can be seen that the fit of modelled to measured data is reasonably good (reflecting the adjusted R² = 87.5–89.2).

Another way to inspect the models is to look at them on a time series compared to measured fan activity. Figure 43, Figure 44 and Figure 45 show the model predicted fan activity and actual measured fan activity for Farm B (as an example) for the entire data set, batch 2, and days 31–41 of batch 2 respectively. These figures demonstrate how the the model accounts for seasonal, batch and diurnal changes in production and weather conditions.

Application of these models to other broiler sheds should be undertaken with caution as these models have not been tested at other sites. Each of these sheds (Farms A to E) was in a different geographic/climatic location, and had different batch length, bird capacity, shed design, ventilation rate, shed air speed and were managed differently by individual growers. If applying these models to other sheds, care should be taken to match the shed in question to one of the monitoring sheds as much as possible, but variation between modelled and actual fan activity should be expected.

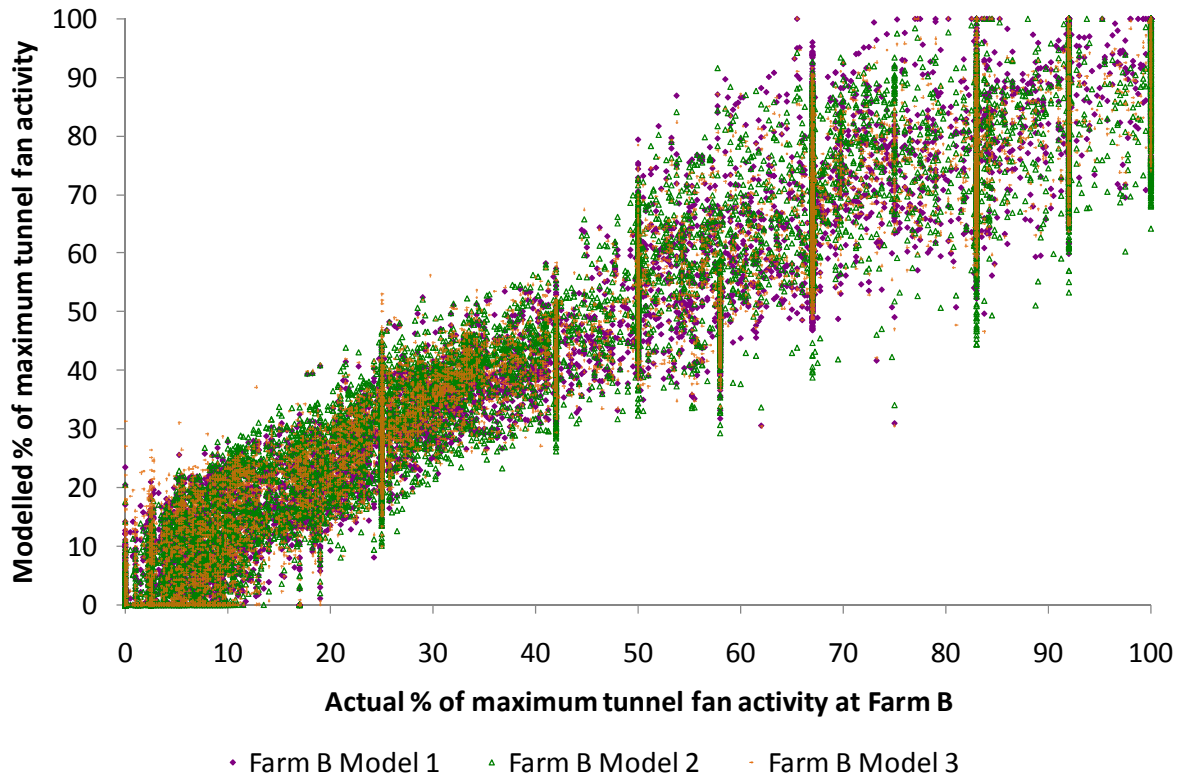


Figure 42 Chart comparing modelled vs actual tunnel fan activity for Farm B

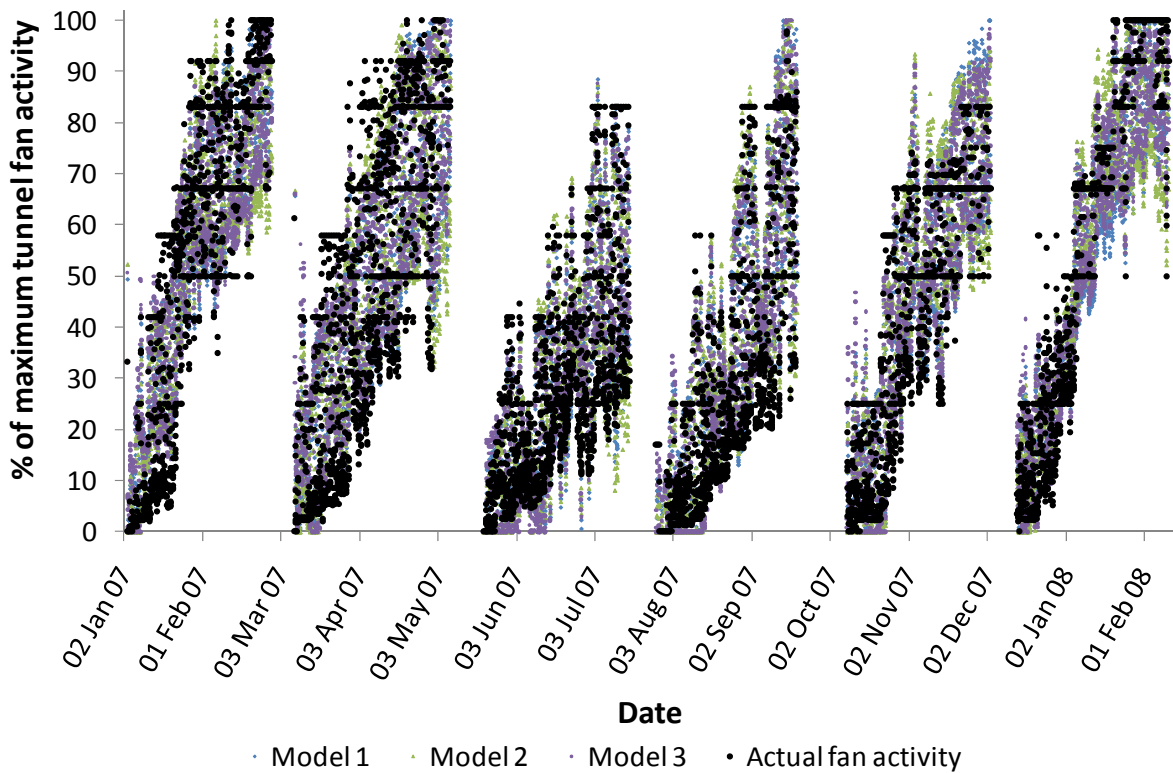


Figure 43 Modelled fan activity vs actual fan activity at Farm B (entire hourly average data series)

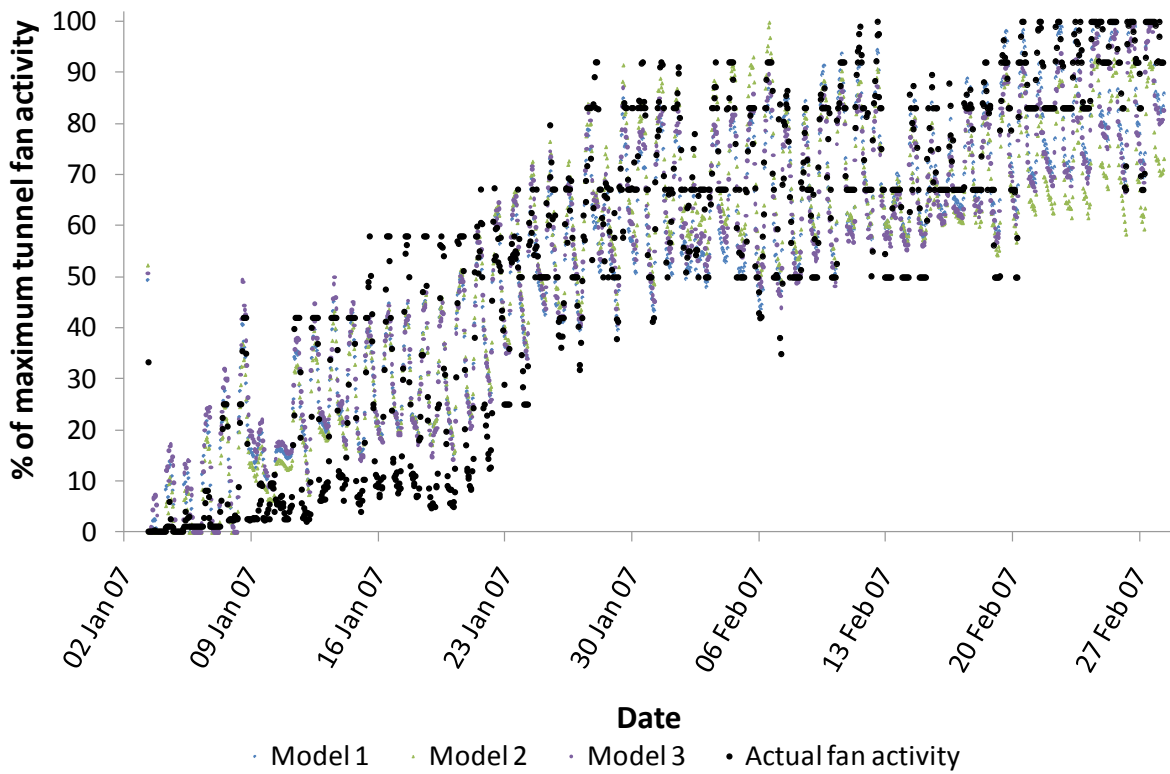


Figure 44 Modelled fan activity vs actual fan activity at Farm B (batch 2)

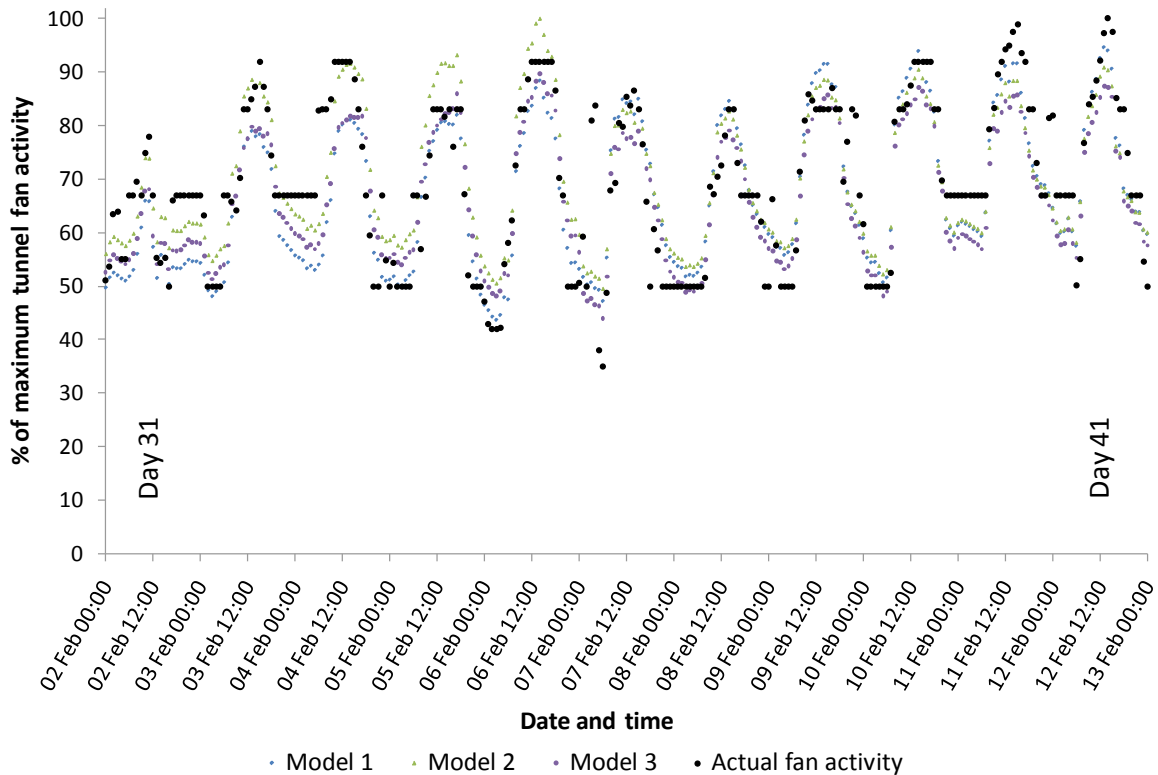


Figure 45 Modelled fan activity vs actual fan activity at Farm B (days 31–41 of batch 2)

Conclusions

Methods and collection of data

- The adoption of technologies to control odour and dust emissions from meat chicken farms will be influenced by shed ventilation rates. This study has collected data that is necessary to improve understanding of ventilation rates on meat chicken farms to assist with the design and adoption of these emission control technologies.
- Equipment was developed to monitor fan activity and relevant environmental conditions. Fan activity data was combined with manufacturer's fan performance data and shed static pressure to estimate actual ventilation rates. Ambient temperature, ambient humidity, solar radiation, internal shed temperature and mini-vent position were monitored at each farm throughout the study. Chicken placement and pickup data was collected from the producer.
- Fan activity and environmental data were collected at five meat chicken farms from August 2006 to February 2008. At least 12 months of data was collected at each farm. These farms were located in south-east Queensland, central and northern tablelands of New South Wales, and in southern Victoria.
- Data was recorded every 15 minutes, leading to the collection of approximately 10 million pieces of data.
- Data has been analysed and presented graphically to enable readers to better understand seasonal, batch and diurnal variability of fan activity at tunnel ventilated broiler sheds.

Conclusions from data analysis

- Ventilation rate in meat chicken sheds is highly variable according to ambient temperature (influenced by season, location and time of day) and batch cycle trends.
 - Fan activity was lower in the cooler periods of the year.
 - Fan activity was lower at night compared to during the day and early evening.
 - Fan activity increased as the mass of chickens increased in the shed. When chickens were removed from the shed during partial cleanouts, ventilation requirements reduced slightly.
 - Side fan activity (as opposed to tunnel fan activity) varied throughout the batch and due to seasonal and climatic influences. These fans need to be considered when designing an add-on technology.
- The data that has been collected will allow potential users of odour and dust control technologies to identify the expected level of fan activity at the times when odour impacts are occurring in their situation. This will enable the technology to be customised to suit their particular situation.
- If an emission treatment device was only required during the cooler months or at night, it would only need to have capacity for a small percentage of the maximum shed ventilation rate.
- Fan activity prediction models have been developed and these compare well with measured fan activity ($R^2 = 66.7\text{--}89.2$).

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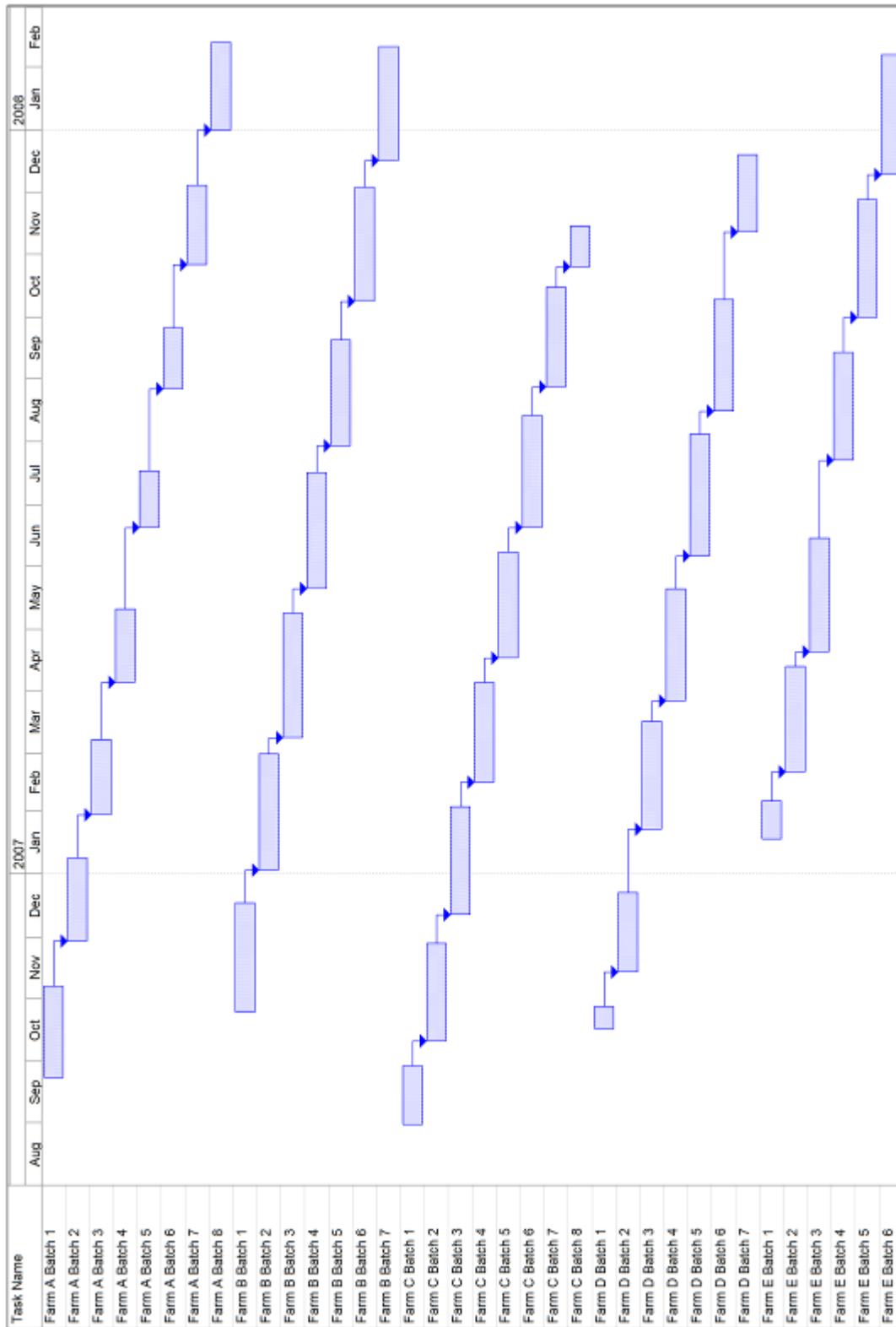
Appendices

Appendix 1 Sensor specifications

Specifications of the sensors used for monitoring fan activity and environmental conditions

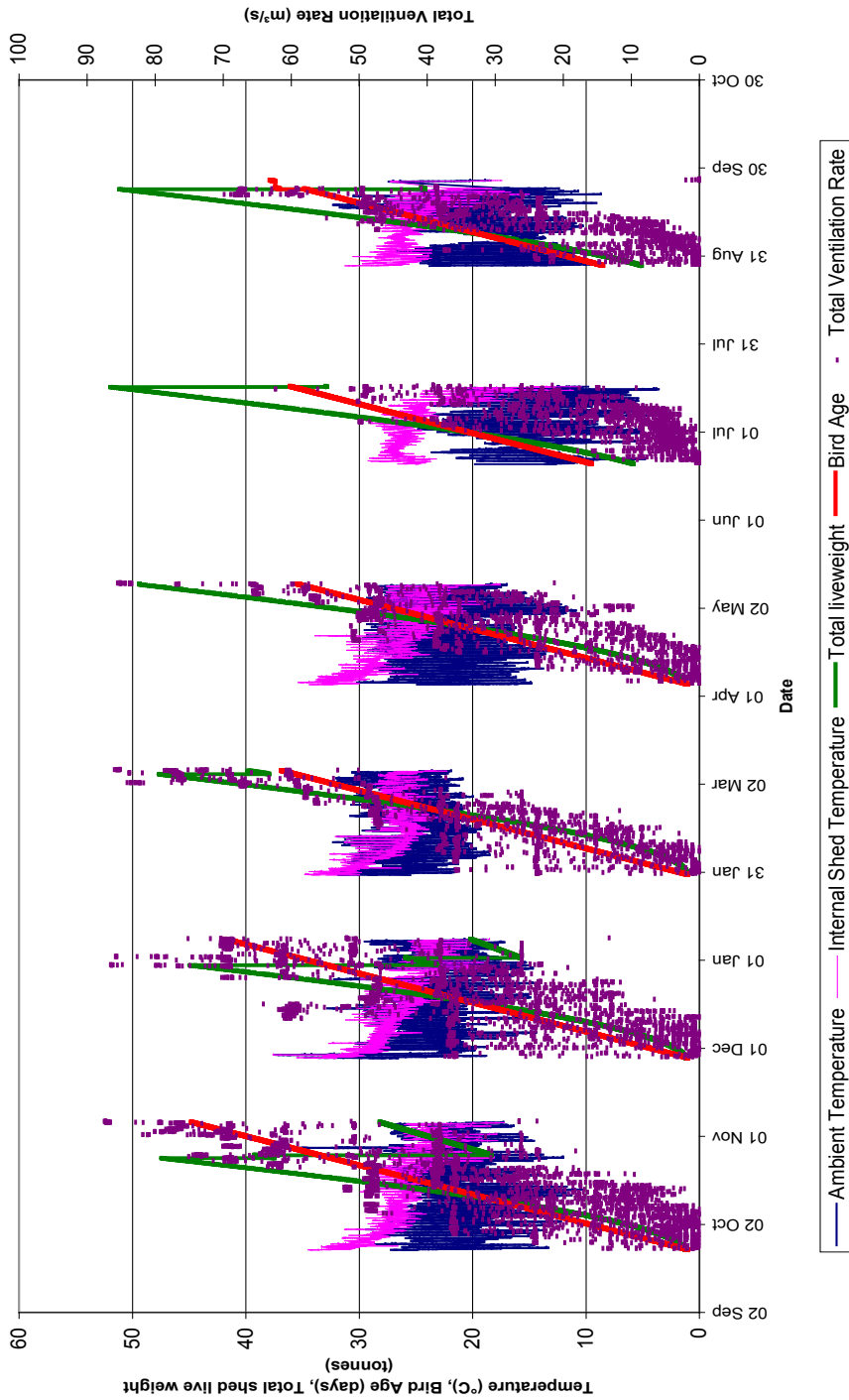
Measurement parameter	Sensor type and description	Specifications
Fan activity	Mercury Tilt Switch	Glass encapsulated mercury, plastic case; single pole single throw (SPST), (commonly used in home security systems)
Internal Temperature	PT100 Platinum RTD, PTFE sheathed, 4 wire, thin film element Labfacility Ltd	Range: -50°C to +550°C Operating range -50°C to 500°C Thermal response: 0.1 s Stability: ±0.05% Output: voltage
Hall effect sensor	Model SS496A1, miniature ratiometric linear, solid state Hall effect sensor, Honeywell International USA	Supply voltage: 4.5–10.5 VDC (V_s) Null voltage: 2.5 VDC Typical output span: 0.2 to -0.2 V_s
Ambient temperature	Vaisala Intercap [®] HMP50Y (Humitter 50Y)	Measuring range: -10°C to +60°C Accuracy: ±0.6°C Sensor: PT1000 Output: 0 to 2.5 V DC
Ambient humidity	Vaisala Intercap [®] HMP50Y (Humitter 50Y)	Measuring range: 0–98%RH Accuracy: ±3% (0–90% RH range) ±5% (90–98% RH range) Temperature dependence: ±0.7 to 1%RH over measuring range as temperature changes from -10°C to +60°C Output: 0 to 2.5 V D C
Solar radiation	Li-Cor, Inc. LI200X Pyranometer	Stability: <±2% over 1 year Response time: 10 μs Accuracy: ±3% Sensitivity: 0.2 kW/m ² /mV Light spectrum band: 400 to 1100 nm Output: voltage
Shed static pressure	Model 264 ultra low differential pressure transducer (P/N 2641R25WB11T1C) Setra Systems Inc, USA	Excitation: 9–30 VDC Output: Current 4–20 mA Accuracy: ±1% FS Operating temp range: -18°C to +65°C Operating range: -63.5 to +63.5 Pa

Appendix 2 Gantt chart showing when data was collected at each farm

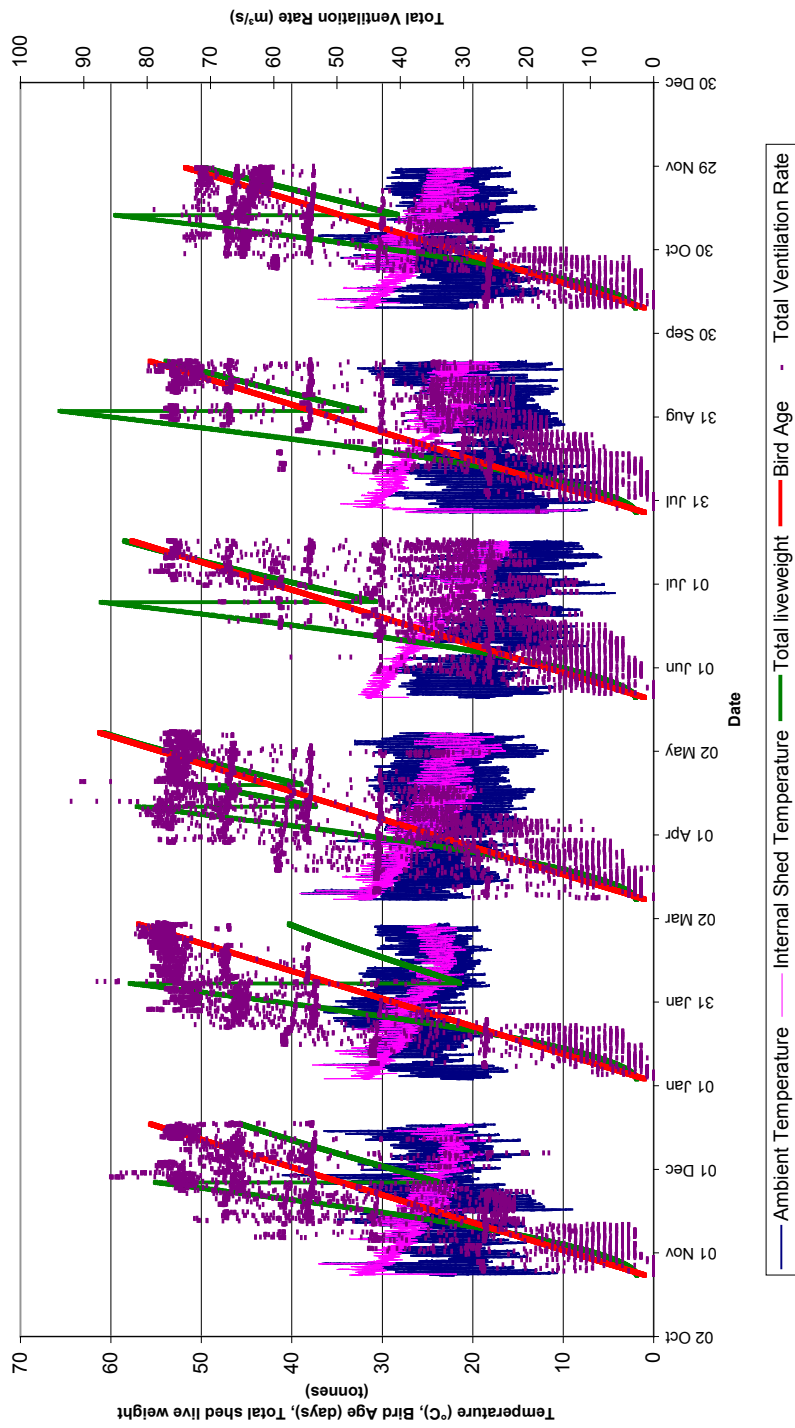


Appendix 3 Charts showing temperature and ventilation data collected at each farm

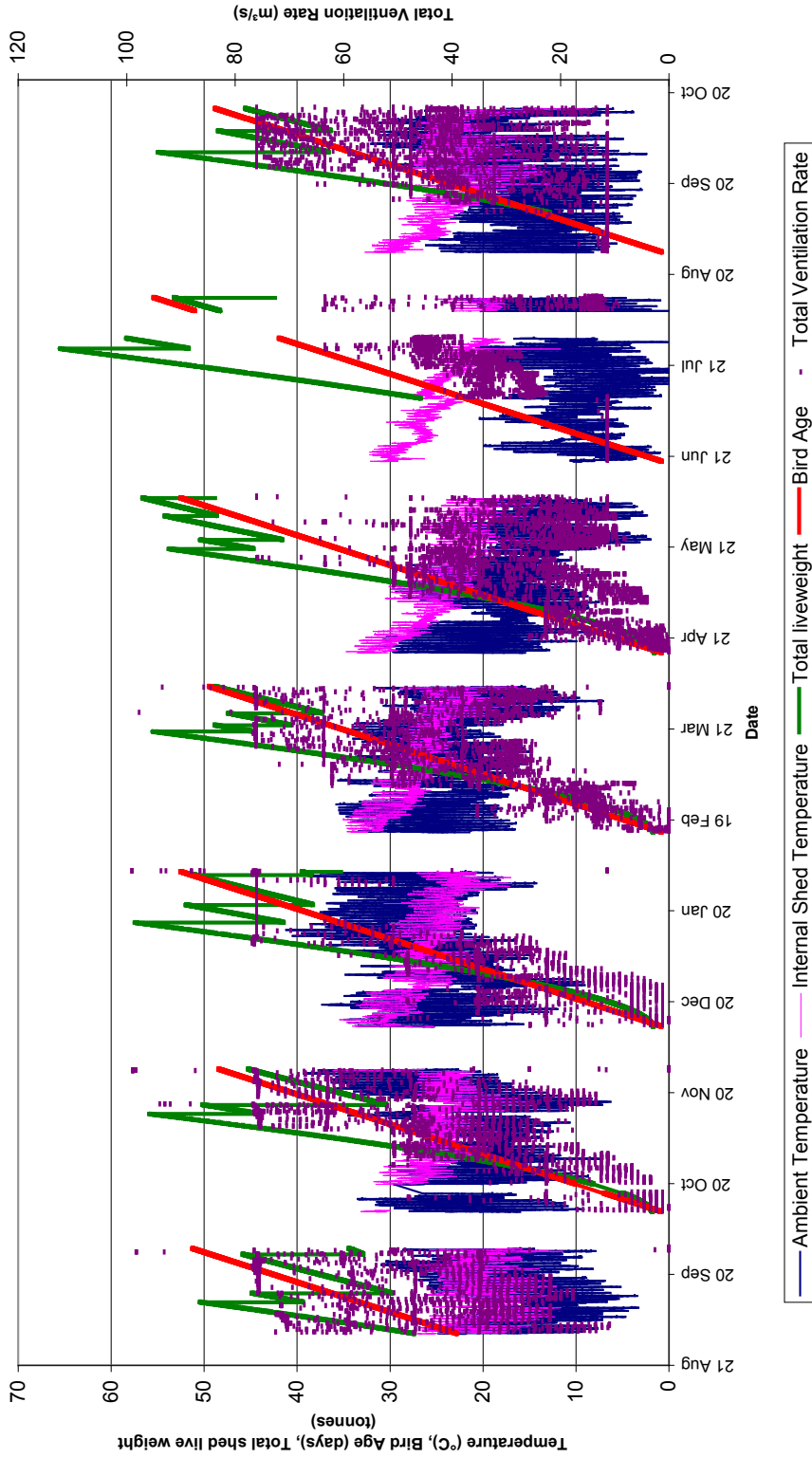
Farm A - Data collected



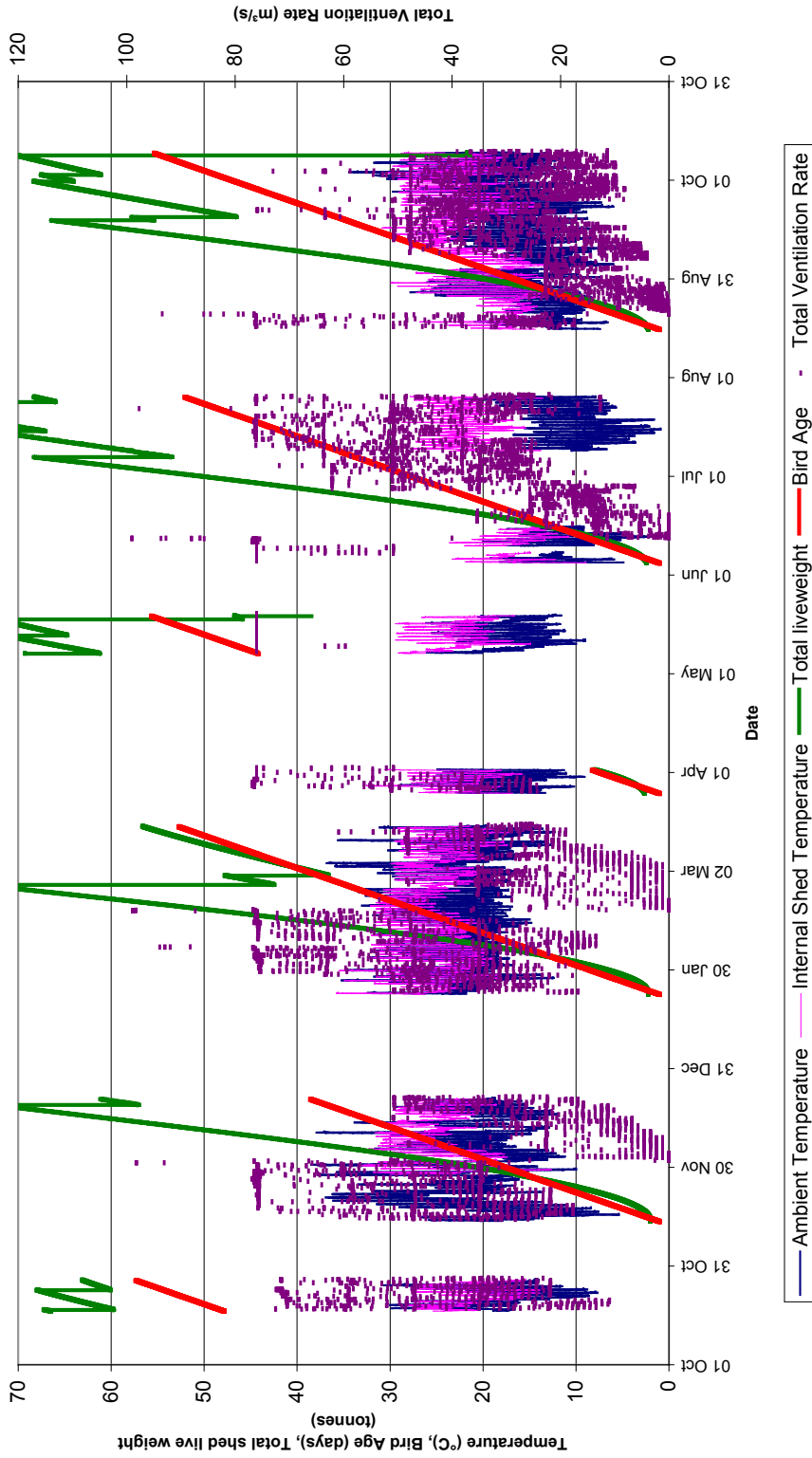
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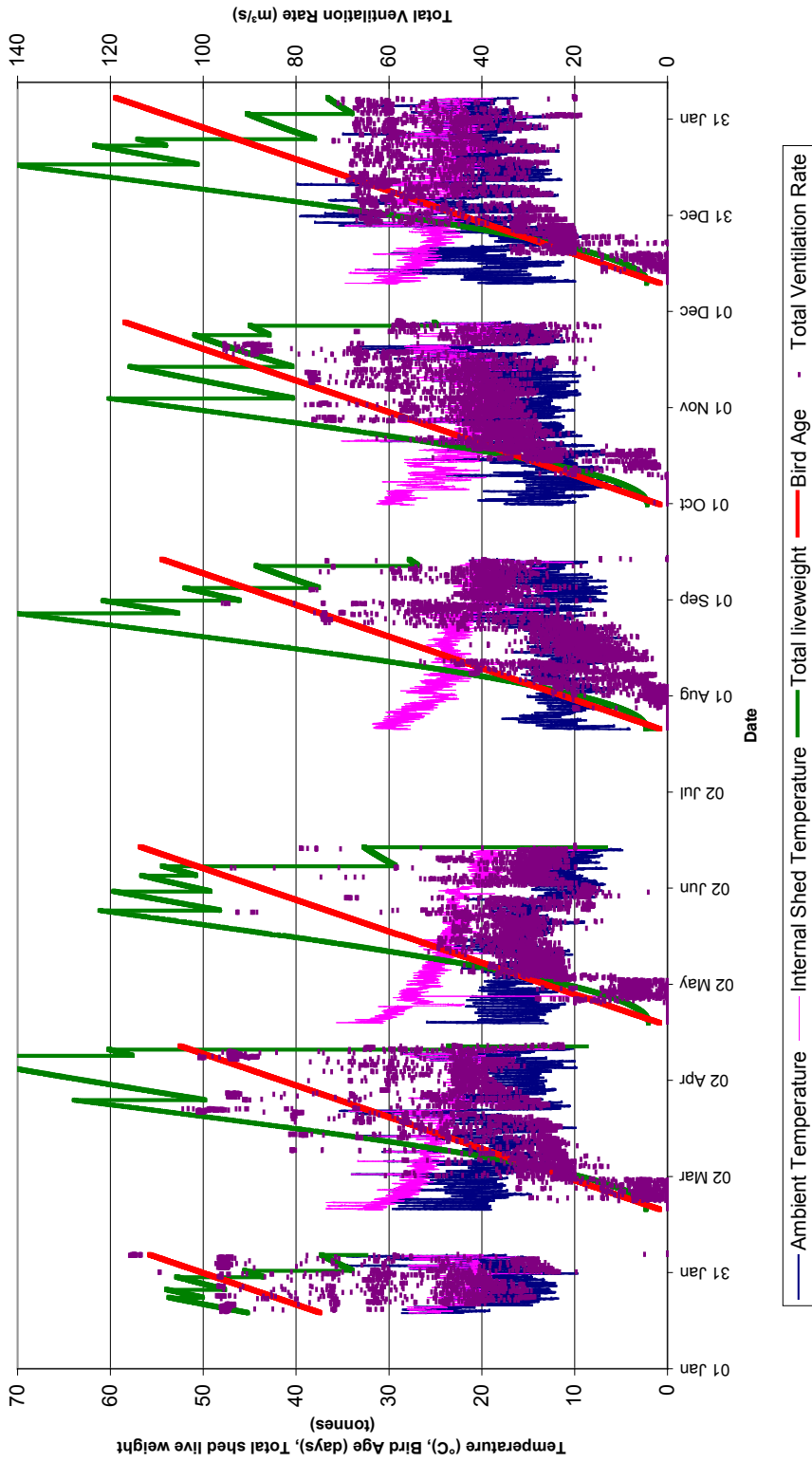
Farm C - Data collected



Farm D - Data collected

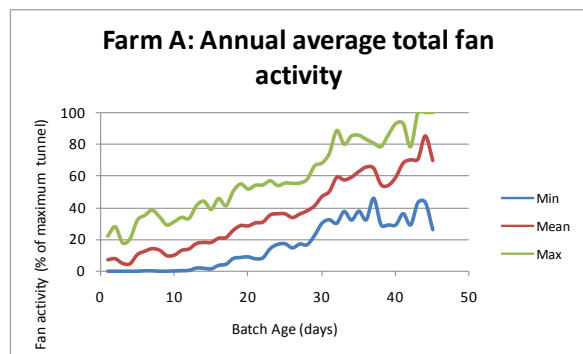
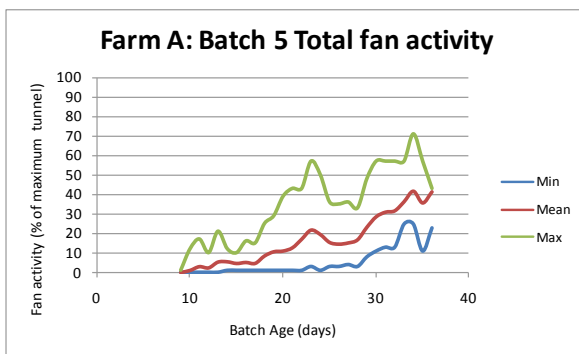
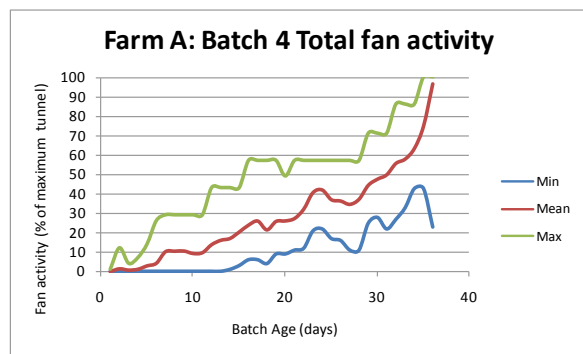
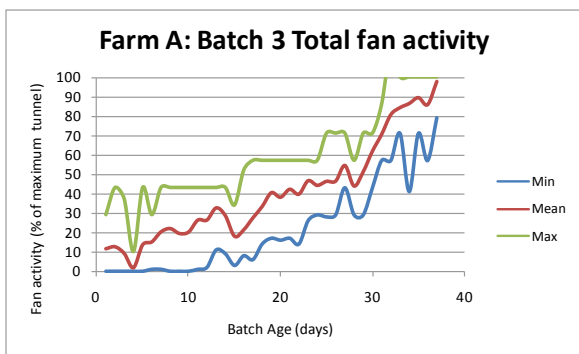
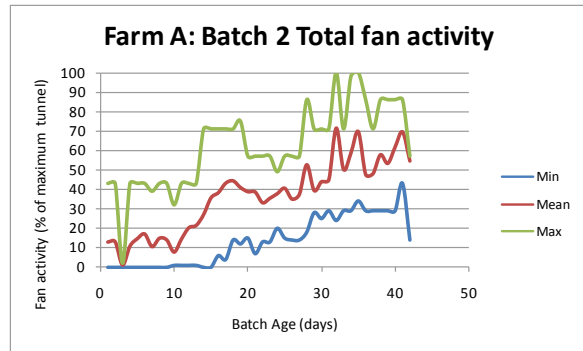
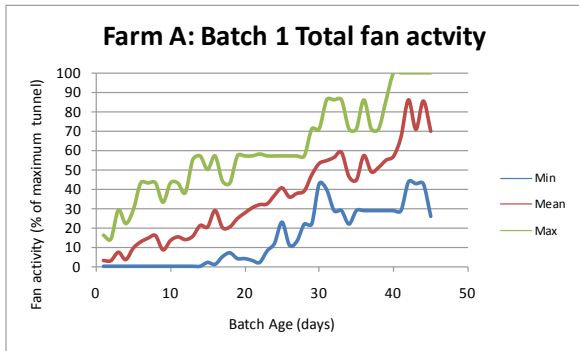


Farm E - Data collected

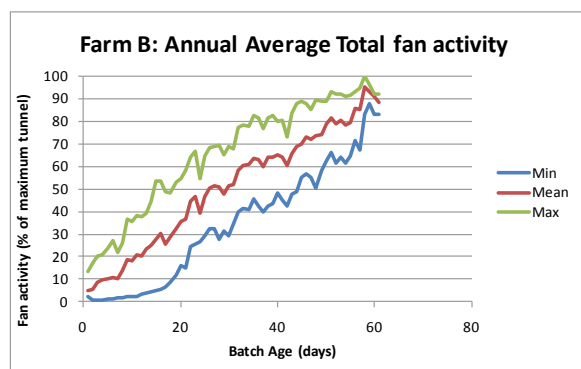
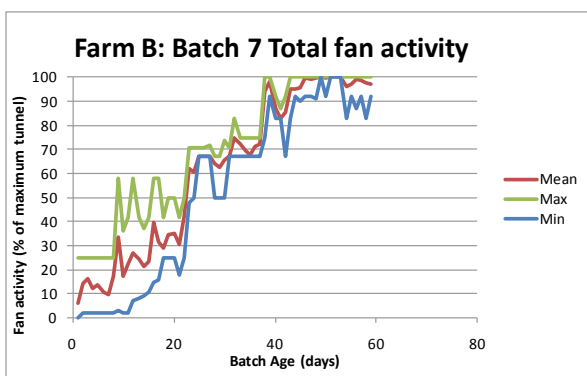
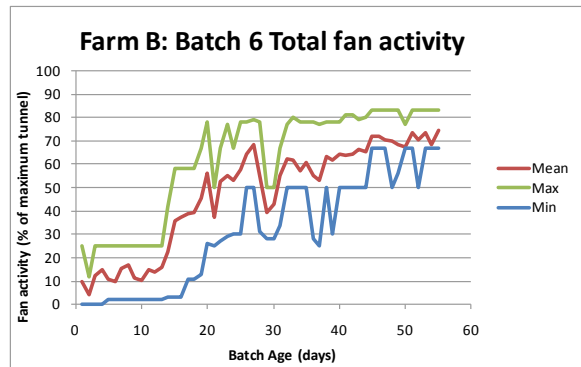
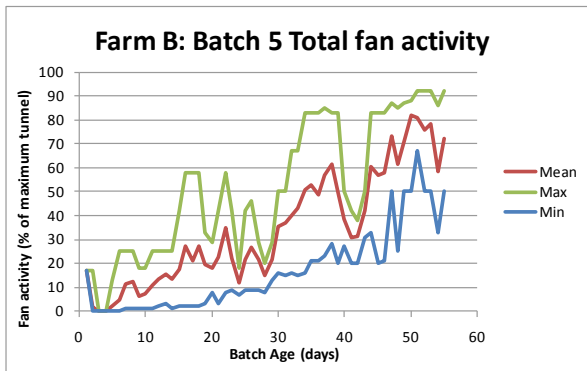
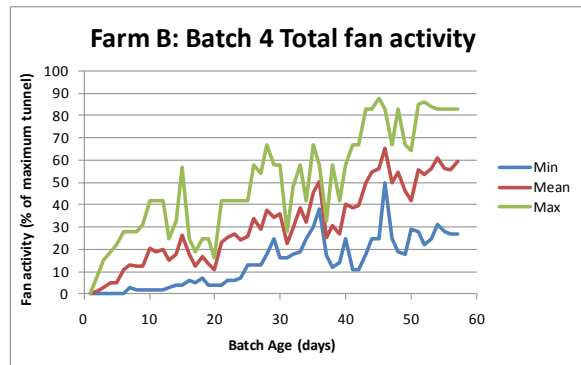
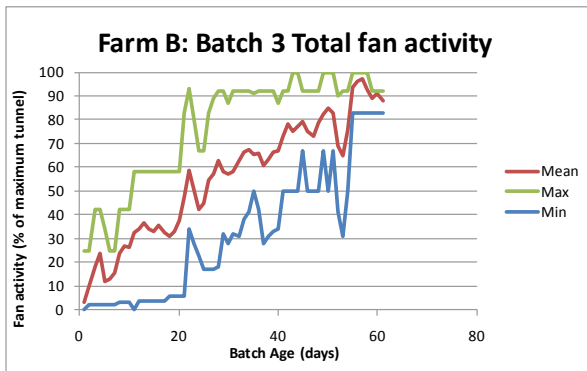
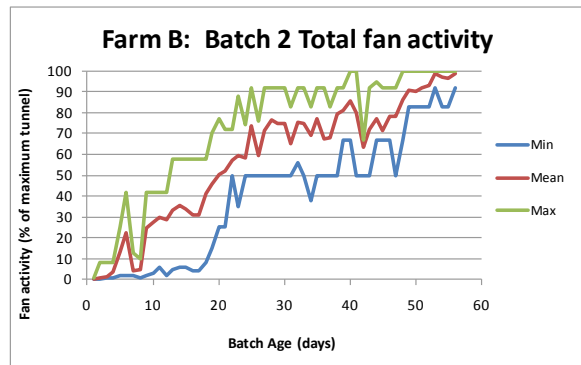
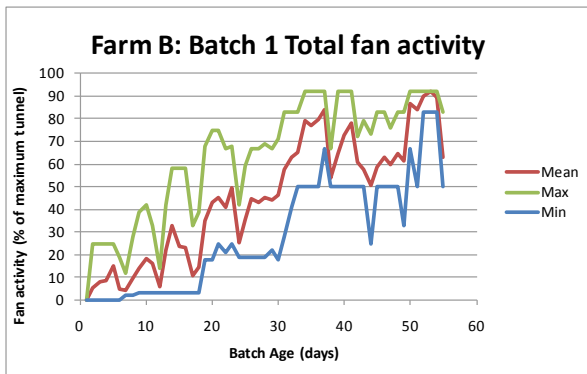


Appendix 4 Farm A daily total fan activity – all sites and all batches

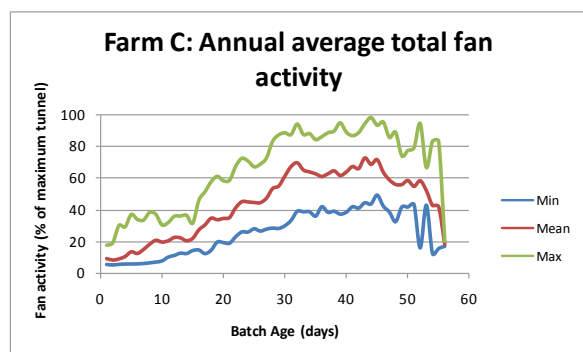
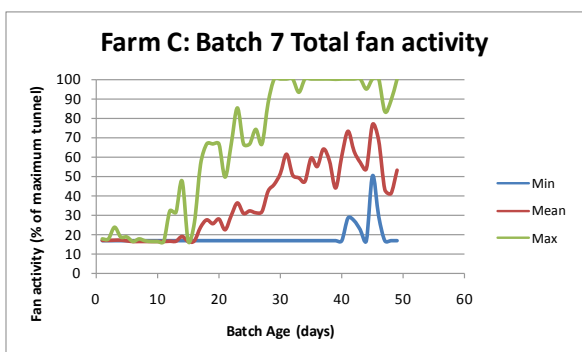
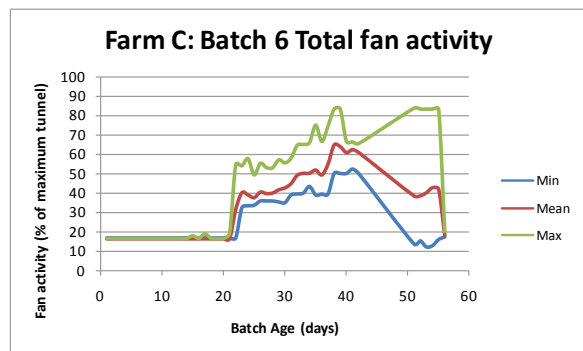
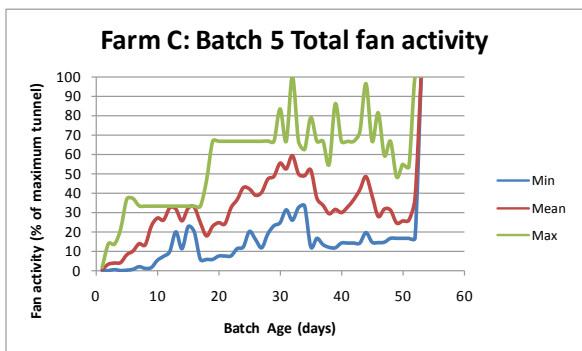
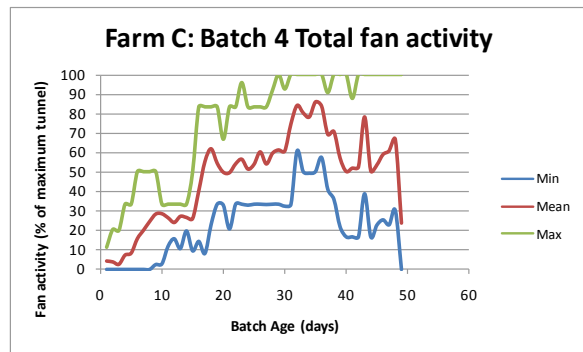
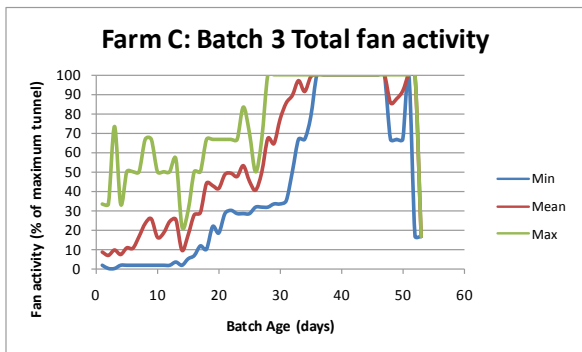
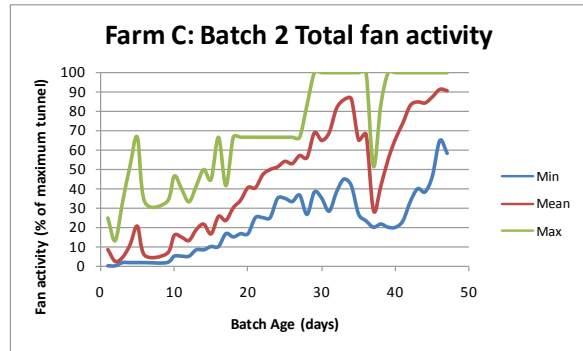
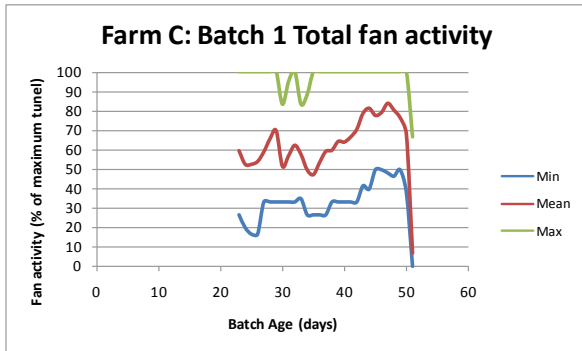
Appendix 4.1 Farm A Total fan activity for all batches



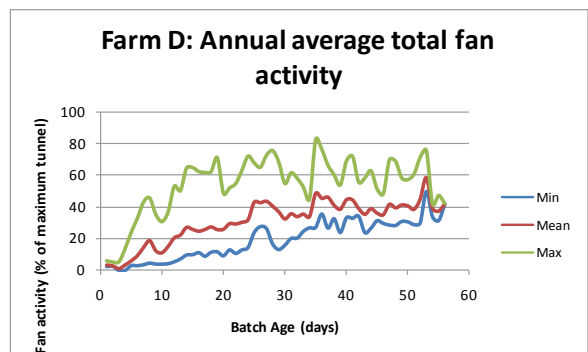
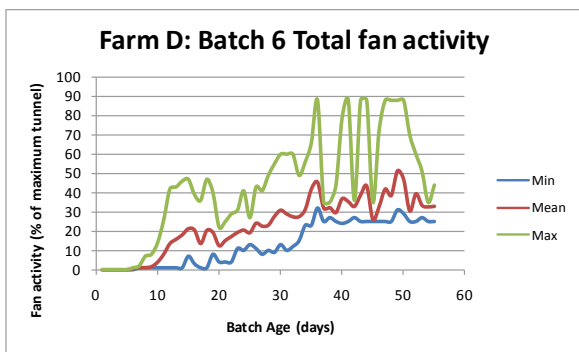
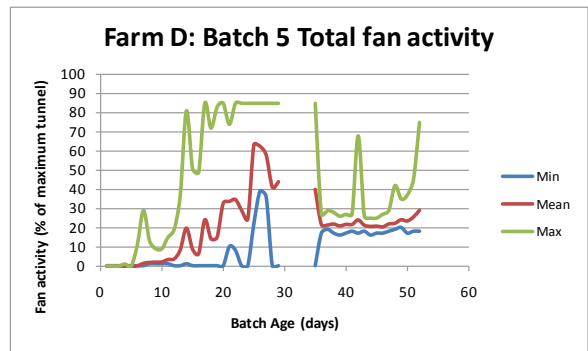
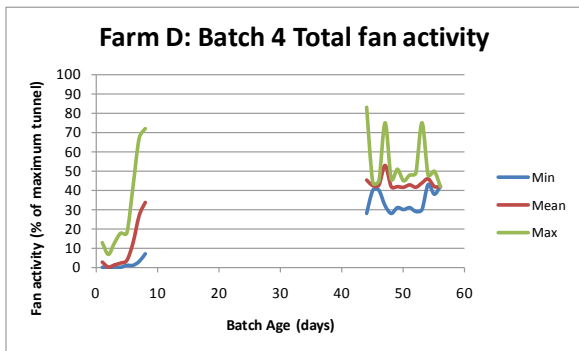
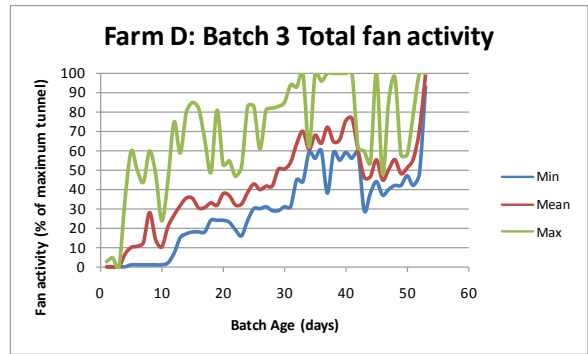
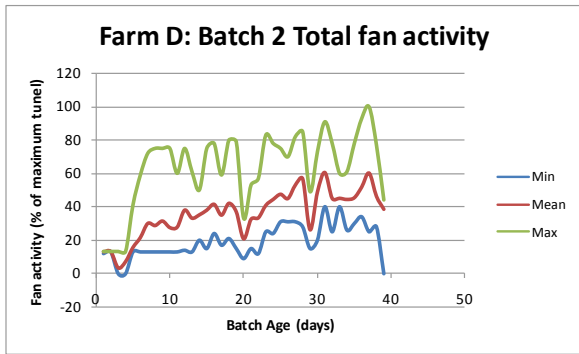
Appendix 4 Farm B Total fan activity for all batches



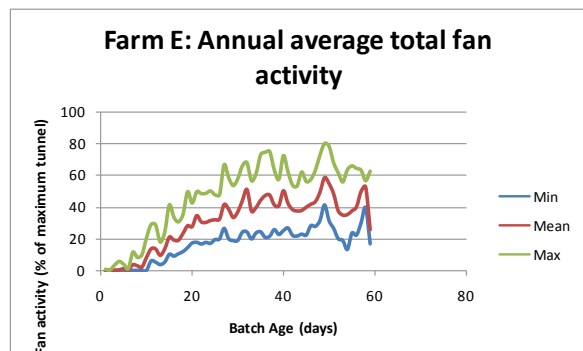
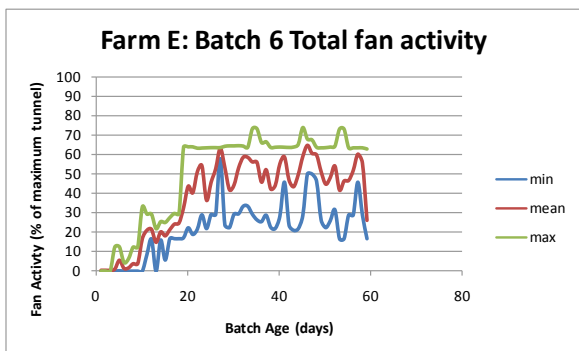
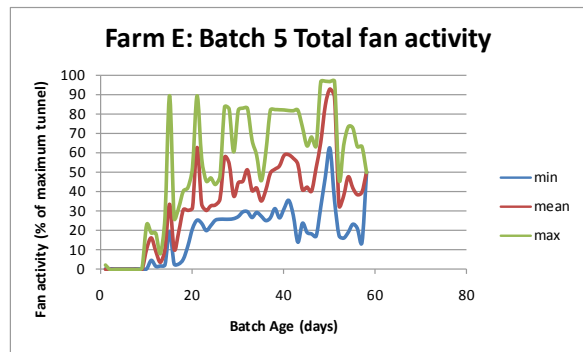
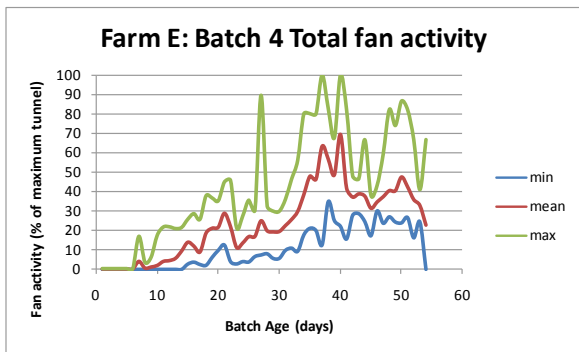
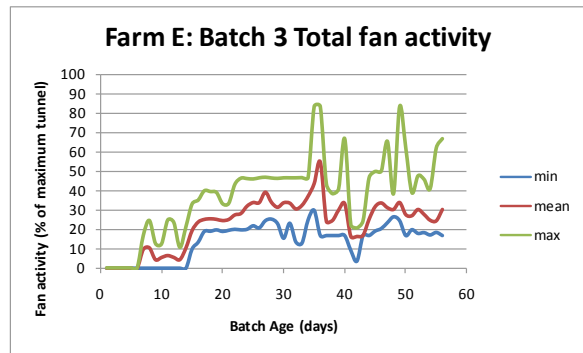
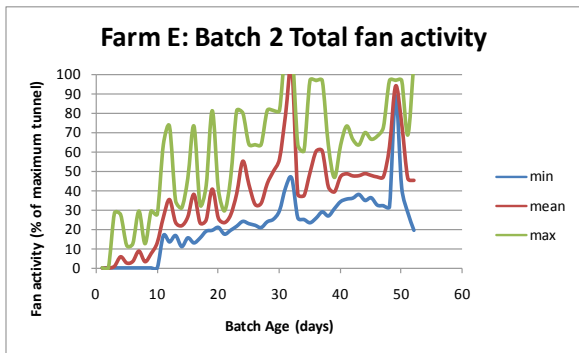
Appendix 4 Farm C Total fan activity for all batches (batch 1 recording commenced approximately half way through batch)



Appendix 4.4 Farm D Total fan activity for all batches (batch 1 excluded as data recording commenced after batch started, equipment failed during batch 4 causing data gap from approximately day 9 to day 43)

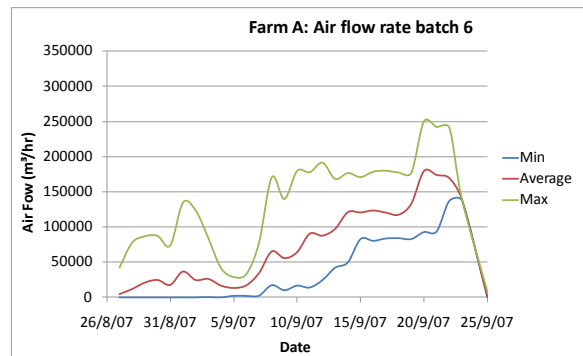
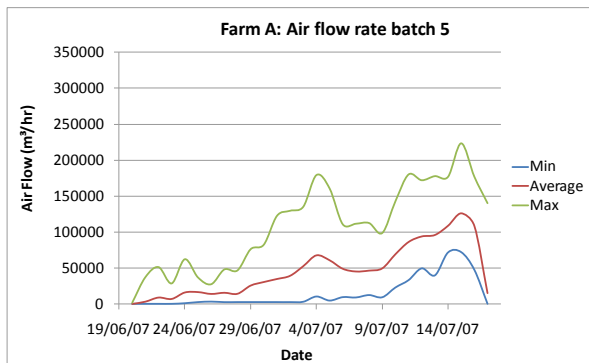
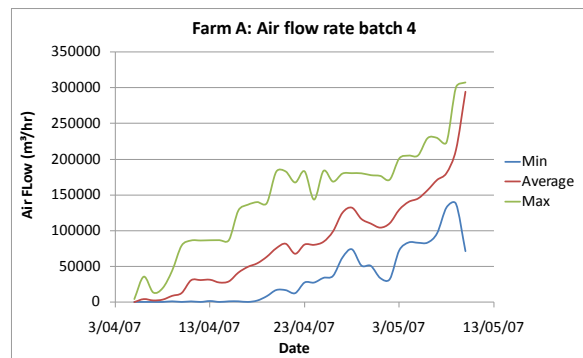
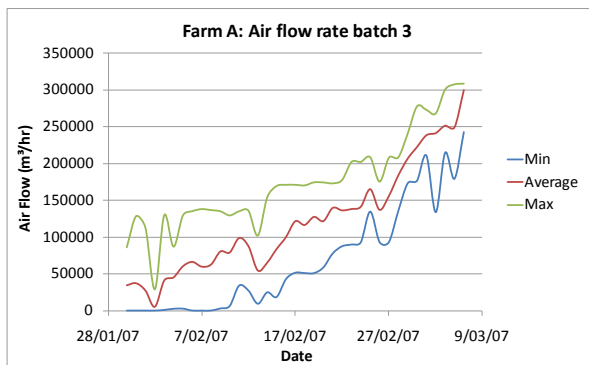
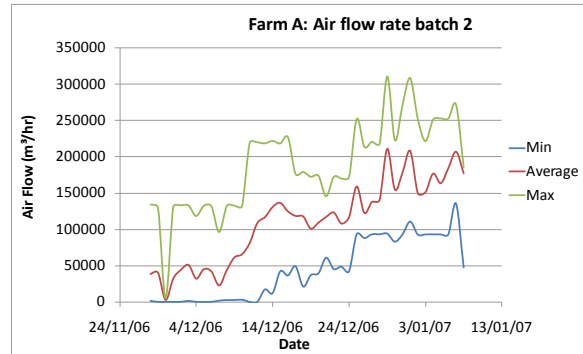
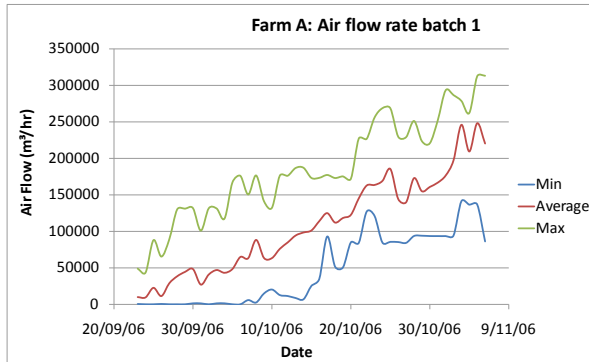


Appendix 4.5 Farm E Total fan activity for all batches (batch 1 excluded as data recording commenced after batch started)

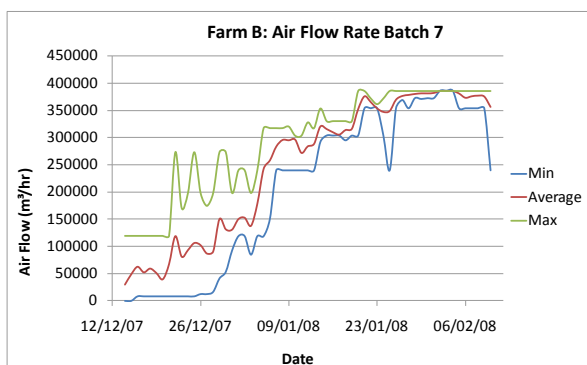
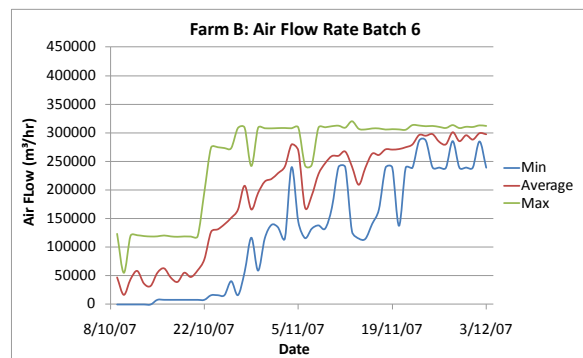
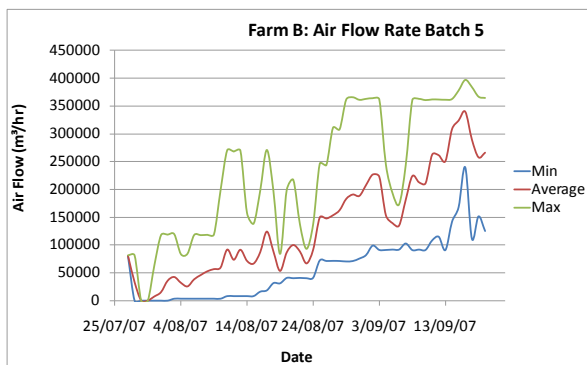
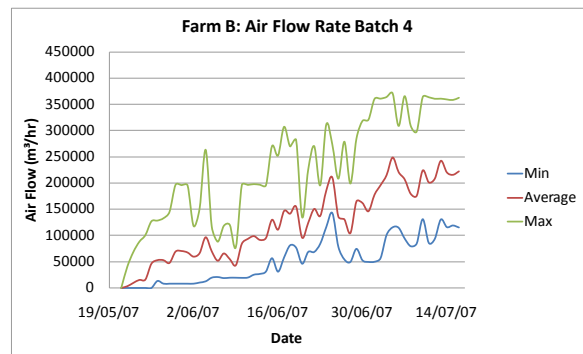
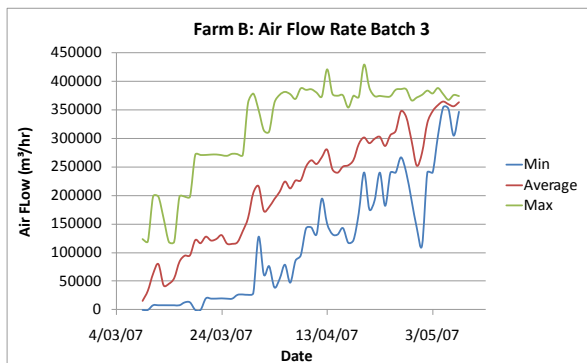
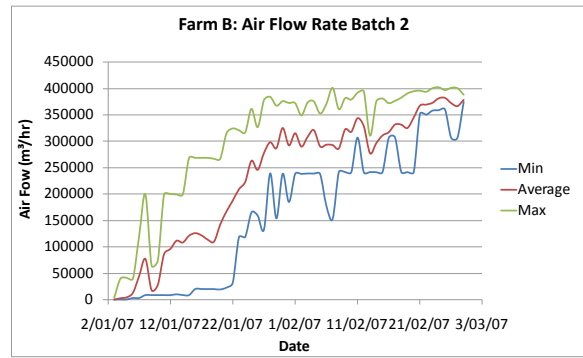
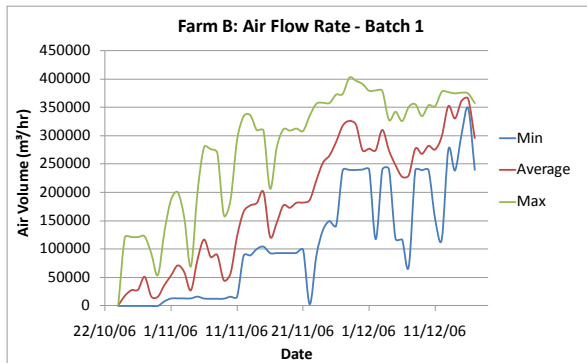


Appendix 5 Daily air flow rates – all sites and all batches

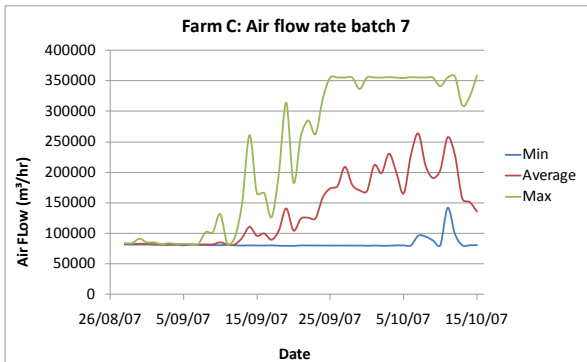
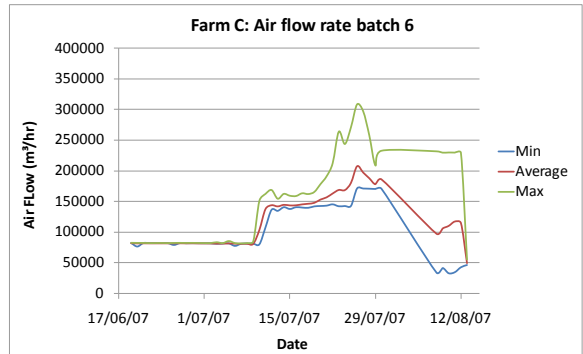
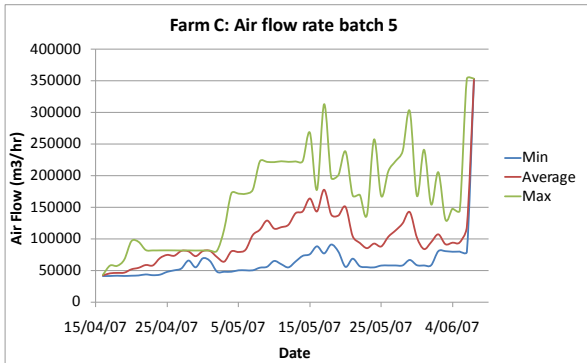
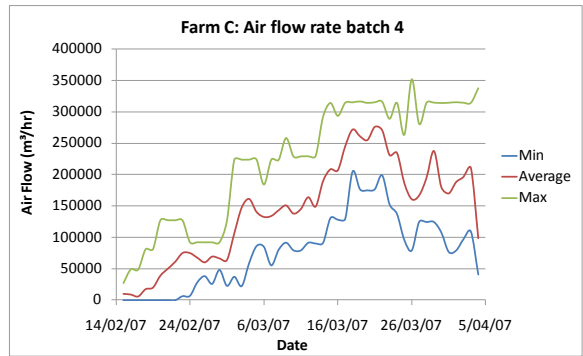
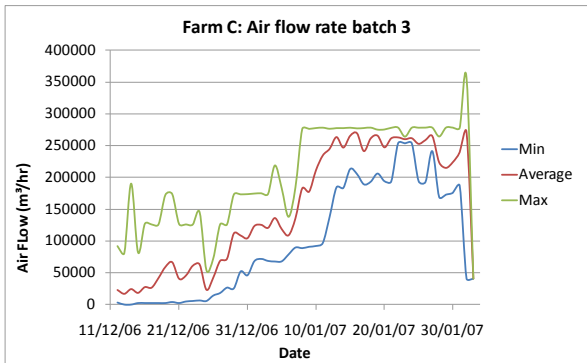
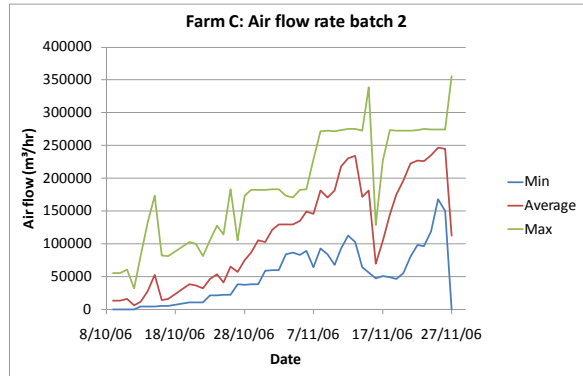
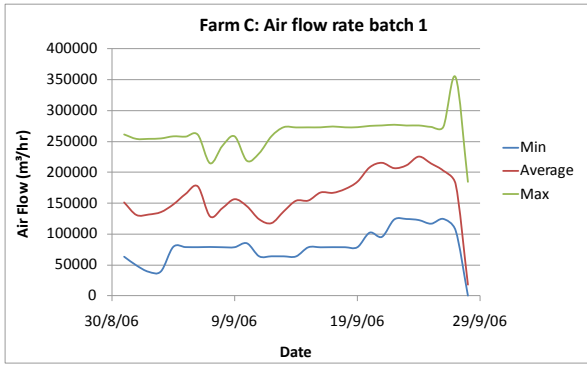
Appendix 5.1 Farm A Ventilation air flow rates all batches



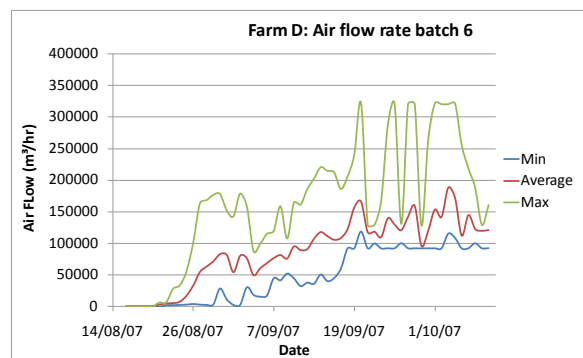
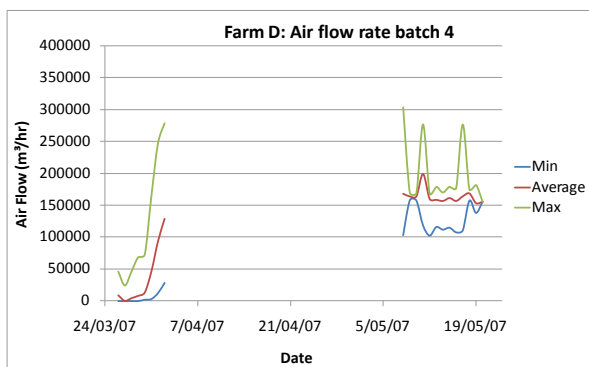
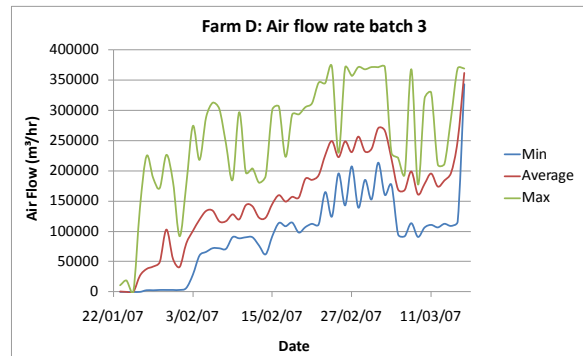
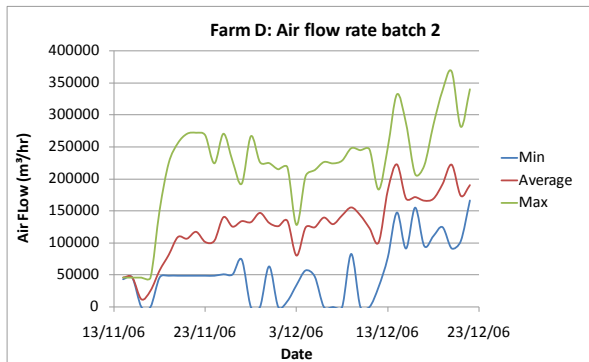
Appendix 5.2 Farm B Ventilation air flow rates all batches



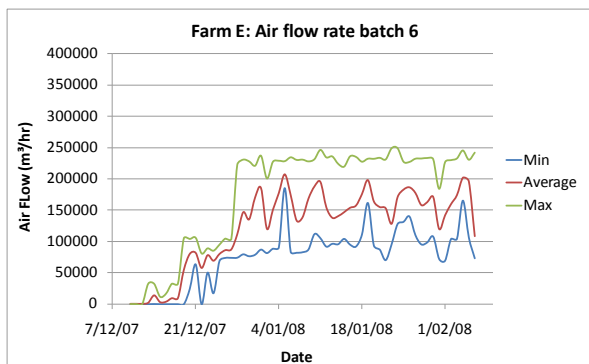
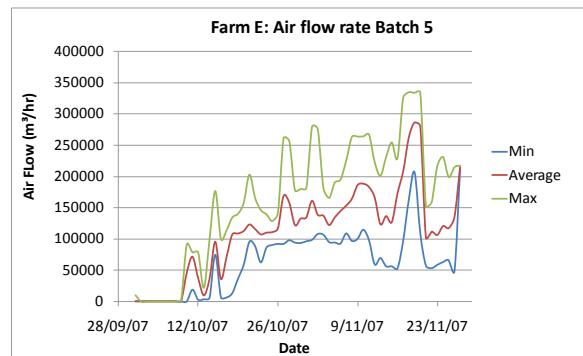
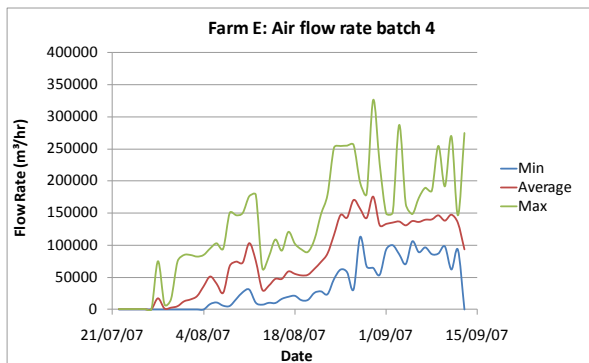
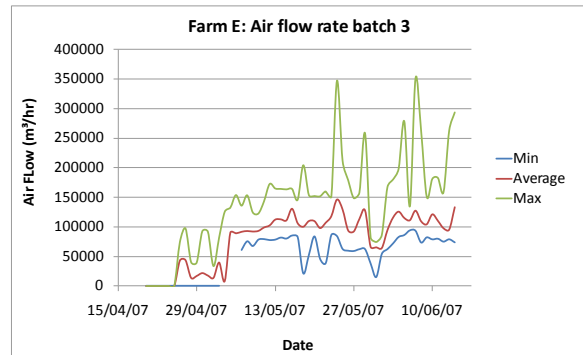
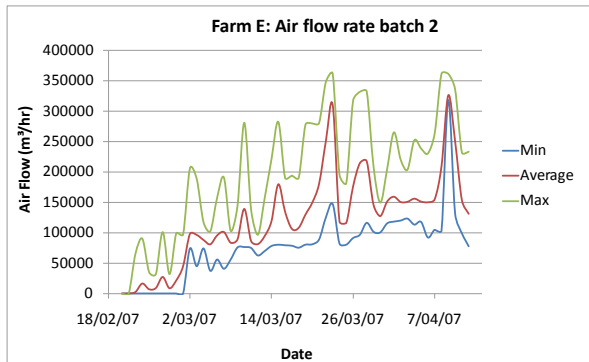
Appendix 5.3 Farm C Ventilation air flow rates all batches



Appendix 5.4 Farm D Air flow rates all batches excepting batch 1 and 5 (batch 1 commenced before recording equipment commissioned, malfunction with recording equipment occurred during batch 5. It should also be noted that there is a gap in the recorded data for batch 4 due to equipment failure. Data was missed from day 9 to day 44)

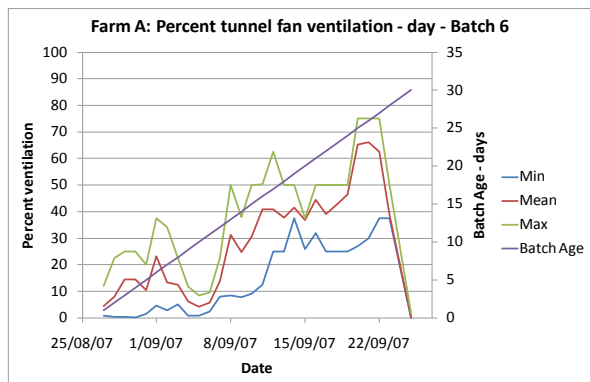
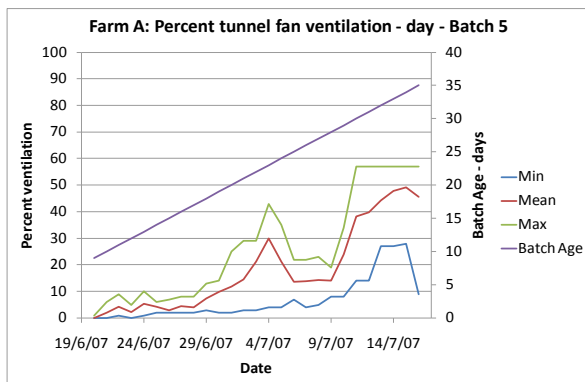
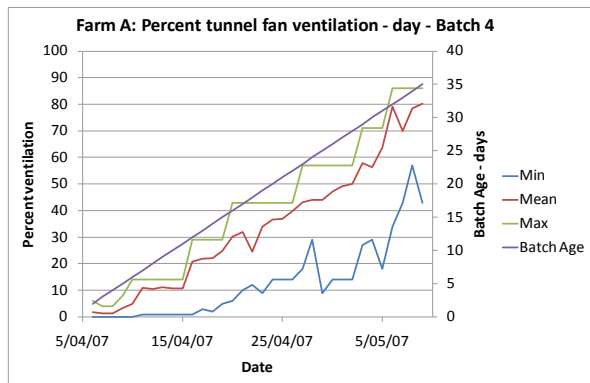
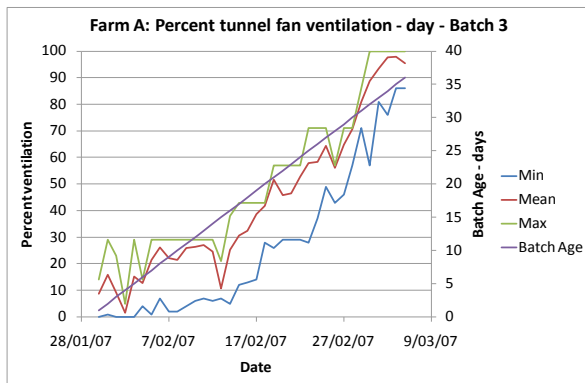
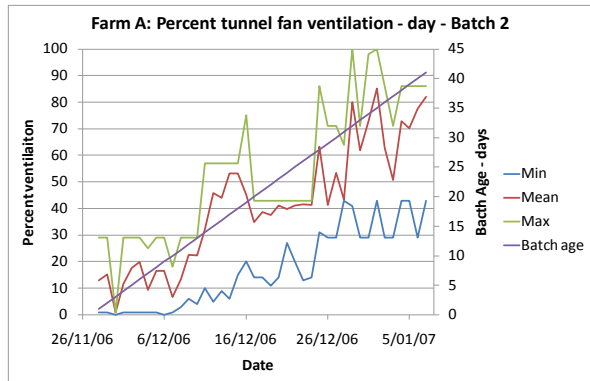
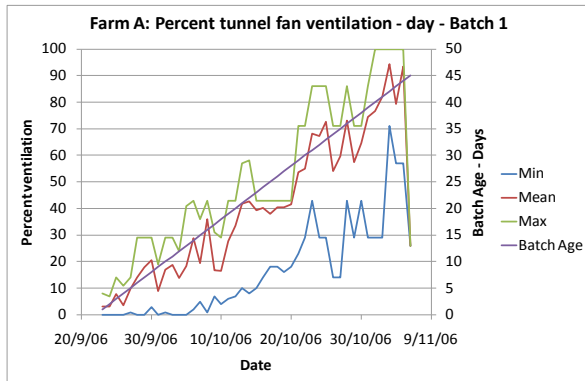


Appendix 5.5 Farm E Air flow rates all batches, excepting batch 1 (batch commenced before recording equipment commissioned)

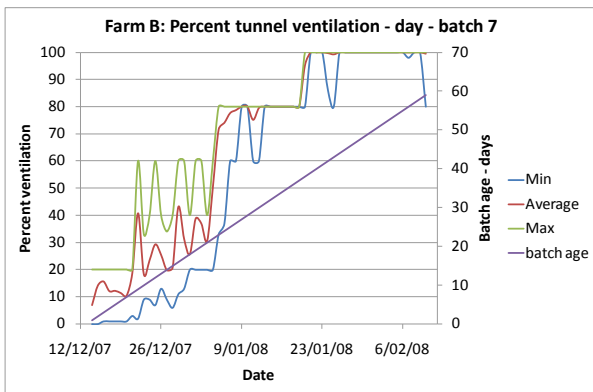
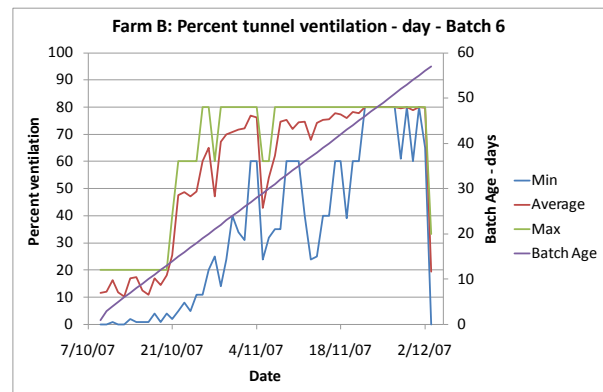
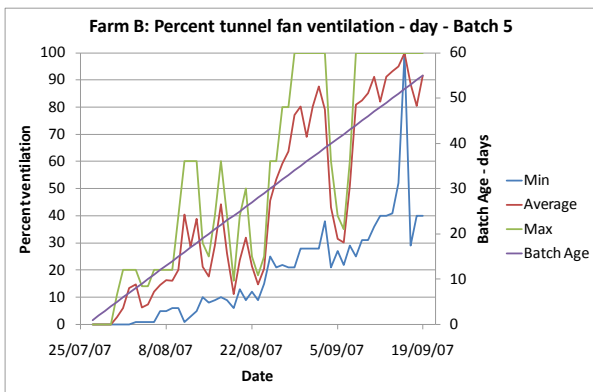
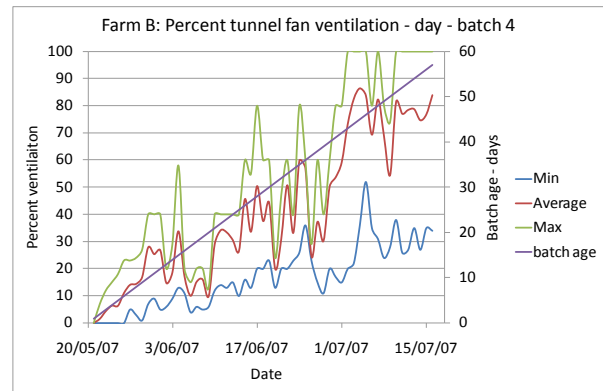
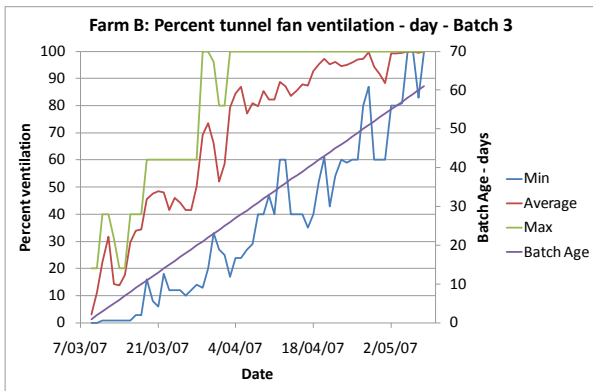
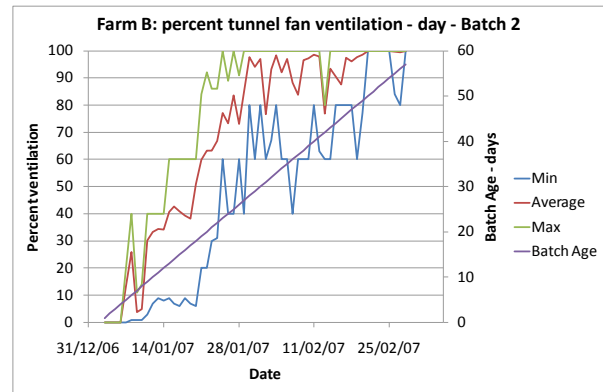
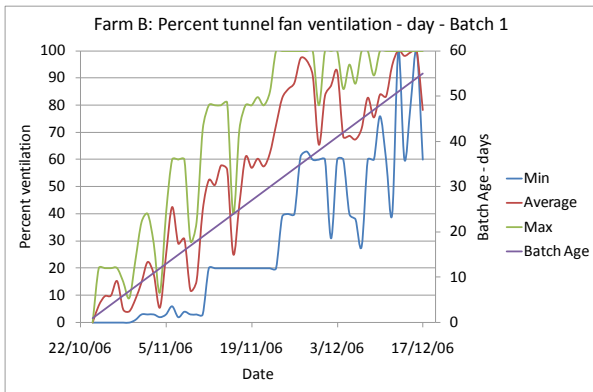


Appendix 6 Tunnel fan activity charts for 'Day' – all sites and all batches

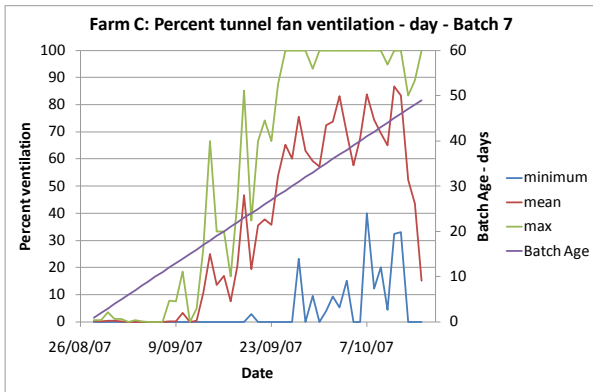
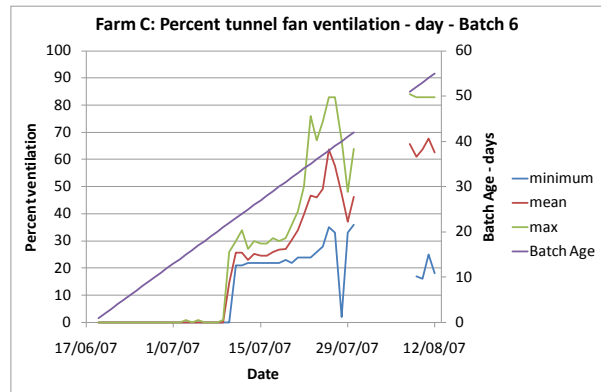
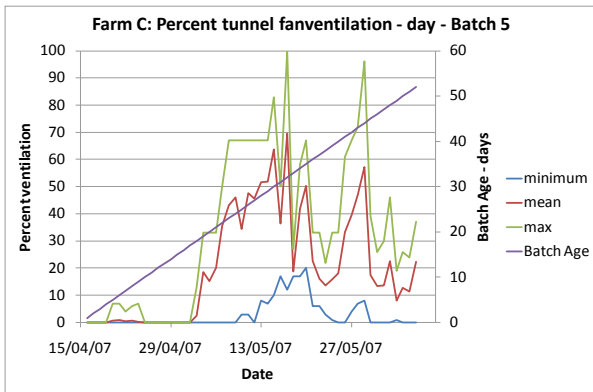
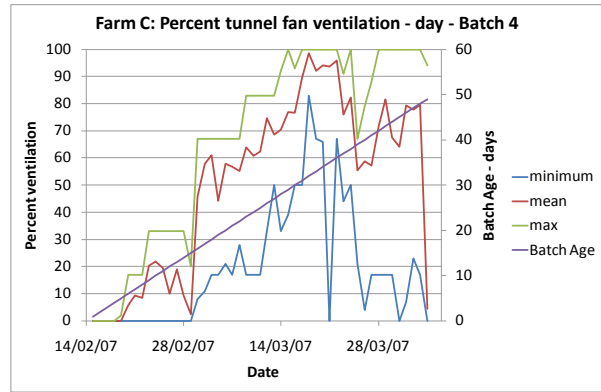
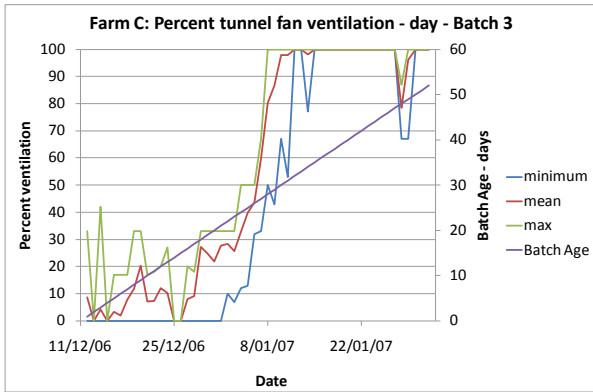
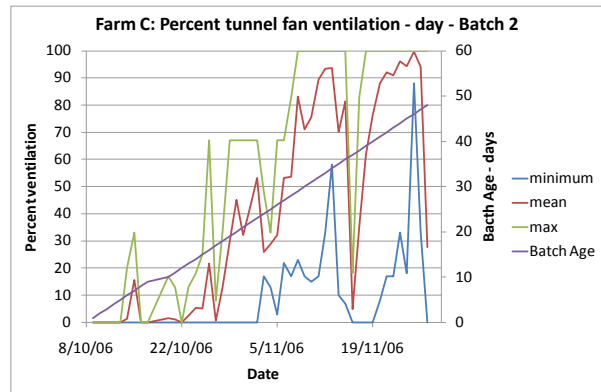
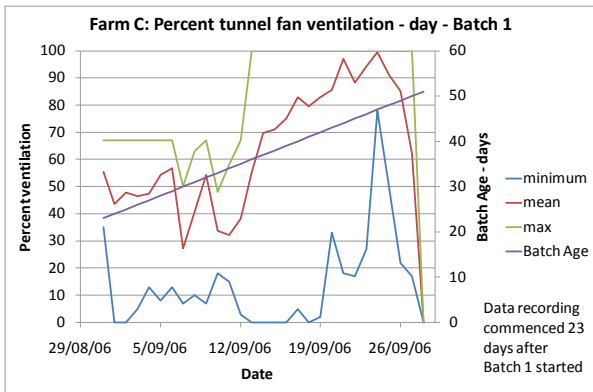
Appendix 6.1 Farm A tunnel fan activity for 'Day' - All batches



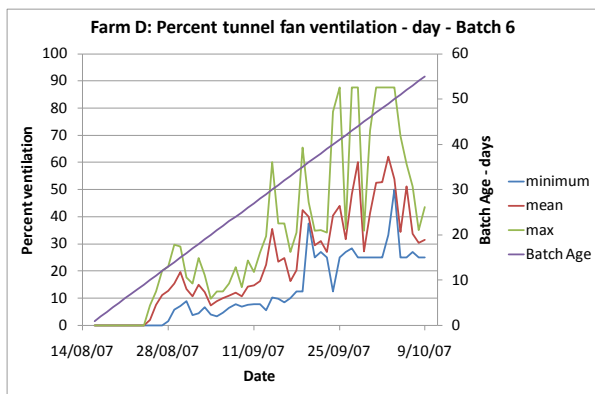
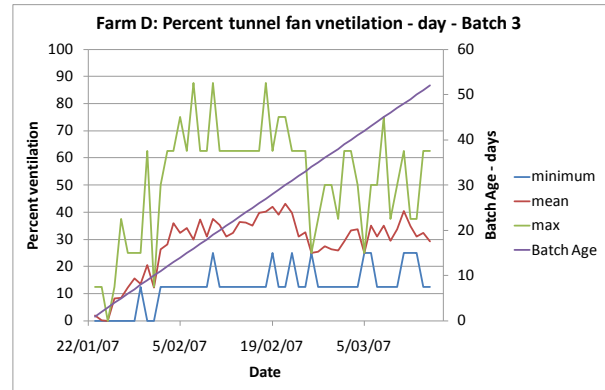
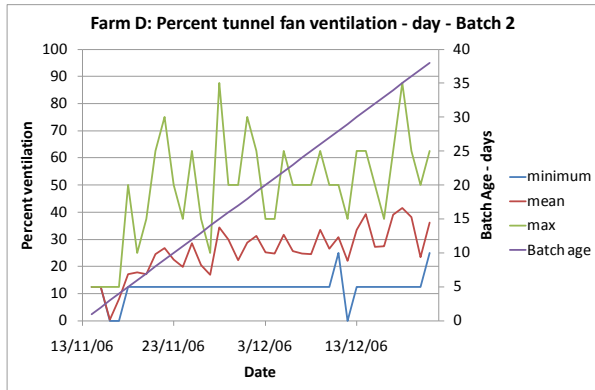
Appendix 6.2 Farm B tunnel fan activity for 'Day' - All batches



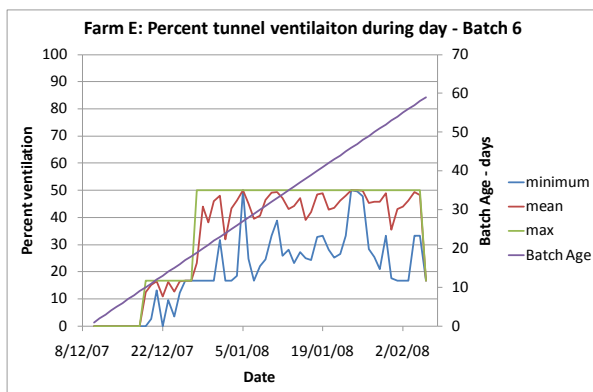
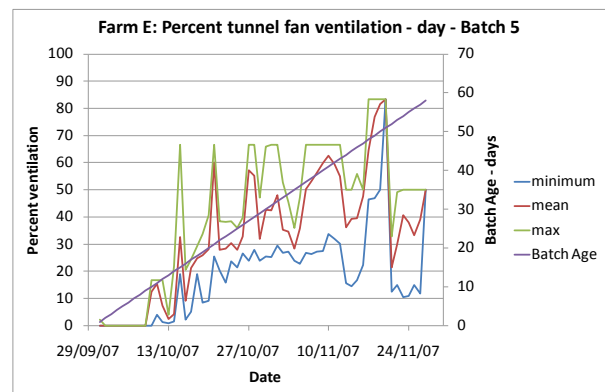
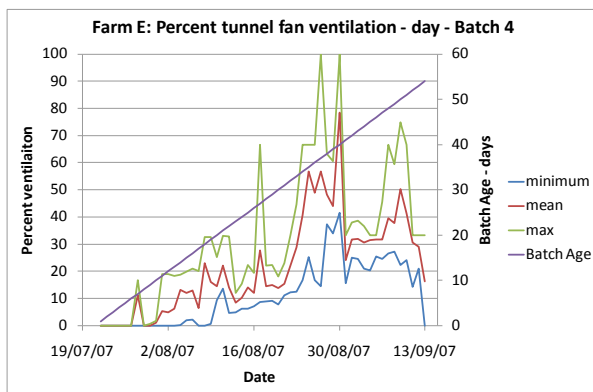
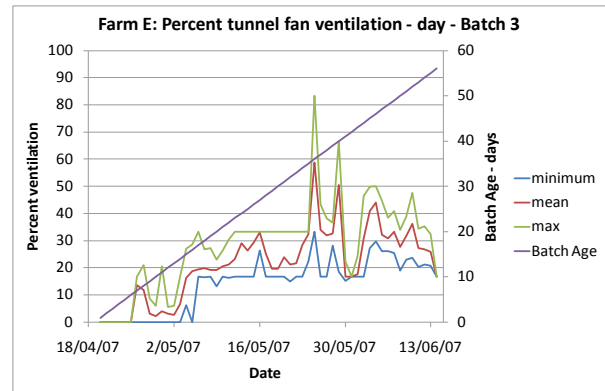
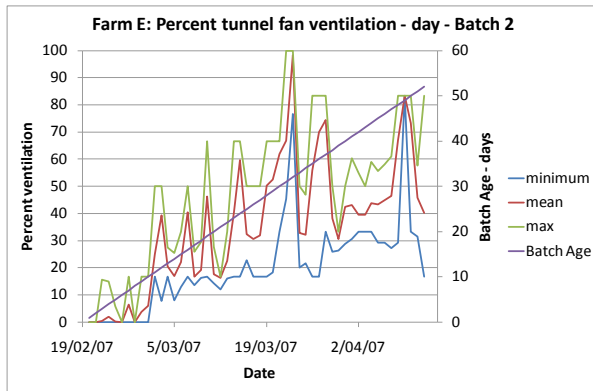
Appendix 6.3 Farm C tunnel fan activity for 'Day' - All batches



Appendix 6.4 Farm D tunnel fan activity for ‘Day’ - Batches 2, 3 and 6. Batch 1 commenced before recording equipment commissioned. Batch 4 and 5 experienced recording equipment malfunctions.

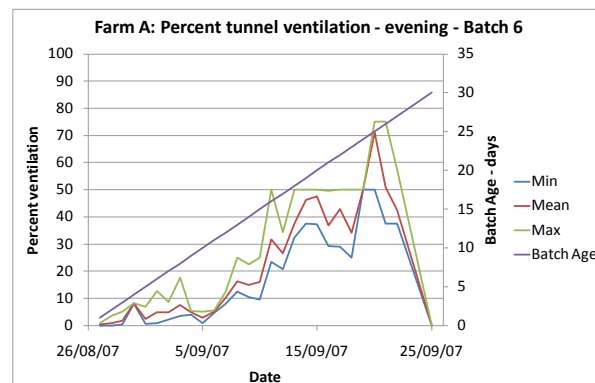
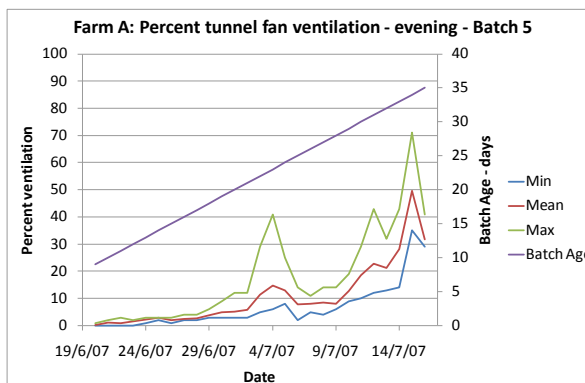
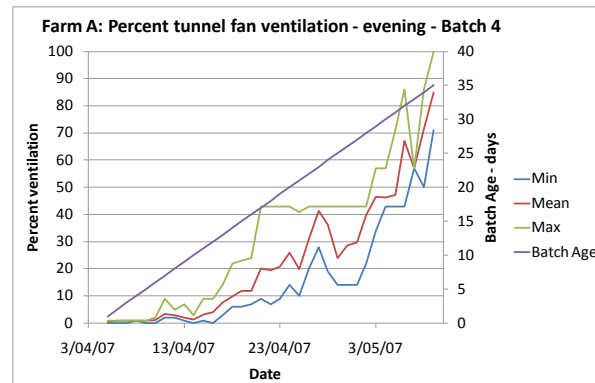
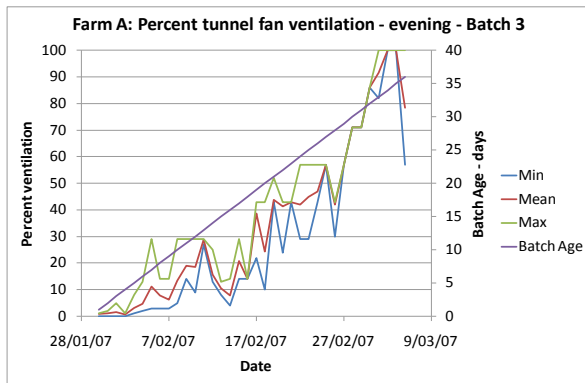
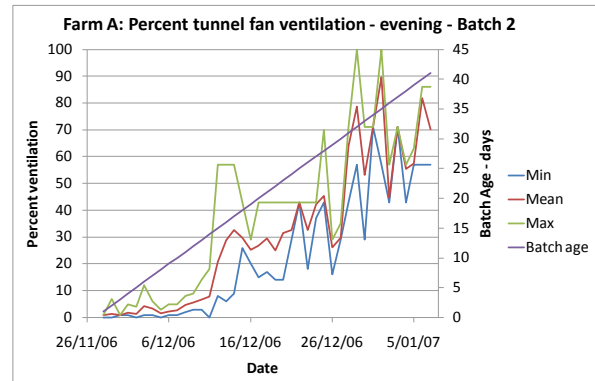
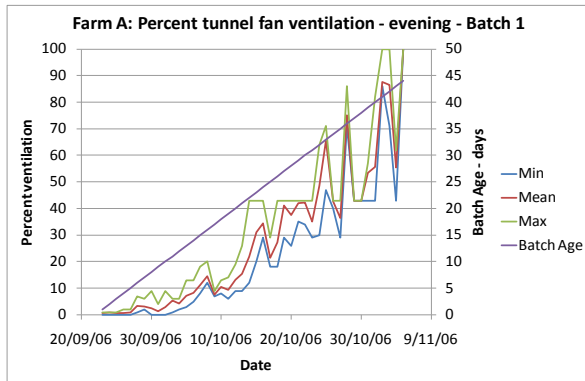


Appendix 6.5 Farm E tunnel fan activity for 'Day' - Batches 2-6. Batch 1 commenced before recording equipment commissioned.

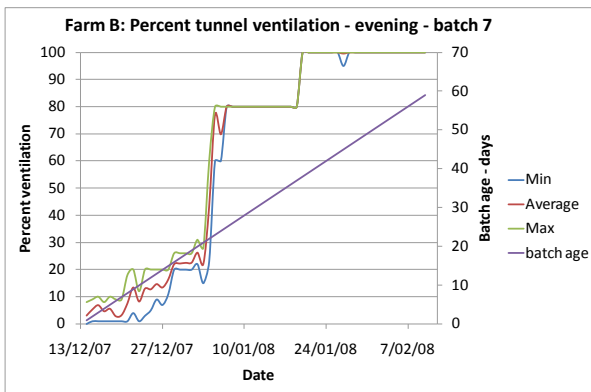
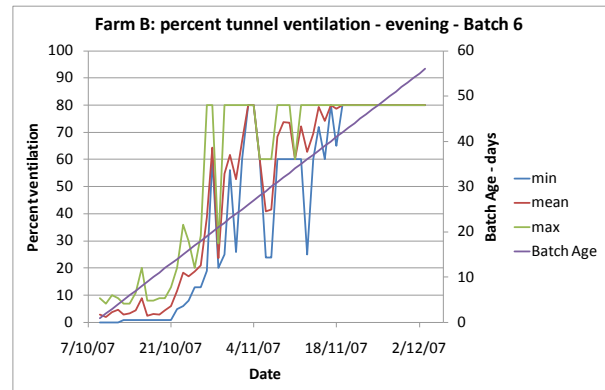
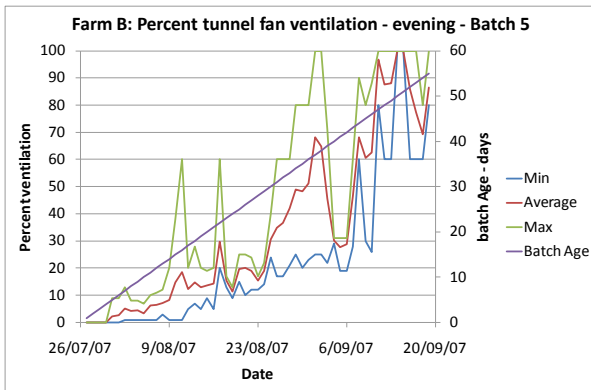
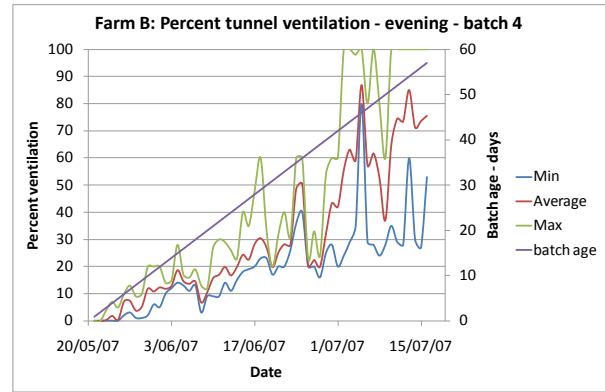
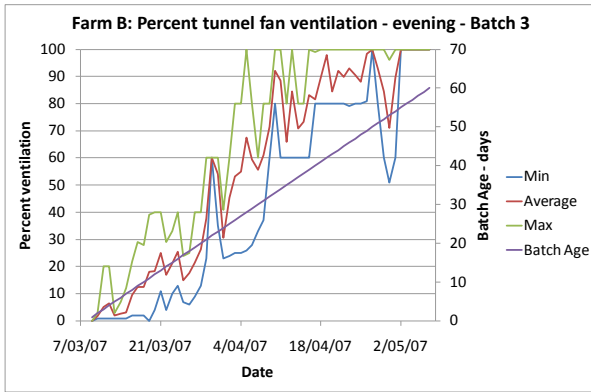
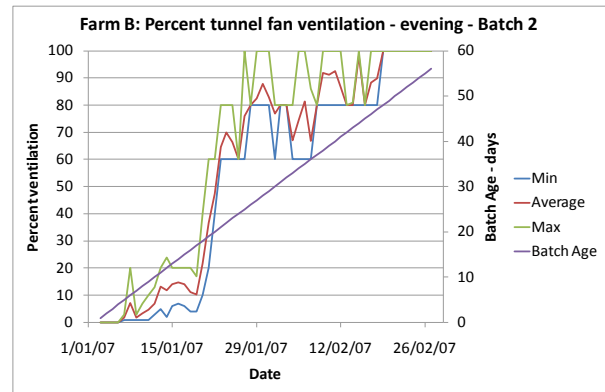
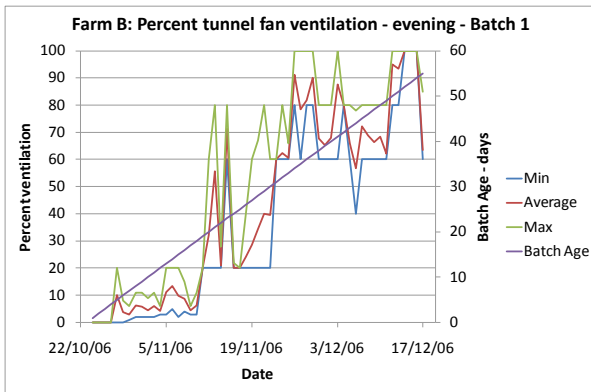


Appendix 7 Tunnel fan activity charts for Evening – all sites and all batches

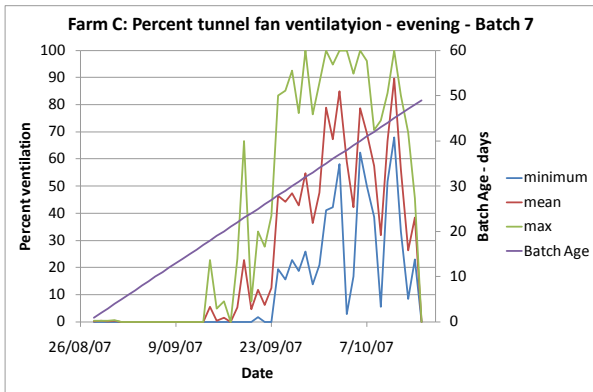
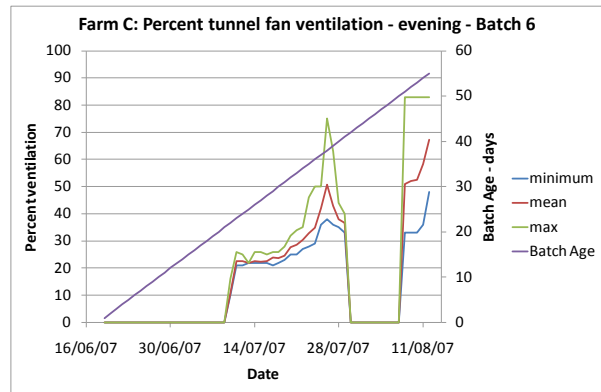
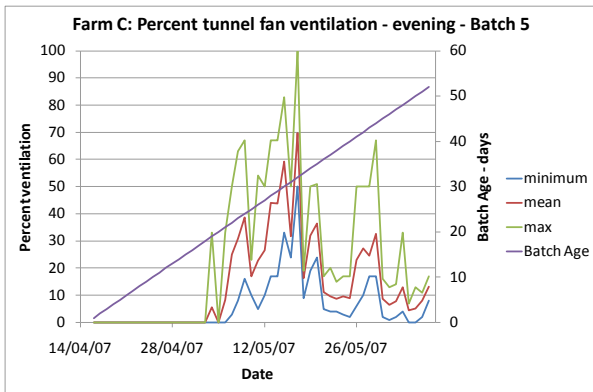
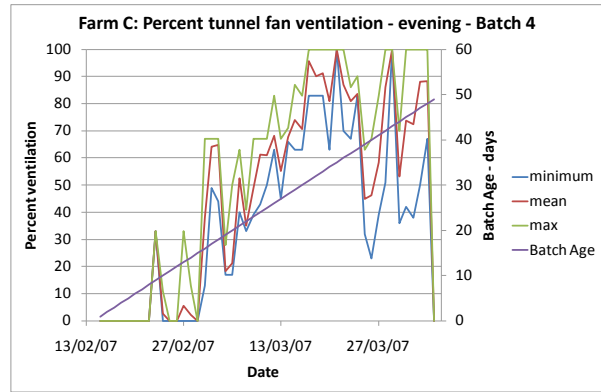
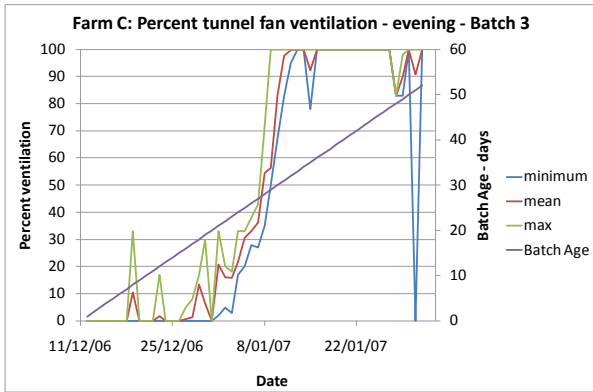
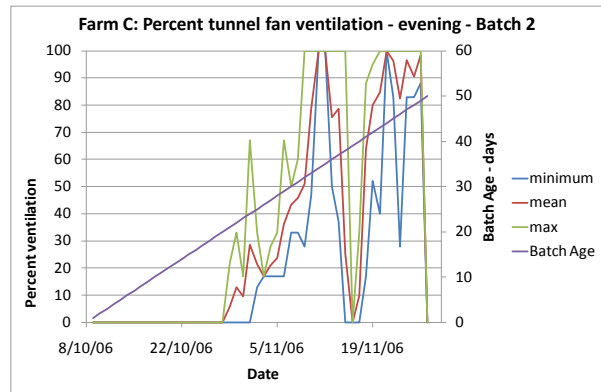
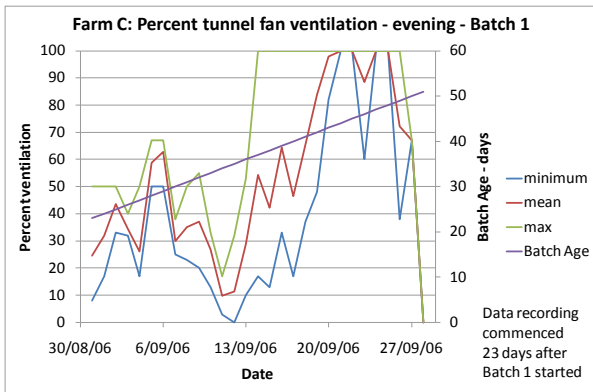
Appendix 7.1 Farm A tunnel fan activity for ‘Evening’ - All batches



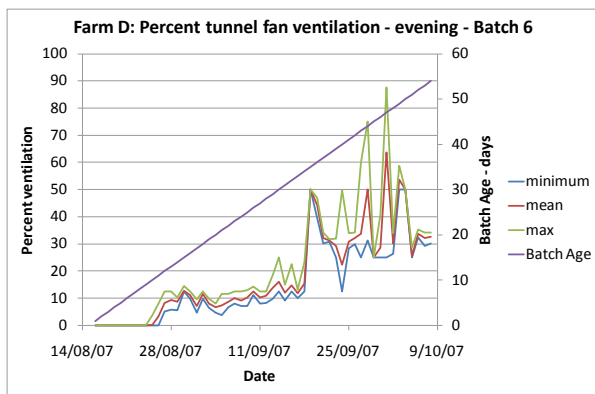
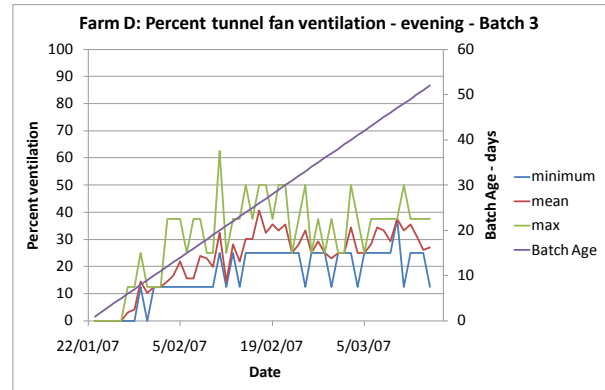
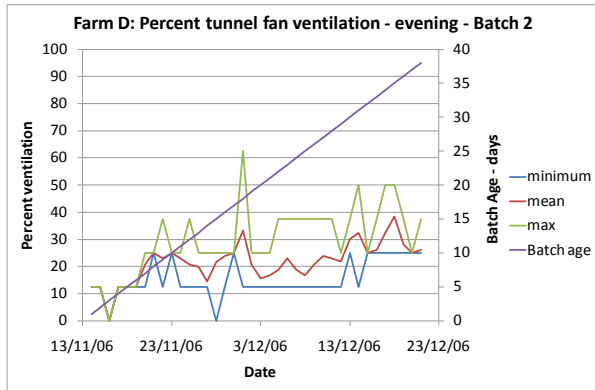
Appendix 7.2 Farm B tunnel fan activity for 'Evening' - All batches



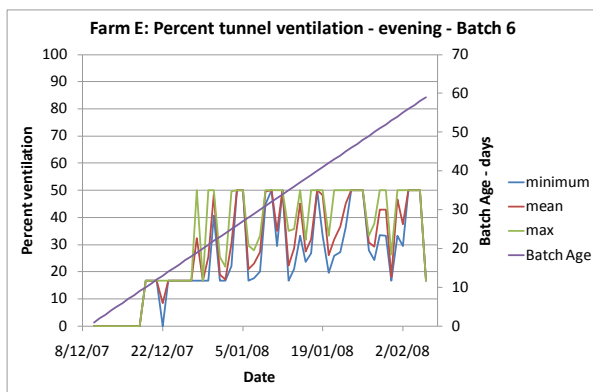
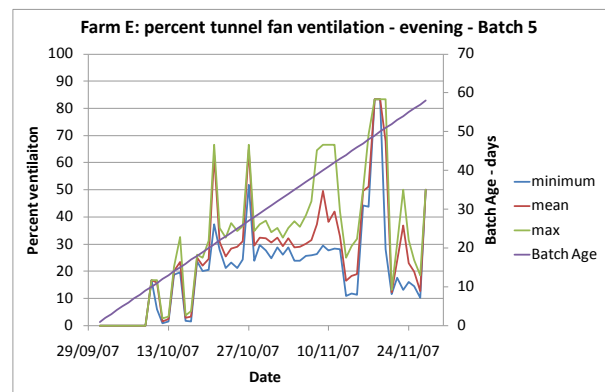
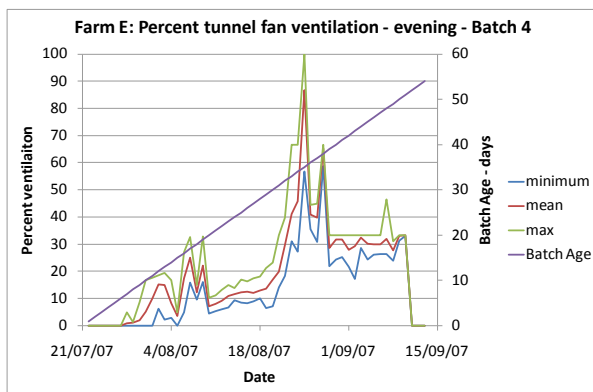
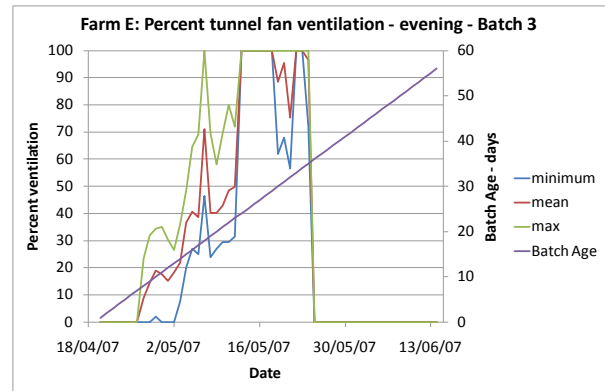
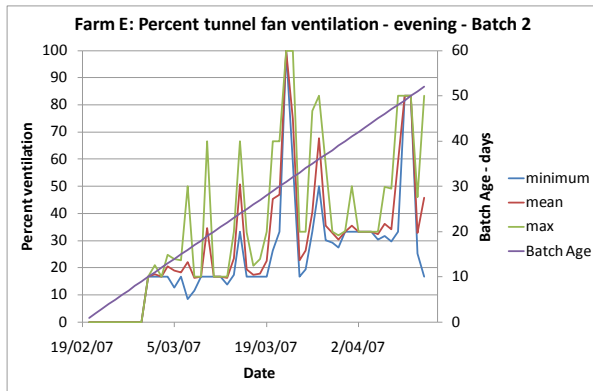
Appendix 7.3 Farm C tunnel fan activity for 'Evening' - All batches



Appendix 7.4 Farm D tunnel fan activity for ‘Evening’ - Batches 2, 3 and 6. Batch 1 commenced before recording equipment commissioned. Batch 4 and 5 experienced recording equipment malfunctions

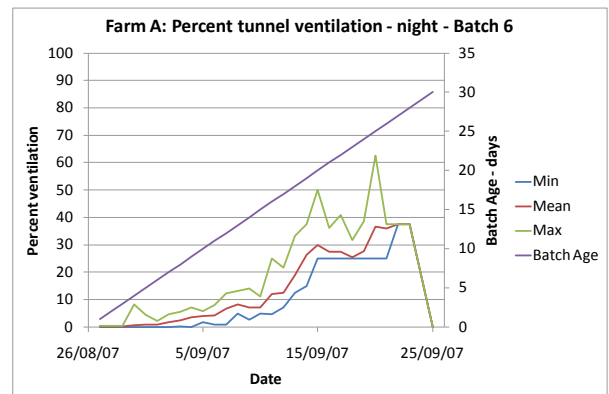
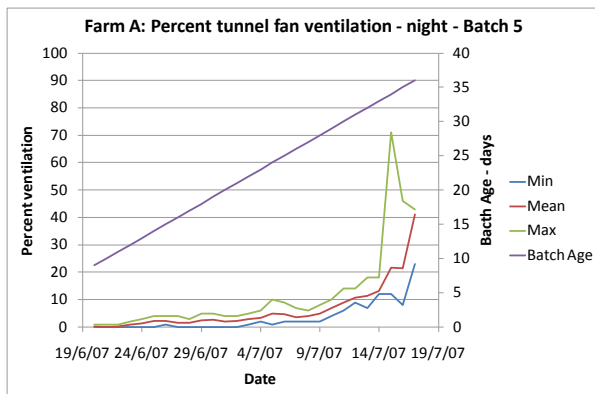
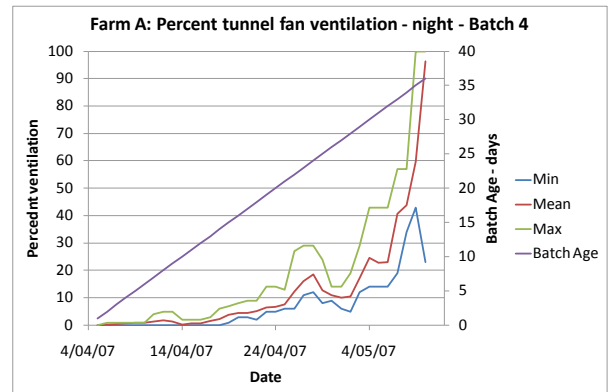
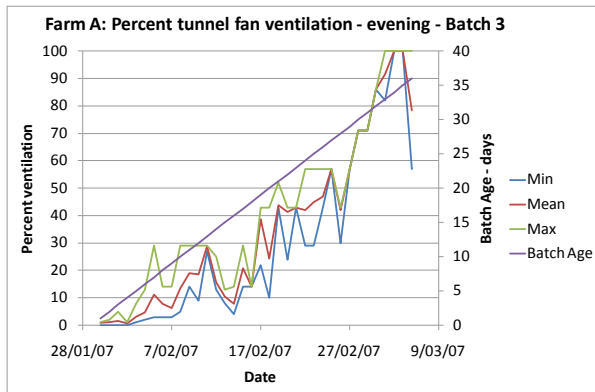
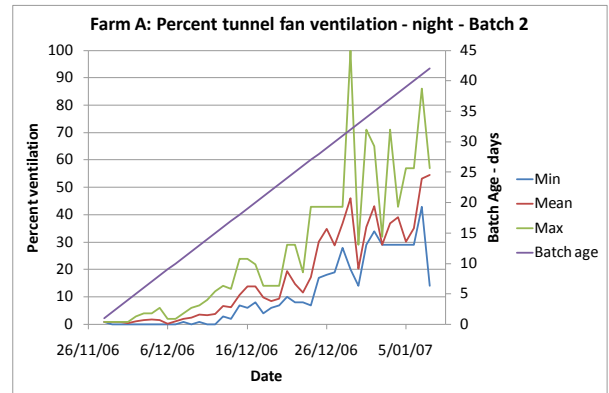
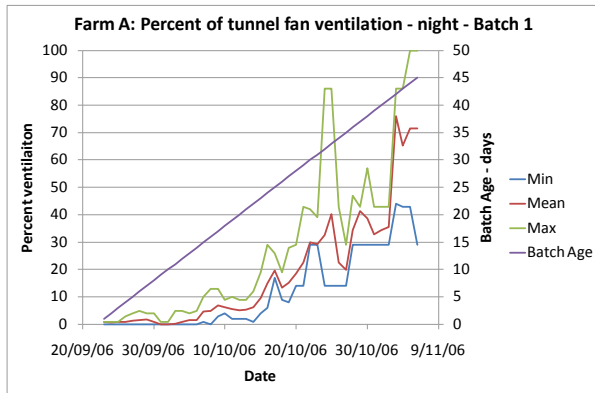


Appendix 7.5 Farm E tunnel fan activity for 'Evening' - Batches 2 through 6 (Batch 1 commenced prior to equipment being commissioned)

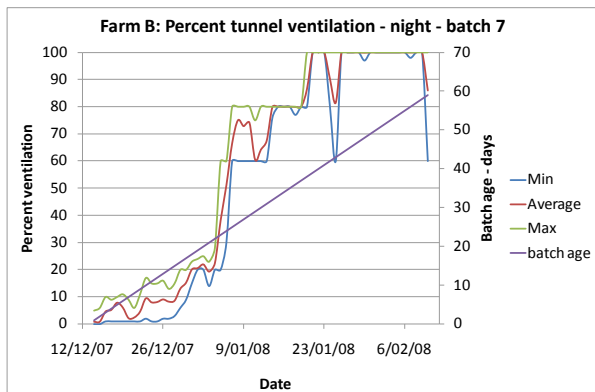
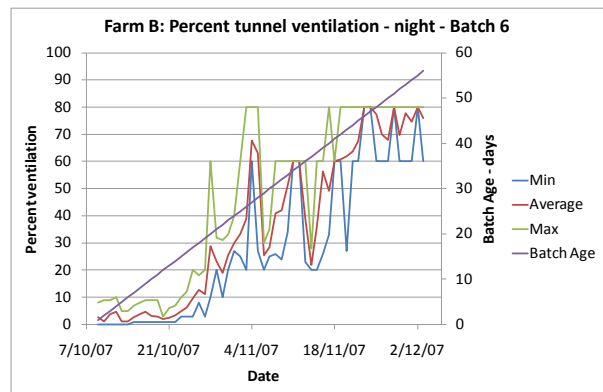
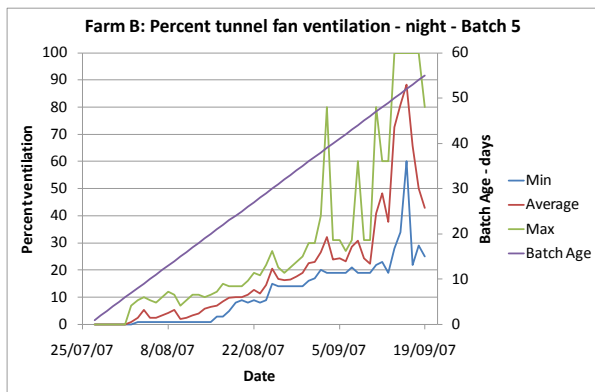
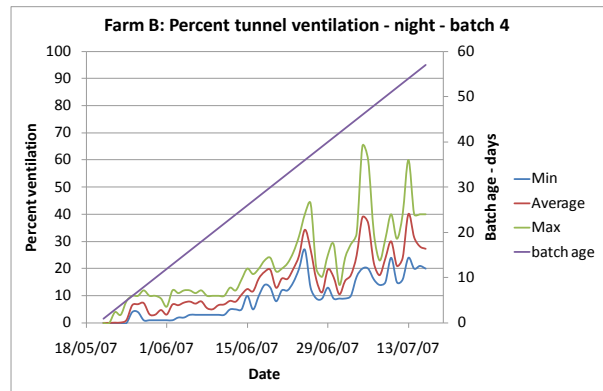
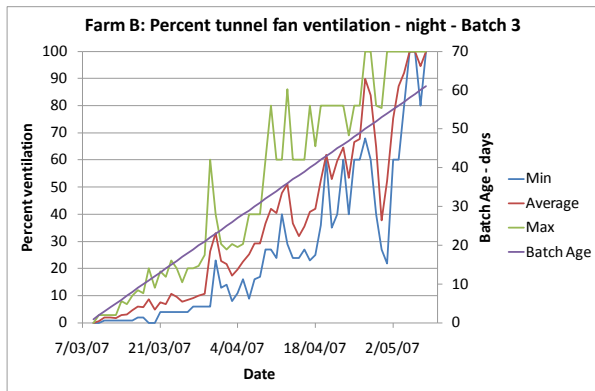
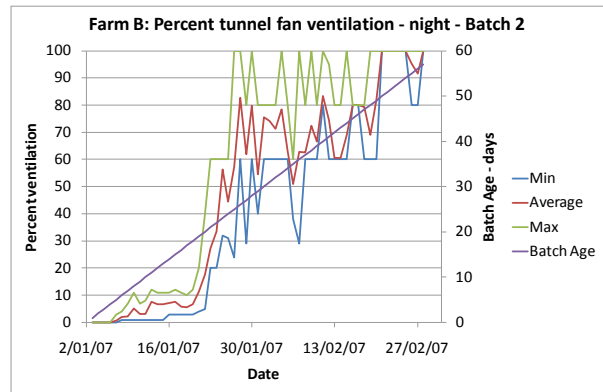
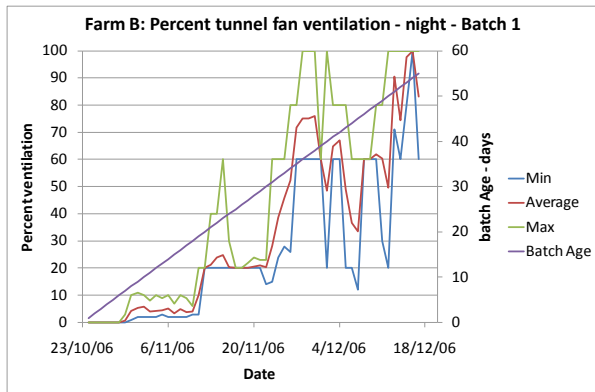


Appendix 8 Tunnel fan activity charts for Night – all sites and all batches

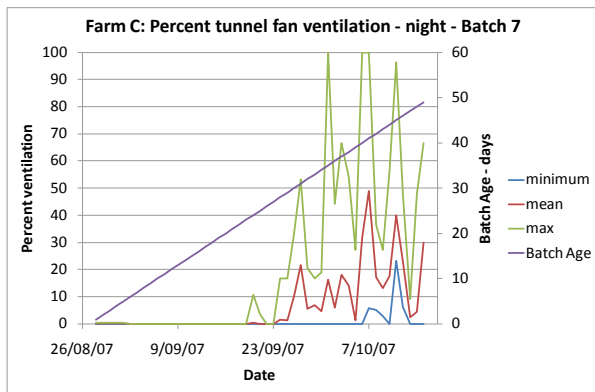
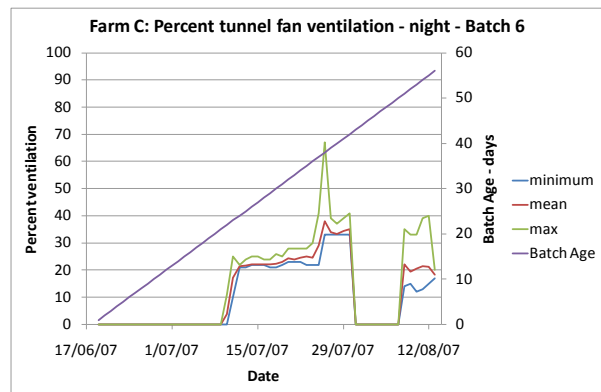
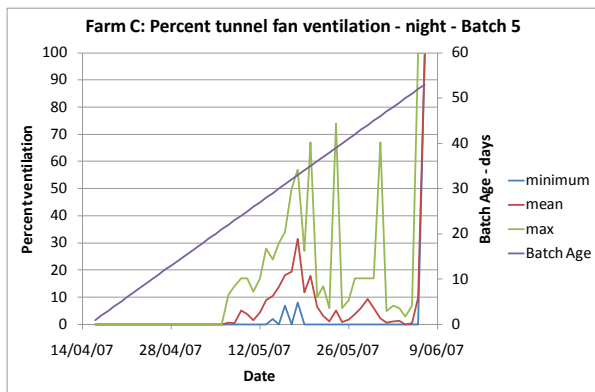
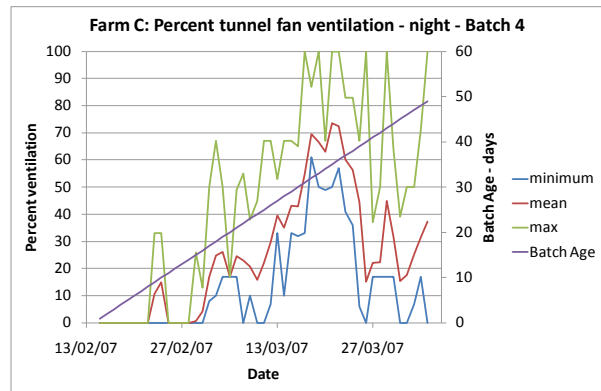
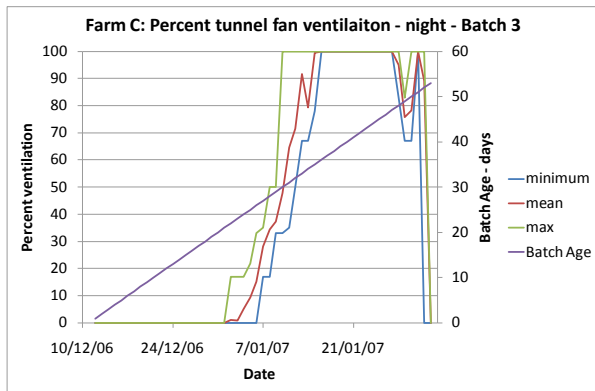
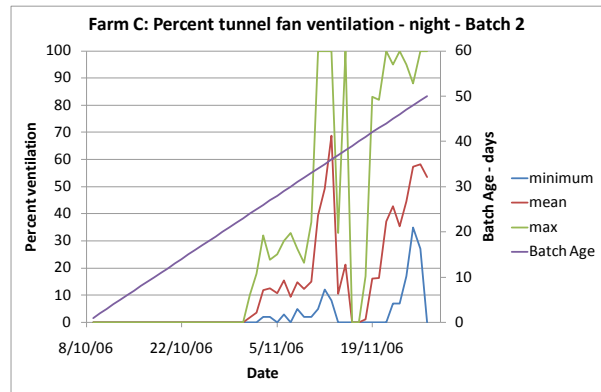
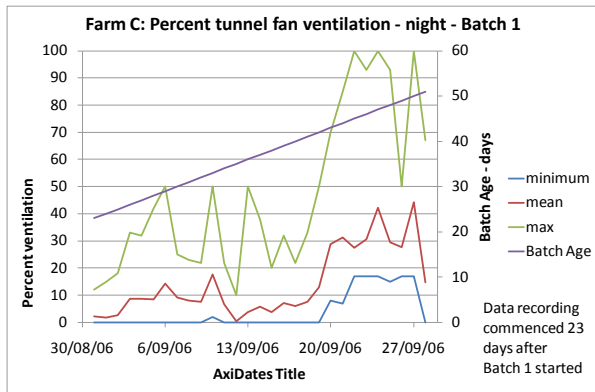
Appendix 8.1 Farm A tunnel fan activity for ‘Night’ - All batches



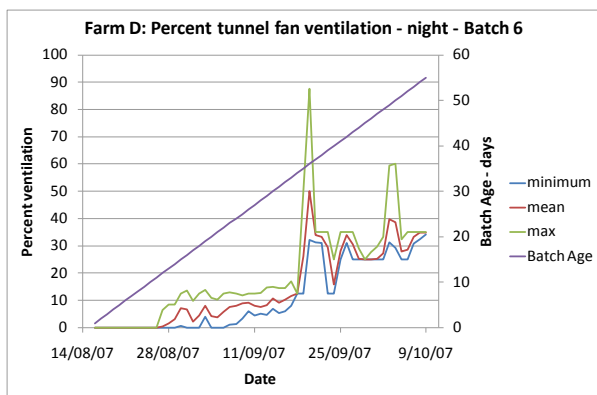
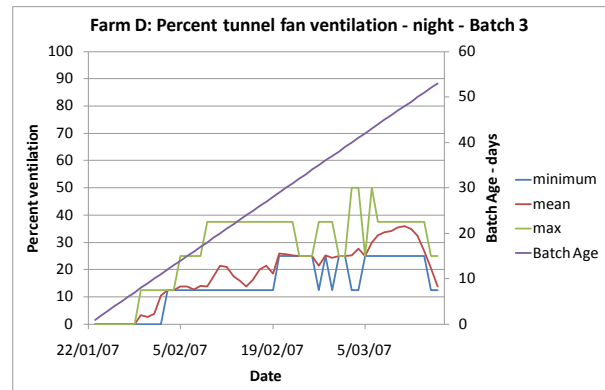
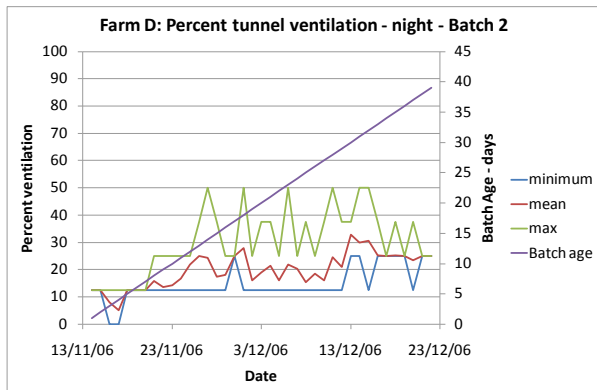
Appendix 8.2 Farm B tunnel fan activity for 'Night' - All batches



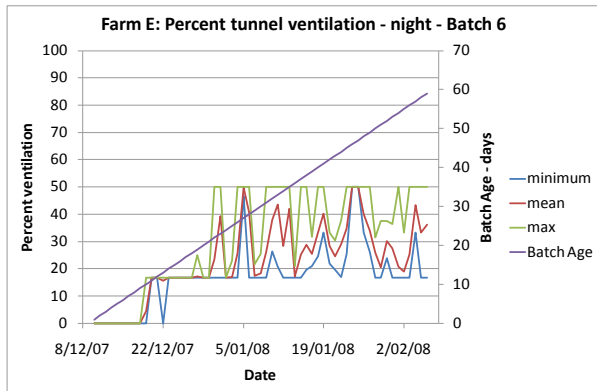
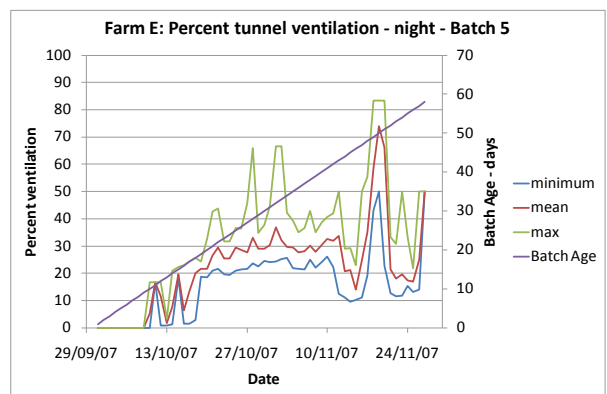
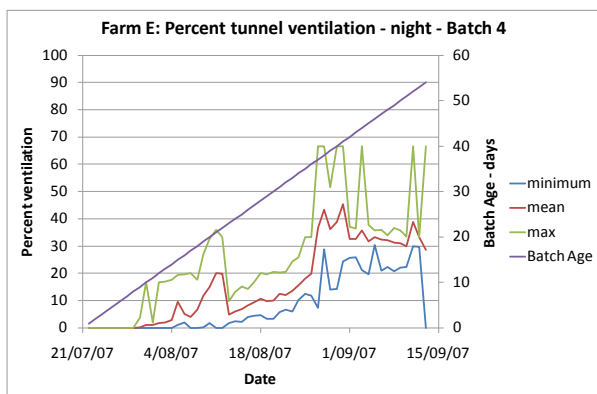
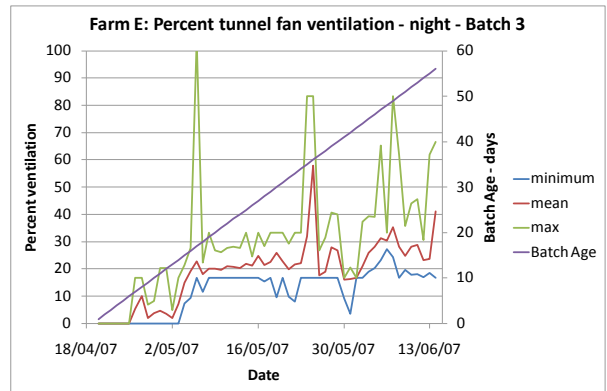
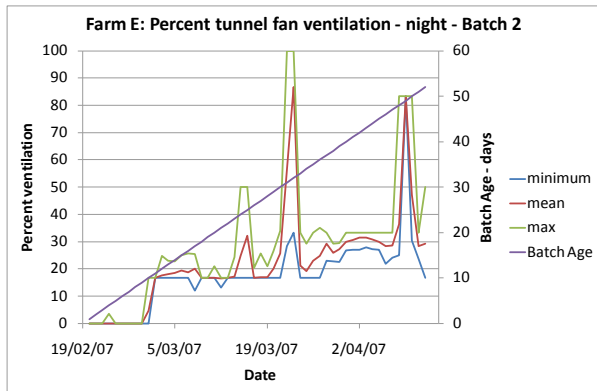
Appendix 8.3 Farm C tunnel fan activity for 'Night' - All batches



Appendix 8.4 Farm D tunnel fan activity for 'Night' - Batches 2, 3 and 6. Batch 1 commenced before recording equipment commissioned. Batch 4 and 5 experienced recording equipment malfunctions

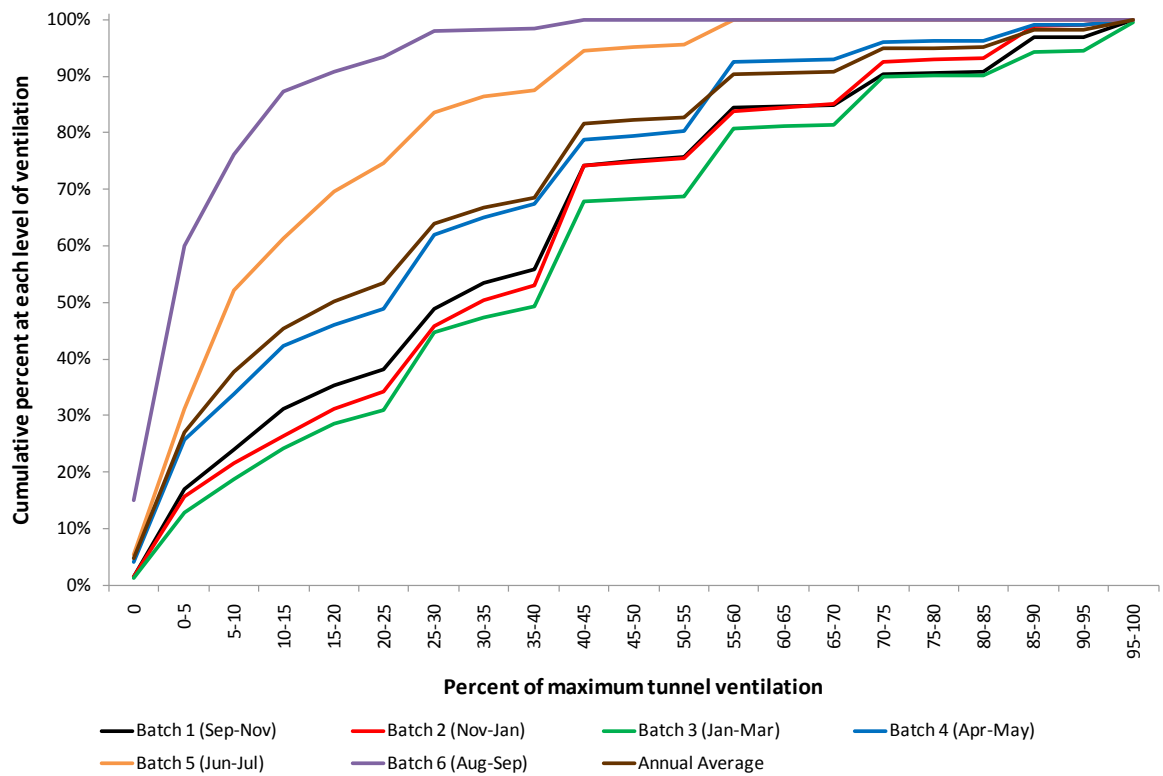


Appendix 8.5 Farm E tunnel fan activity for 'Night' - Batches 2 through 6 (Batch 1 commenced prior to equipment being commissioned)

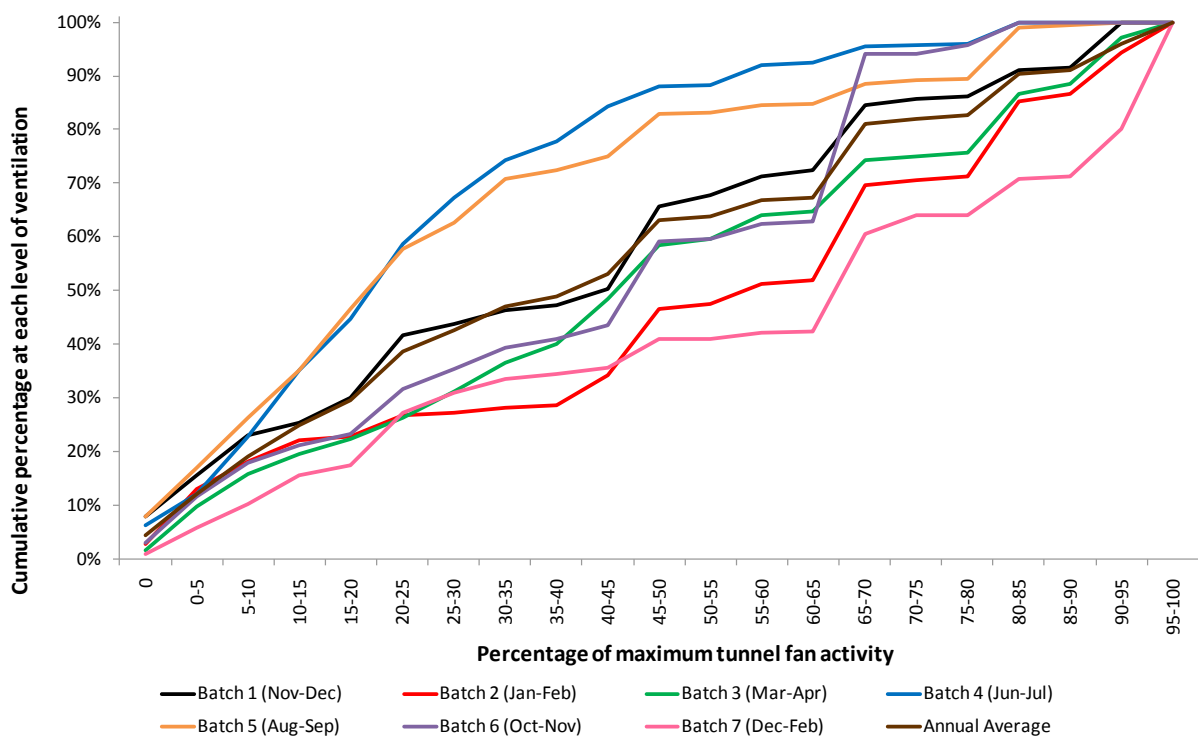


Appendix 9 Cumulative total fan activity all sites and all batches

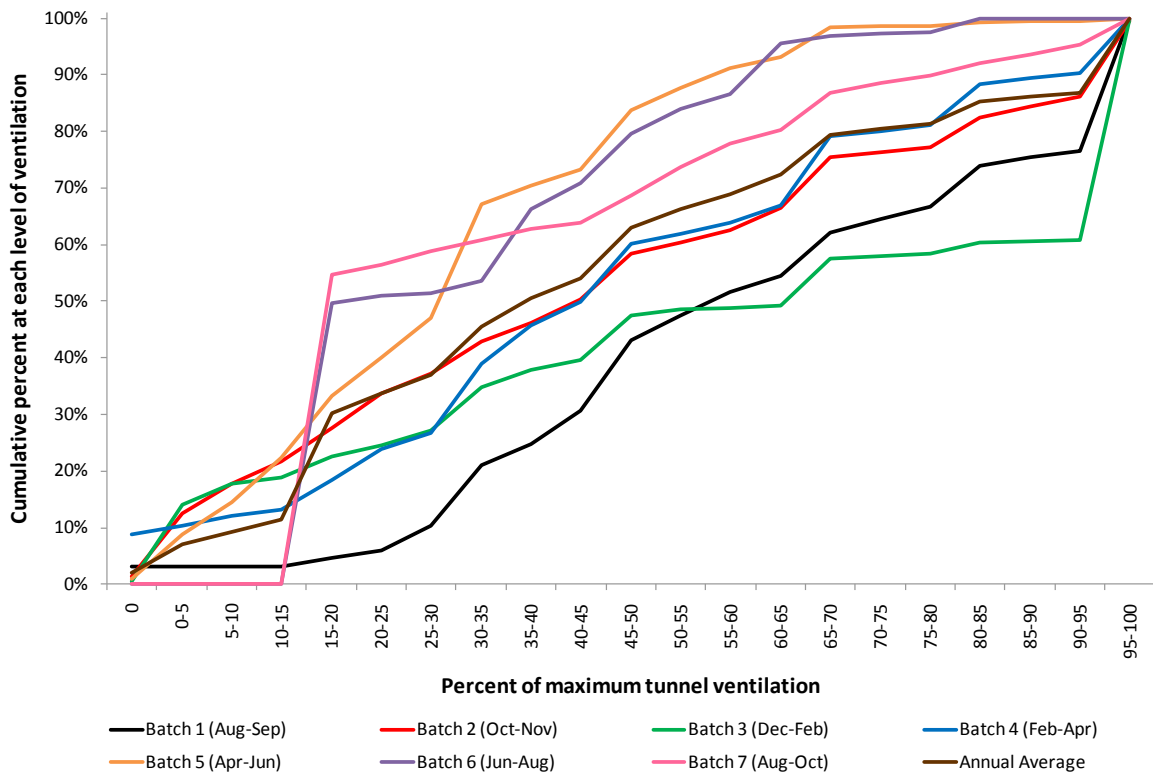
Appendix 9.1 Farm A Cumulative total fan activity—All batches and annual average



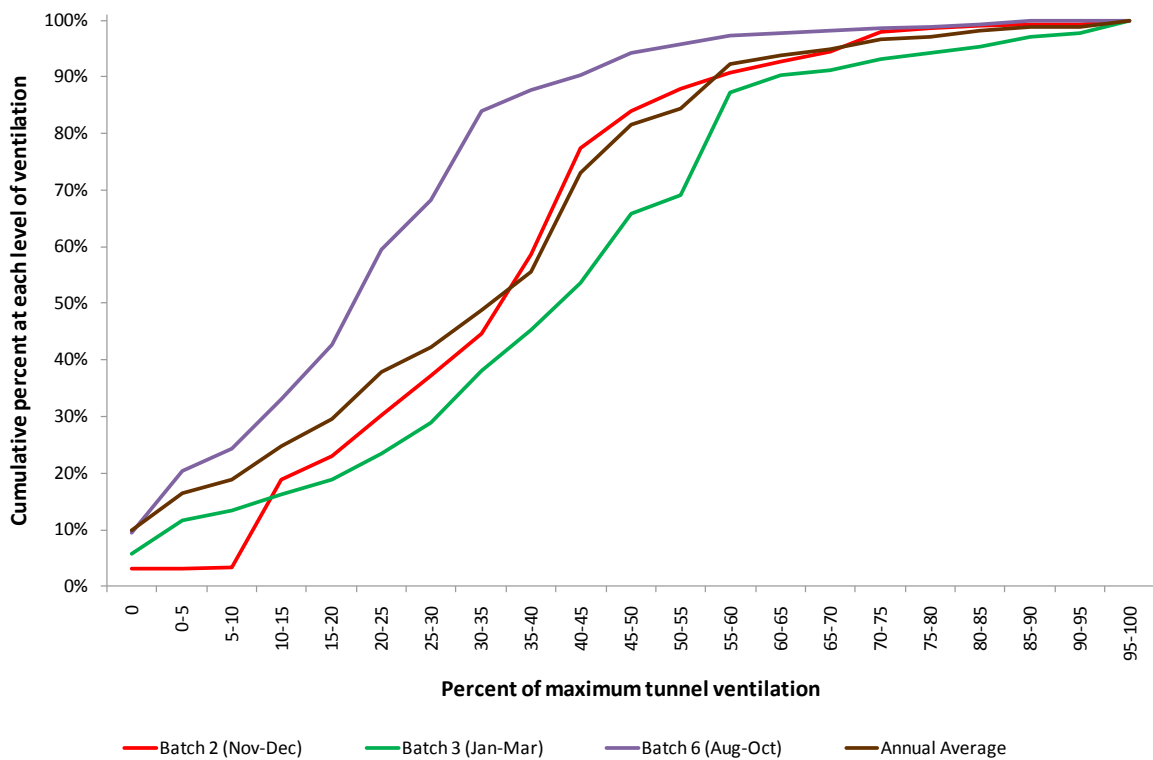
Appendix 9.2 Farm B Cumulative total fan activity—All batches and annual average



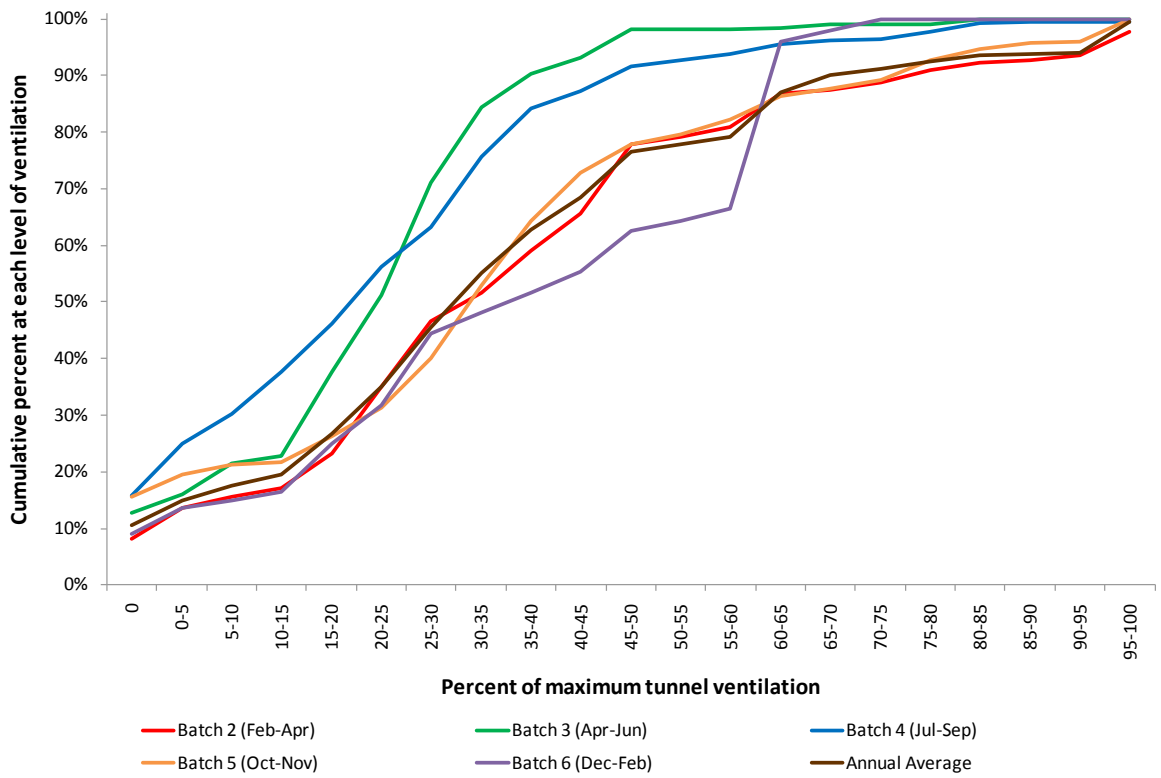
Appendix 9.3 Farm C Cumulative total fan activity—All batches and annual average



Appendix 9.4 Farm D Cumulative total fan activity—All batches and annual average (except batch 1 due to the monitoring equipment only being installed from day 48; batch 4 due to equipment failure days 9–44; and batch 5 due to equipment failure throughout the batch)

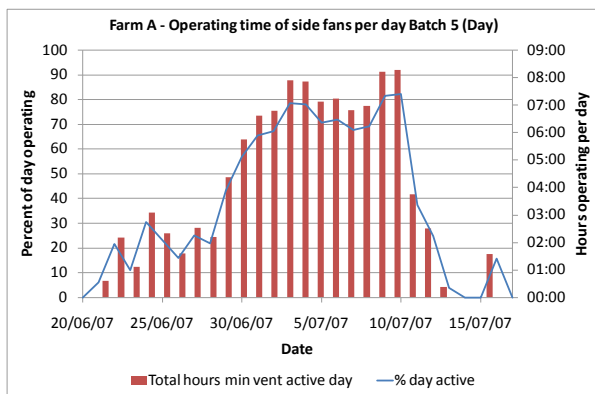
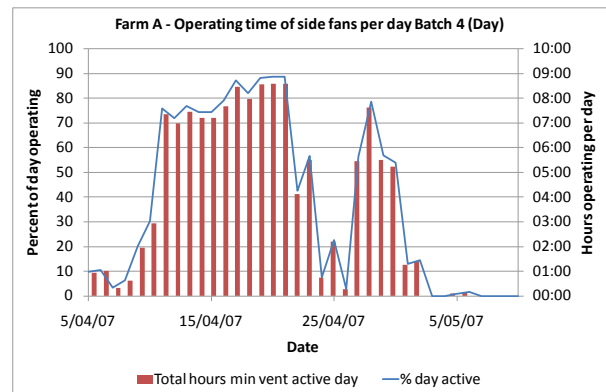
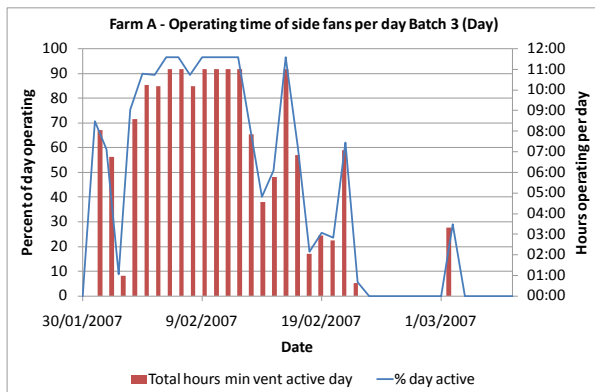
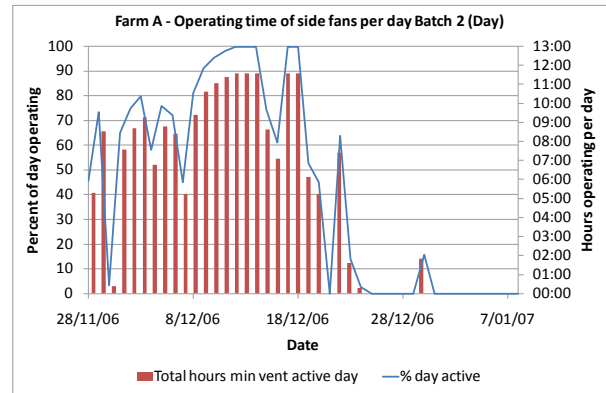
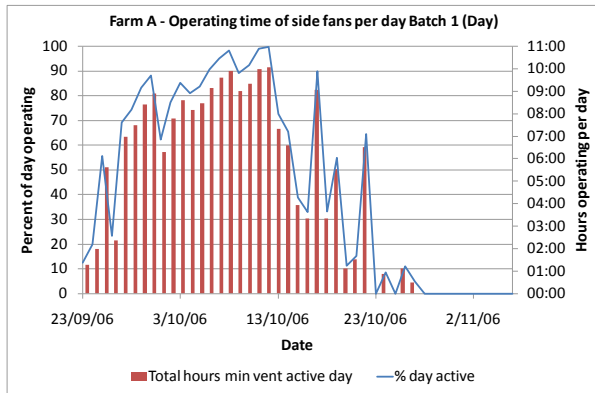


Appendix 9.5 Farm E Cumulative total fan activity—All batches and annual average (except batch 1 due to the monitoring equipment only being installed on day 37)

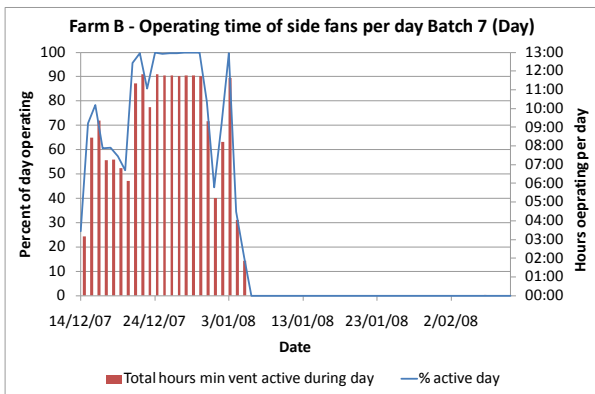
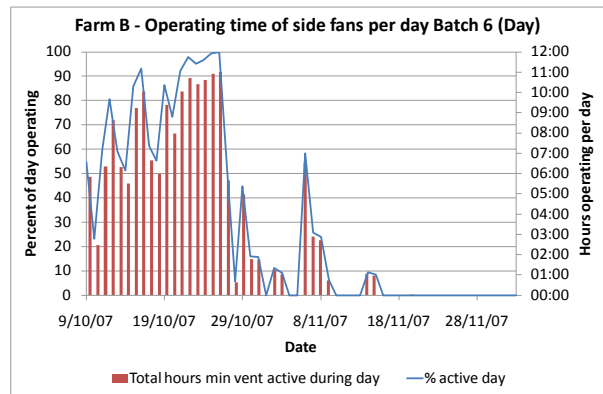
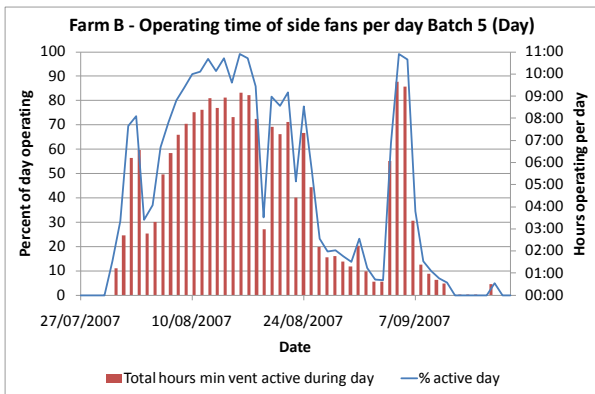
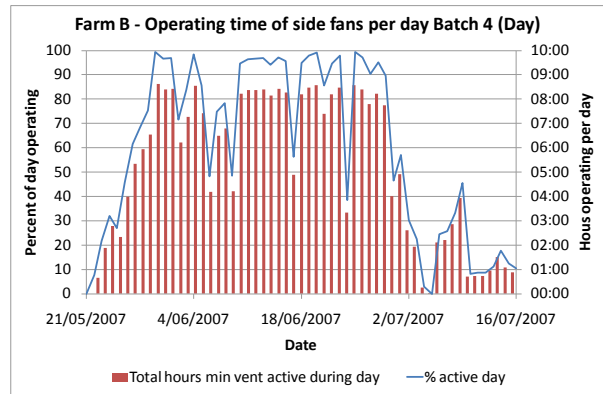
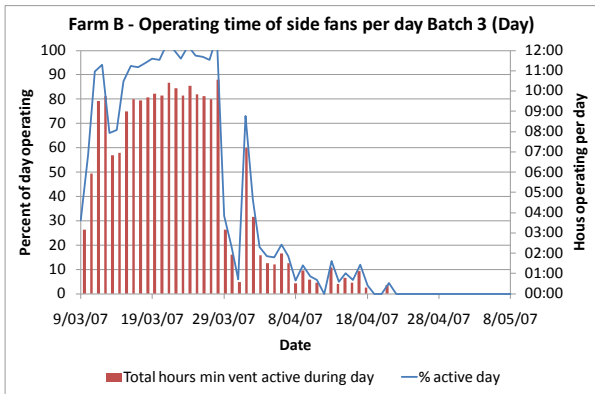
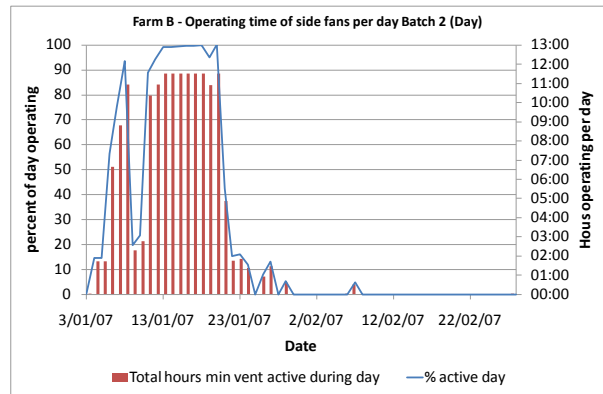
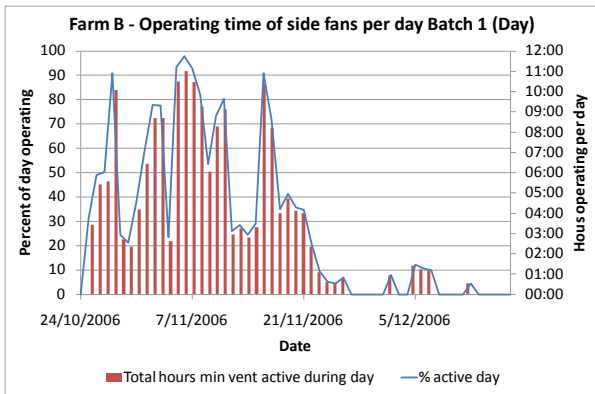


Appendix 10 Side fan percentage activity and sum – ‘Day’: All sites and all batches

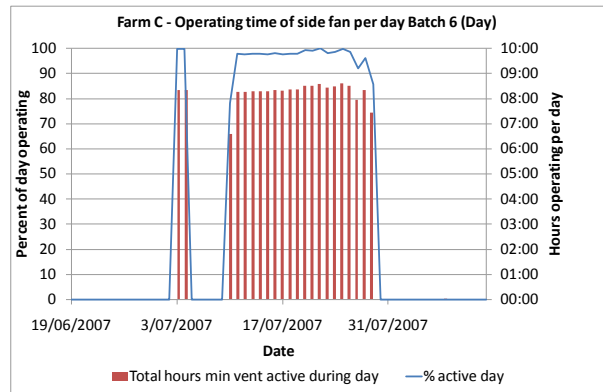
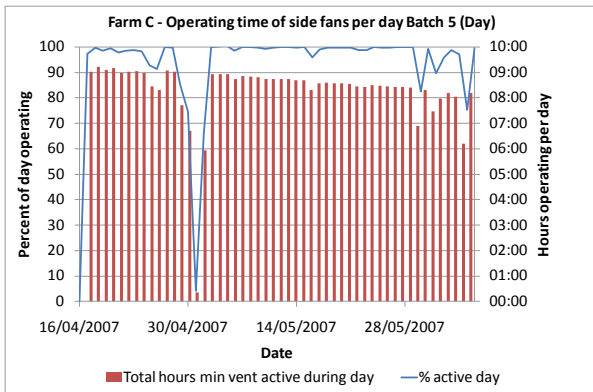
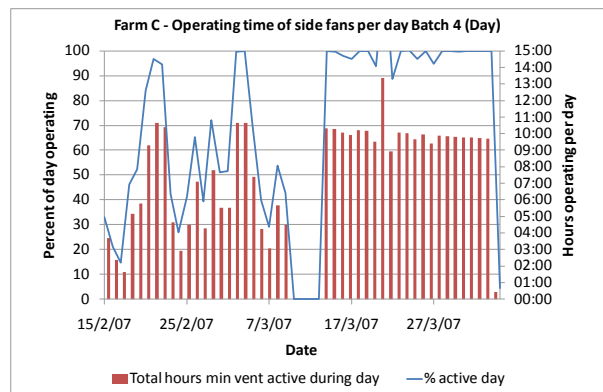
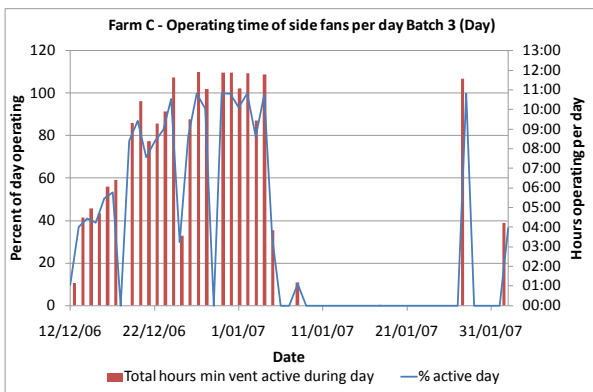
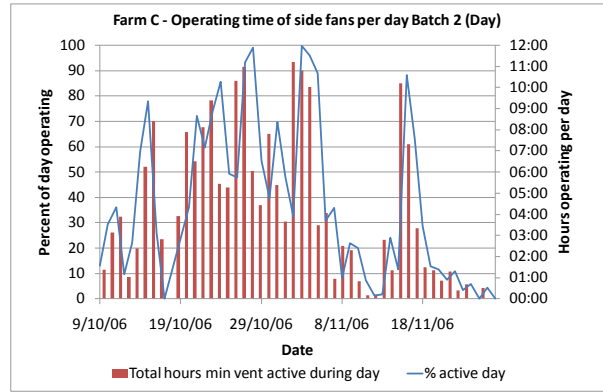
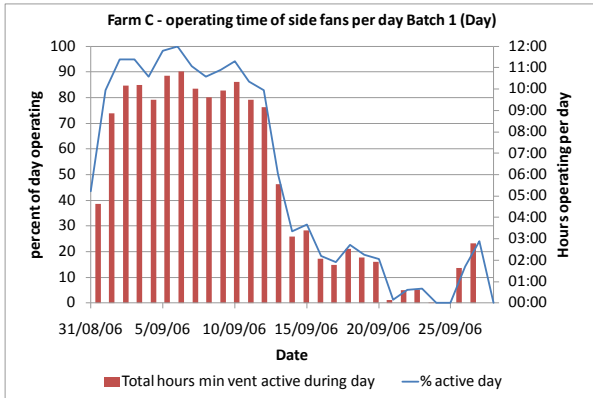
Appendix 10.1 Farm A side fan operating hours and percentage of ‘Day’ - All batches



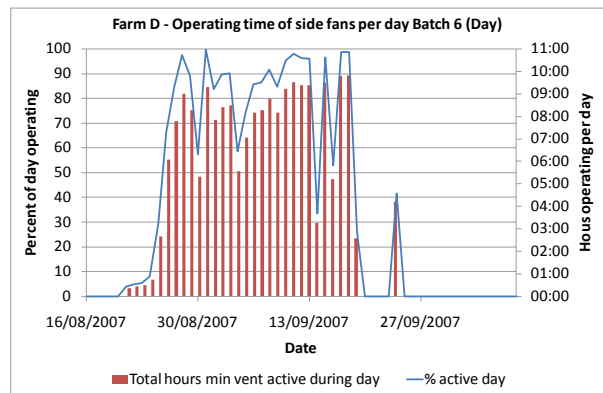
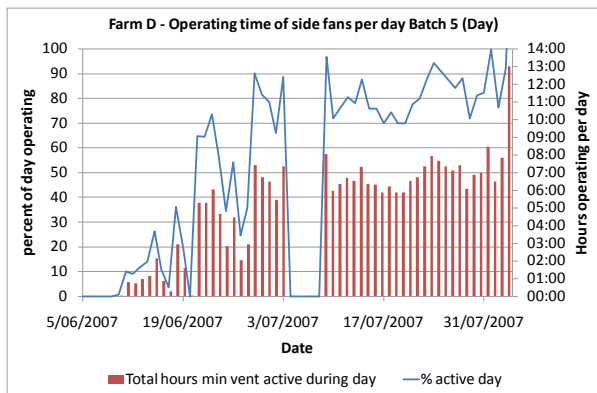
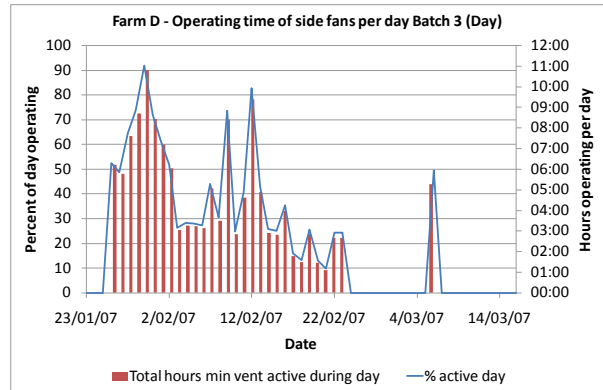
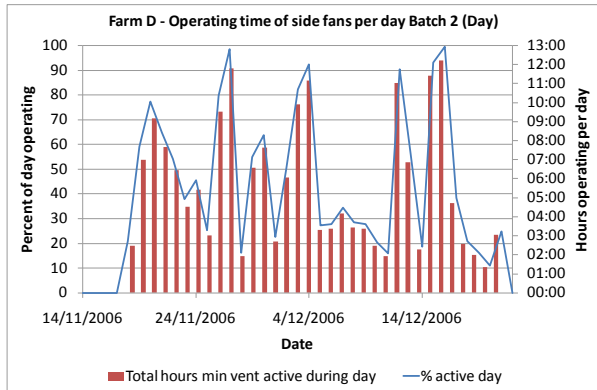
Appendix 10.2 Farm B side fan operating hours and percentage of 'Day' - All batches



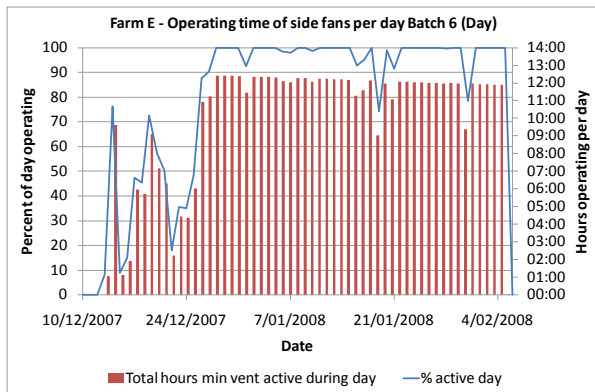
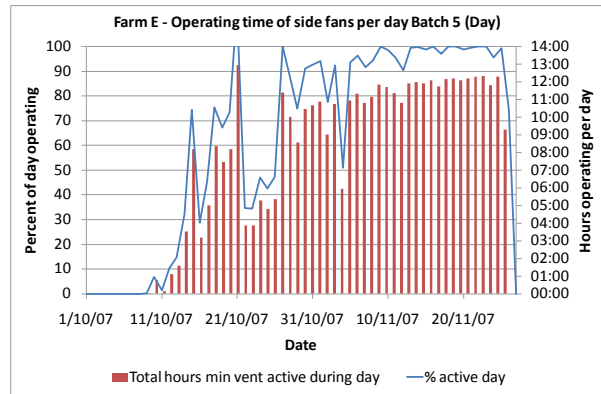
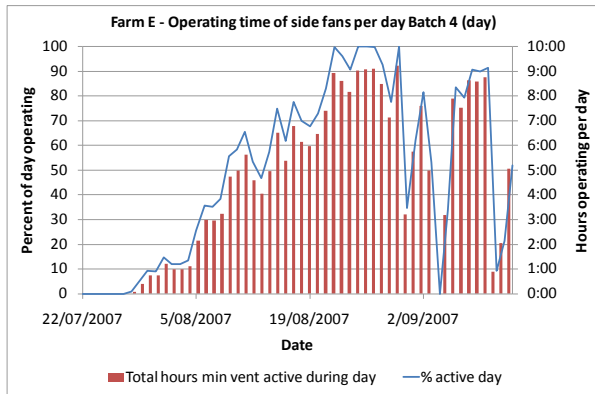
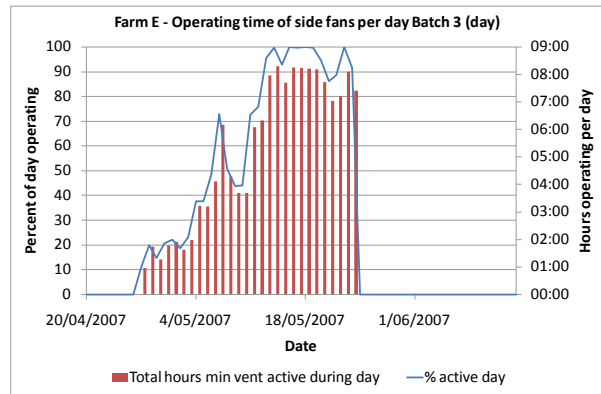
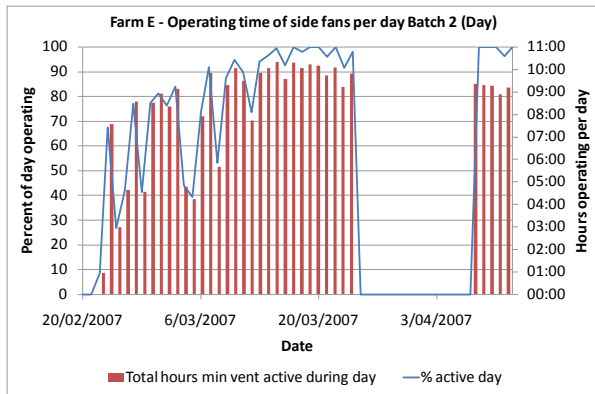
Appendix 10.3 Farm C side fan operating hours and percentage of 'Day' - All batches excluding batch 7 (sensors failed)



Appendix 10.4 Farm D side fan operating hours and percentage of 'Day' - All batches excluding batch 1 due to batch commencing prior to equipment commissioning, and batch 4 due to equipment malfunction

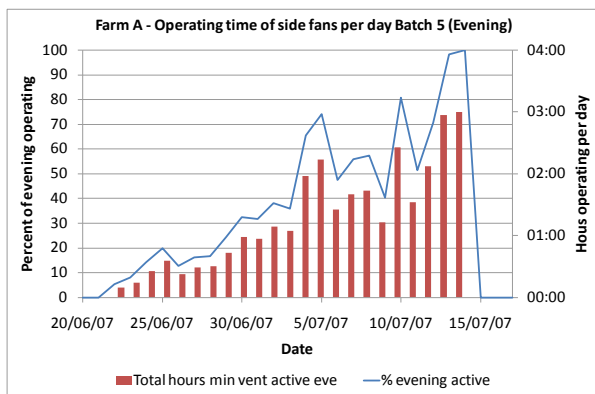
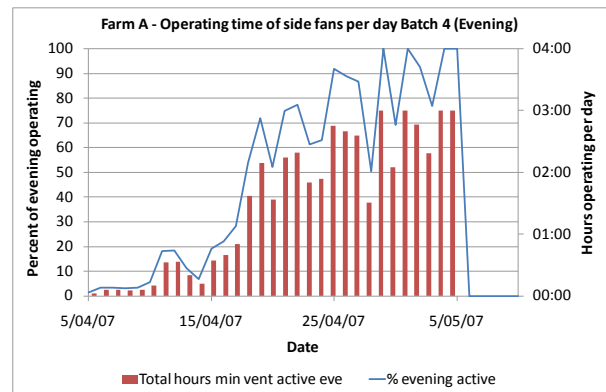
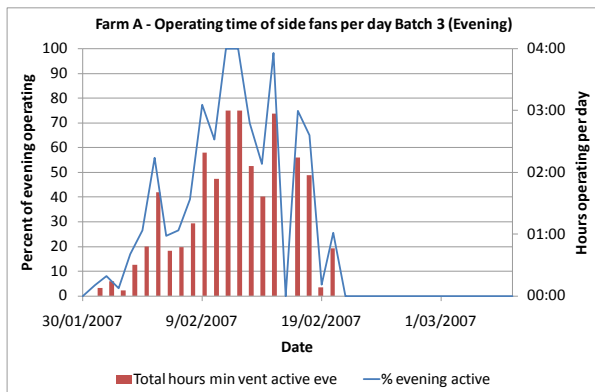
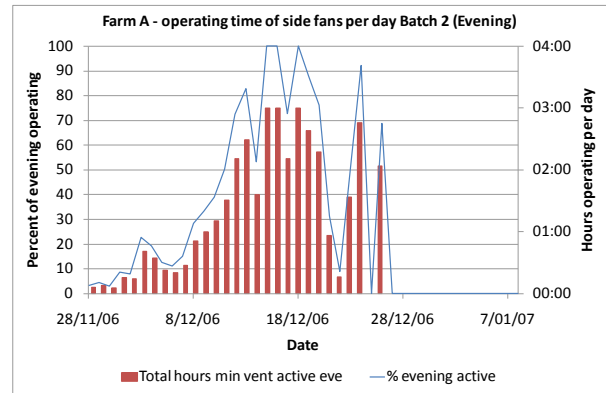
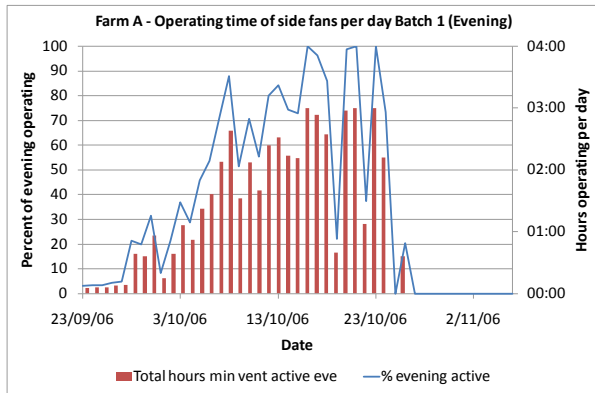


Appendix 10.5 Farm E side fan operating hours and percentage of 'Day' - All batches

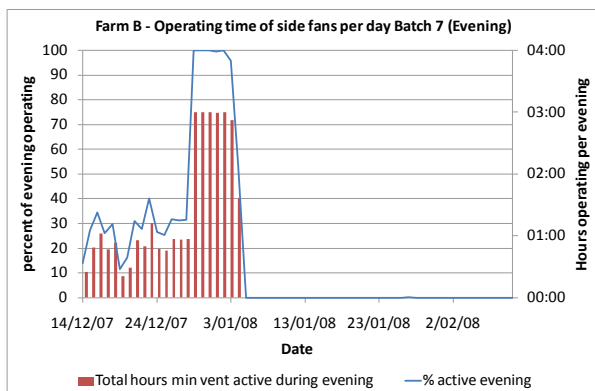
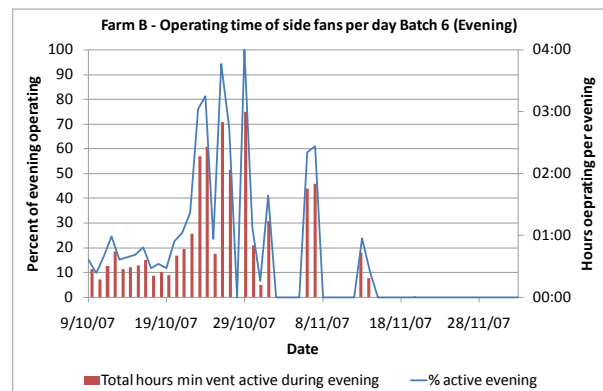
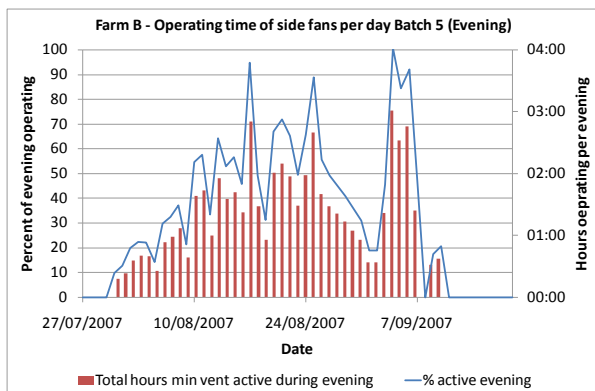
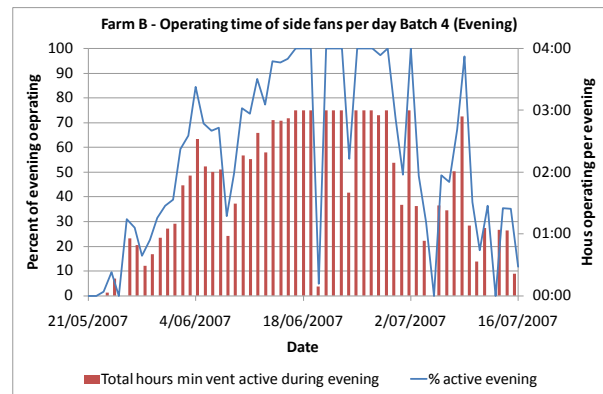
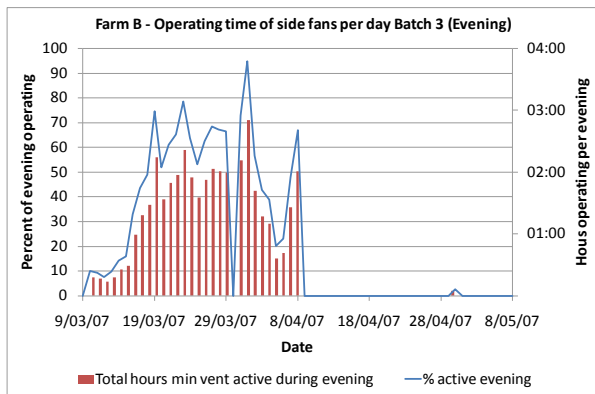
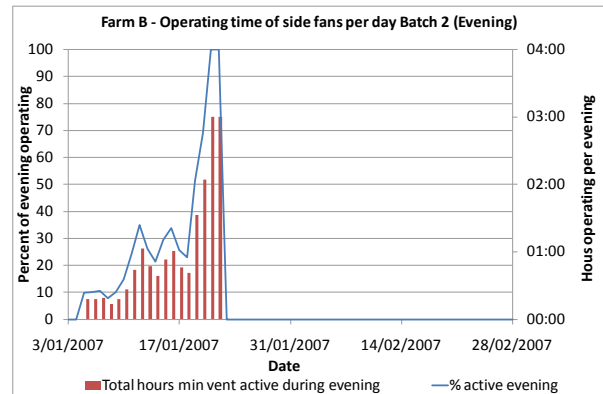
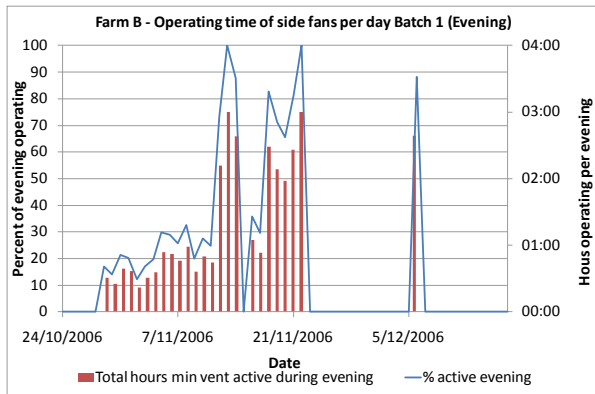


Appendix 11 Side fan percentage activity and sum – Evening: All sites and all batches

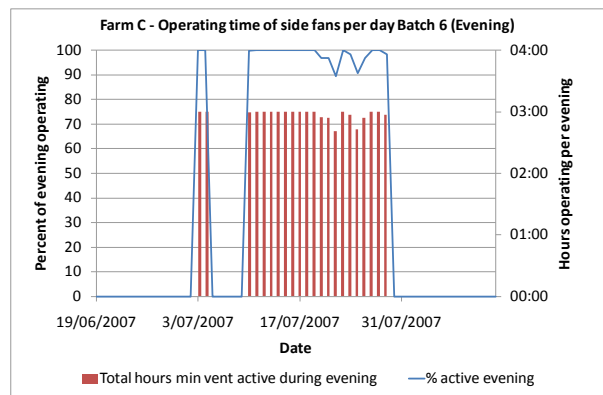
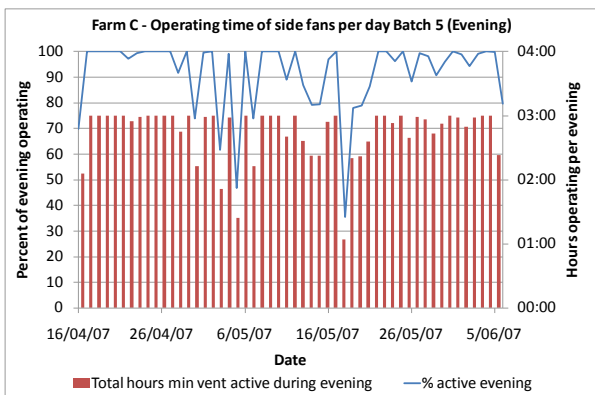
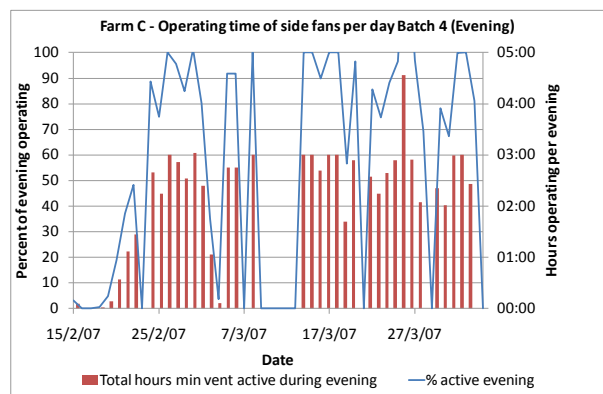
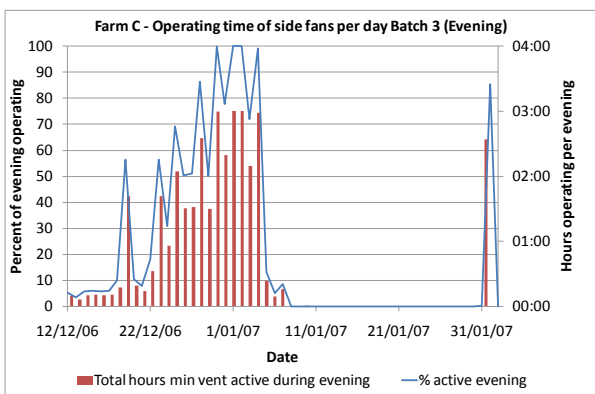
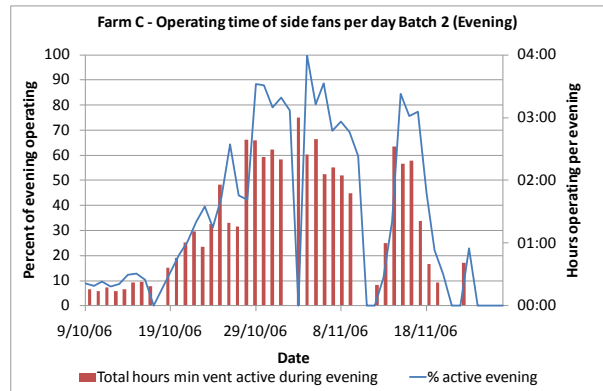
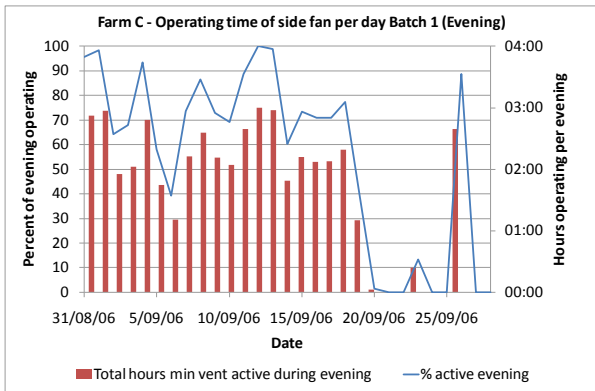
Appendix 11.1 Farm A side fan operating hours and percentage of ‘Evening’ - All batches



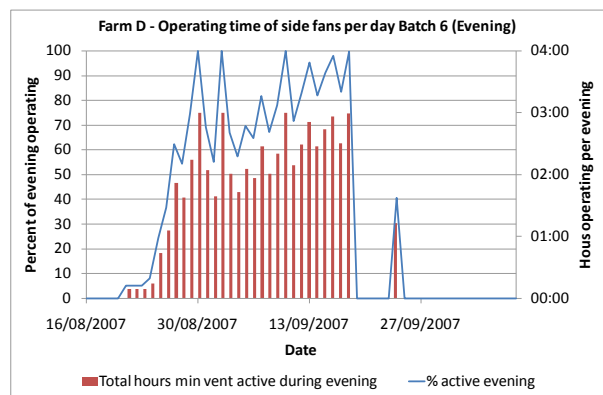
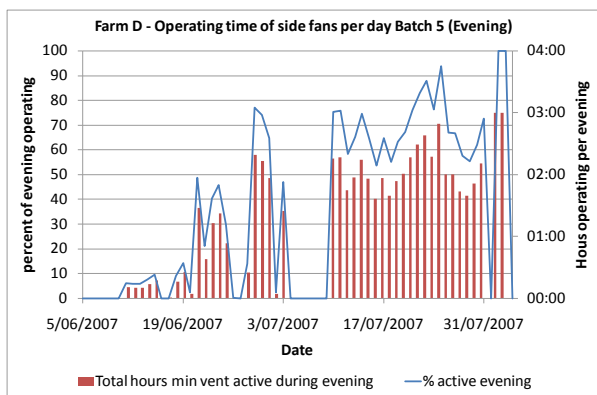
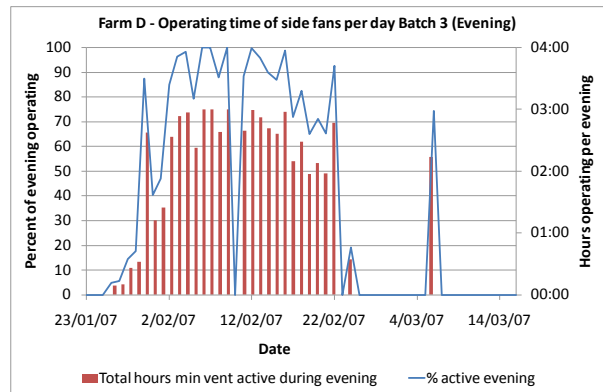
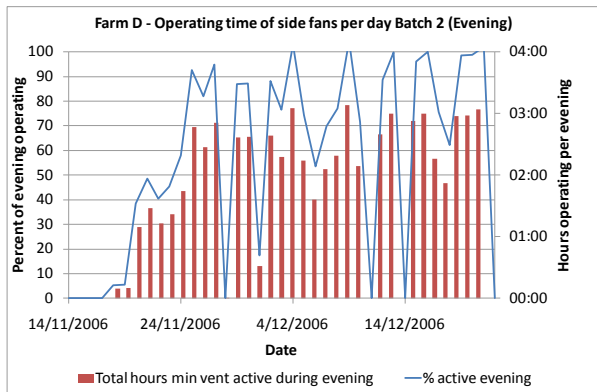
Appendix 11.2 Farm B side fan operating hours and percentage of 'Evening' - All batches



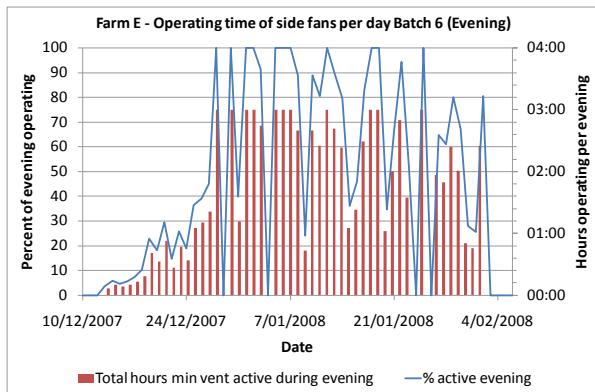
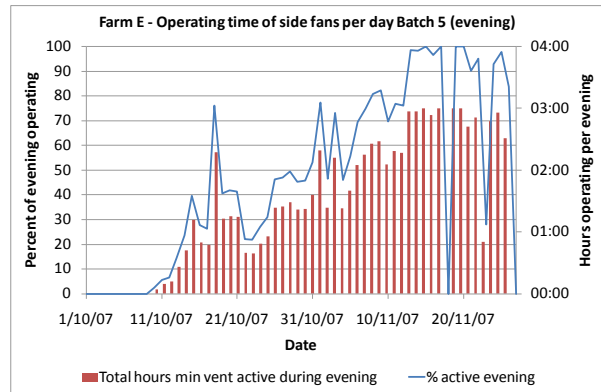
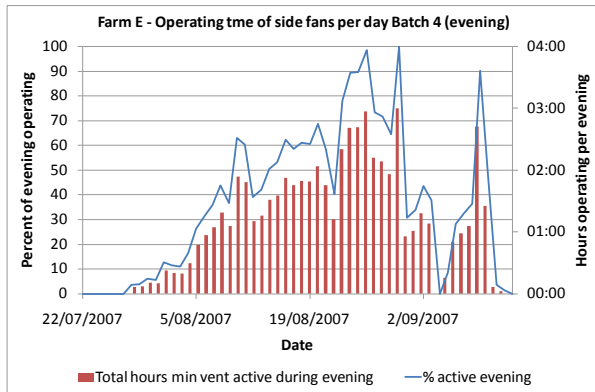
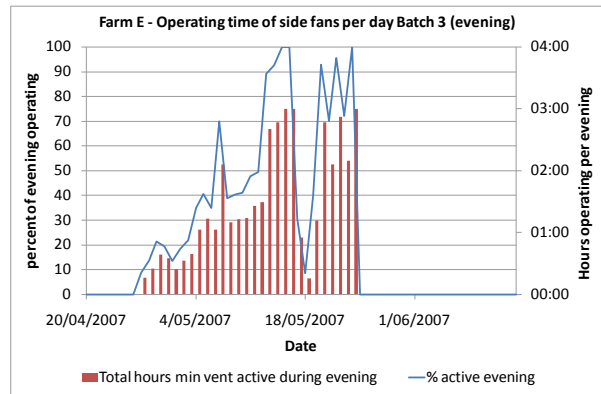
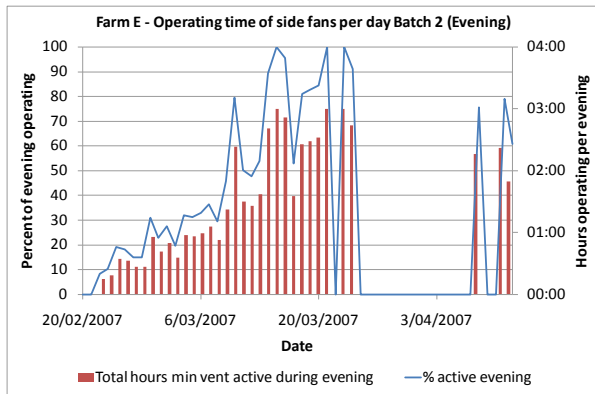
Appendix 11.3 Farm C side fan operating hours and percentage of 'Evening' - All batches excluding batch 7 (sensors failed)



Appendix 11.4 Farm D side fan operating hours and percentage of ‘Evening’ - All batches (excluding batch 1 as batch commenced prior to equipment commissioned, and batch 4 due to equipment malfunction)

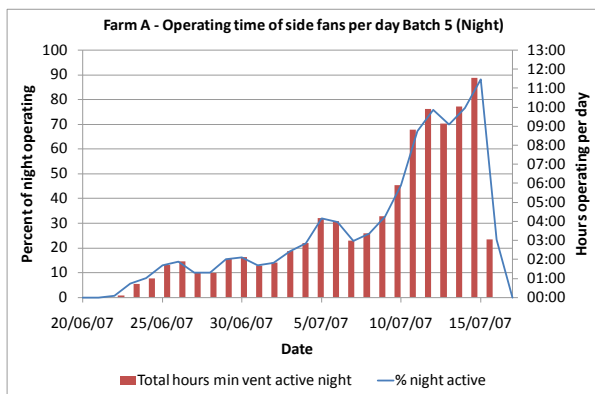
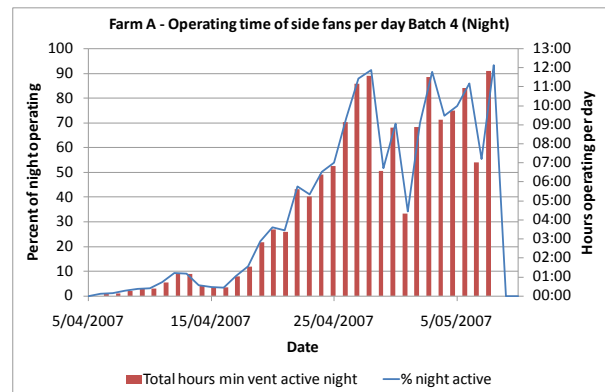
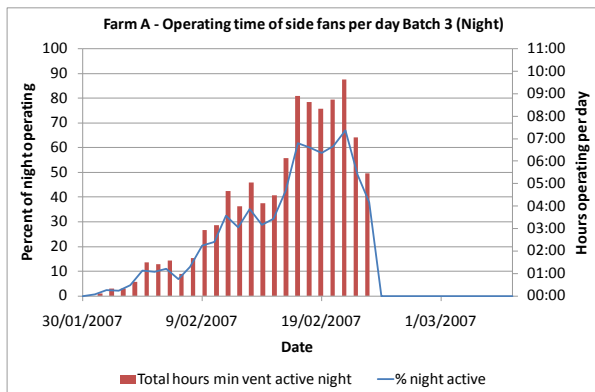
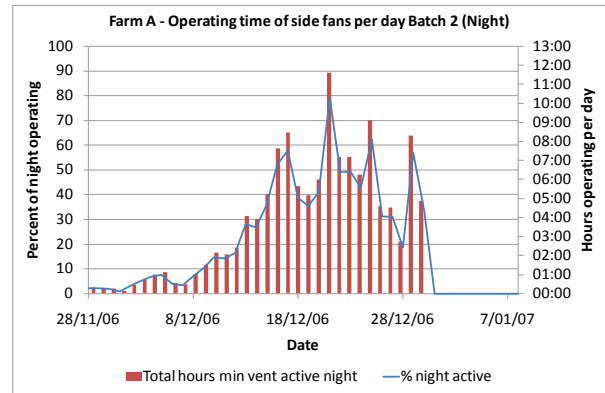
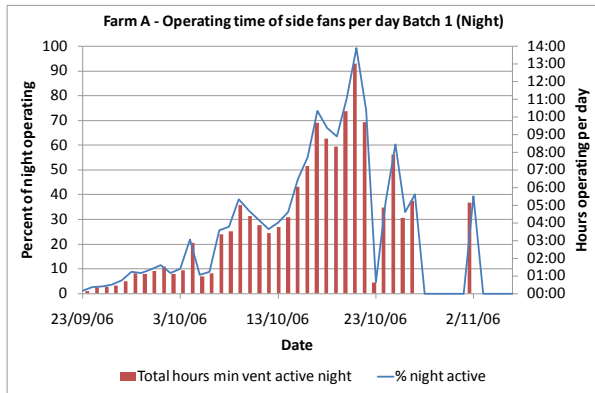


Appendix 11.5 Farm E side fan operating hours and percentage of 'Evening' - All batches

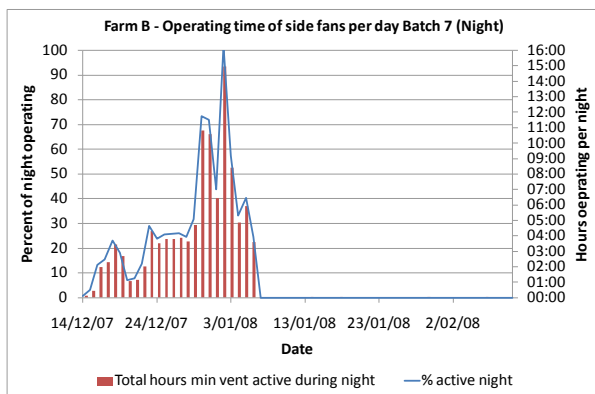
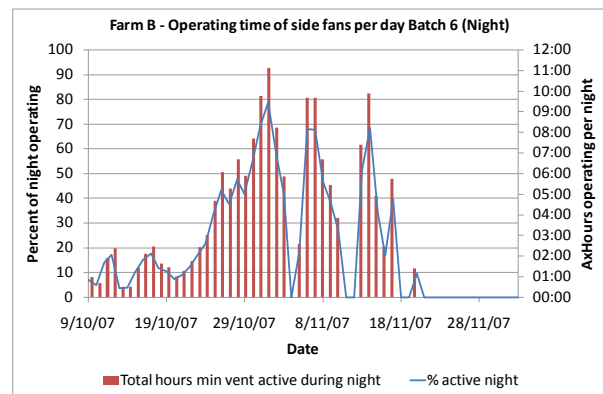
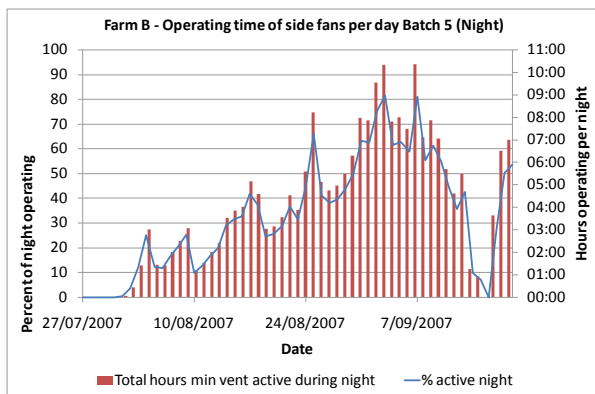
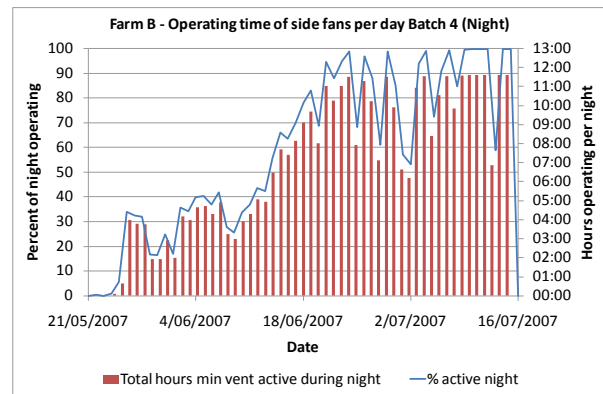
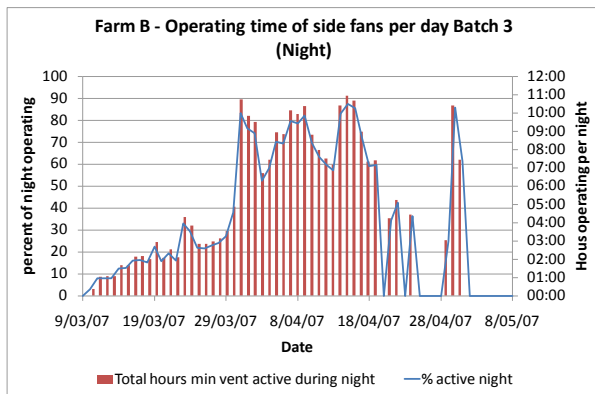
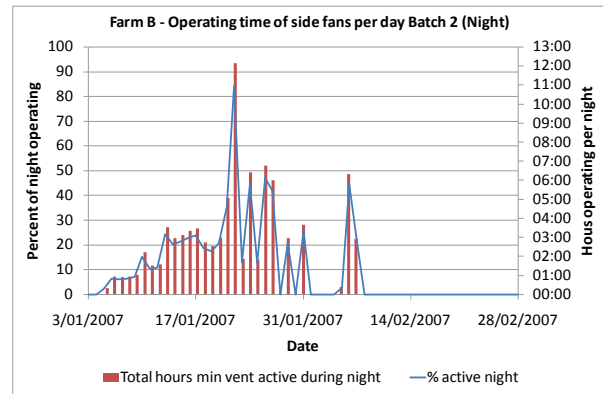
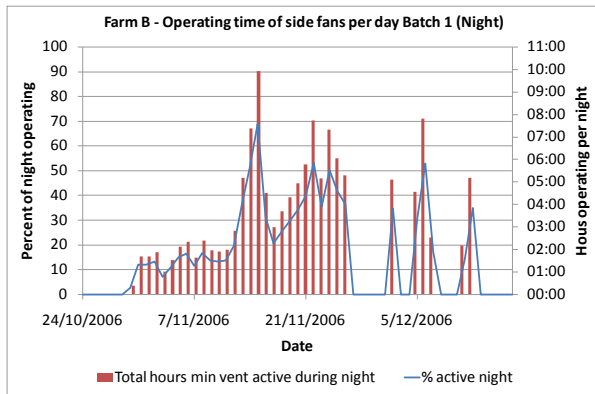


Appendix 12 Side fan percentage activity and sum – Night: All sites and all batches

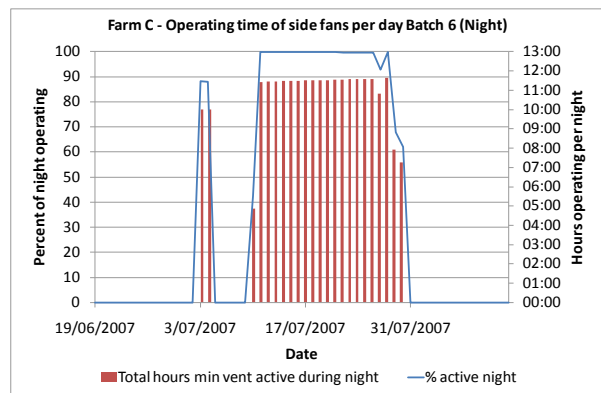
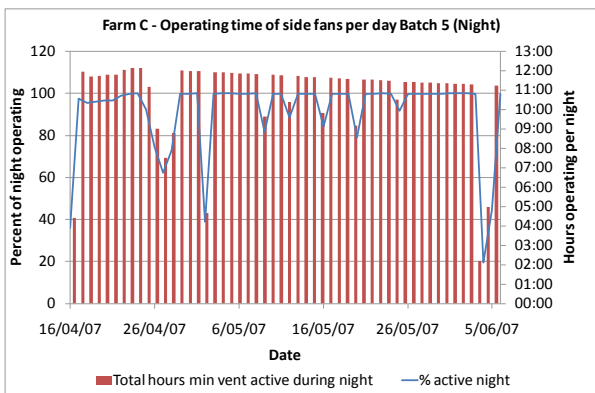
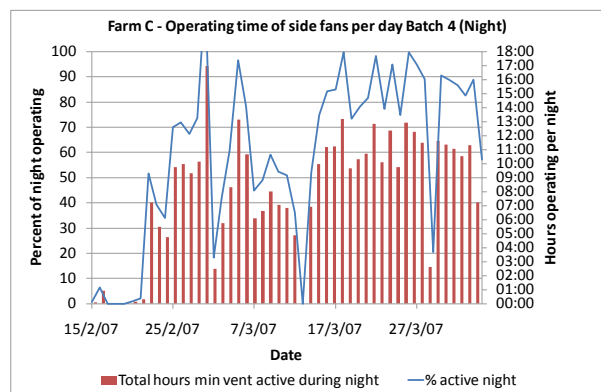
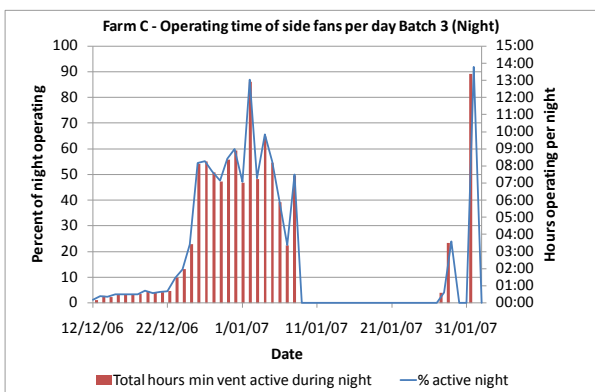
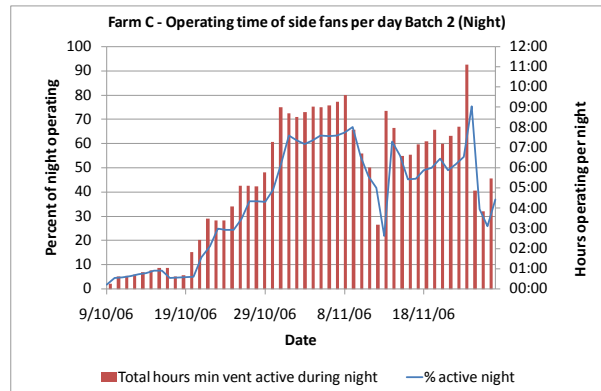
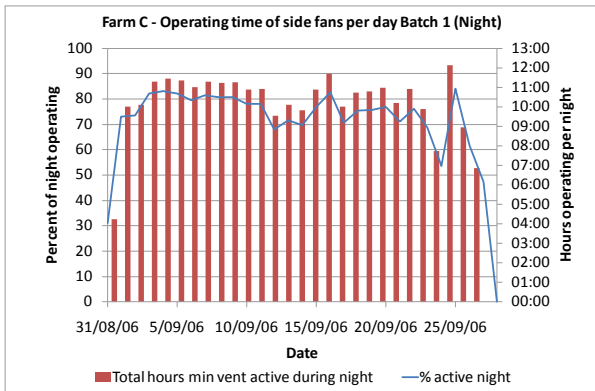
Appendix 12.1 Farm A side fan operating hours and percentage of ‘Night’ - All batches



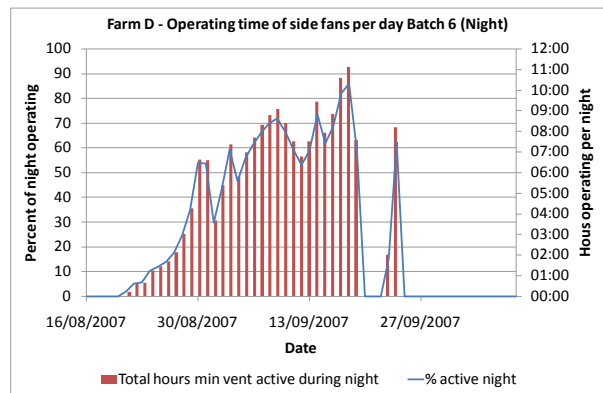
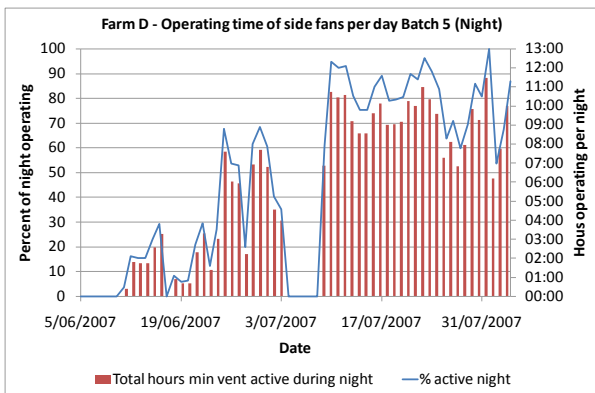
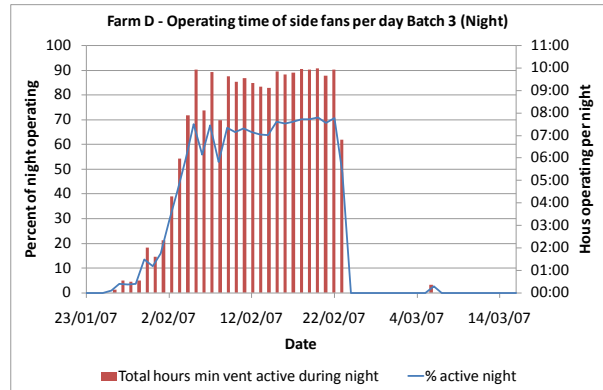
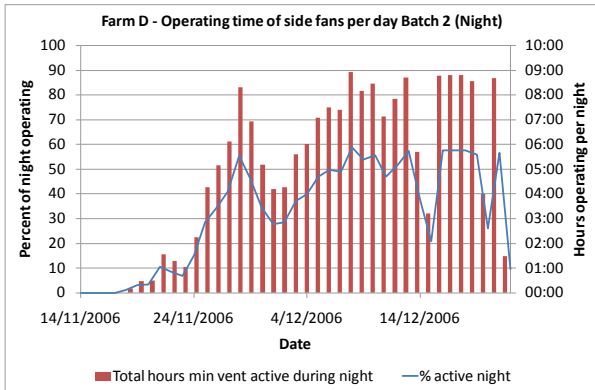
Appendix 12.2 Farm B side fan operating hours and percentage of 'Night' - All batches



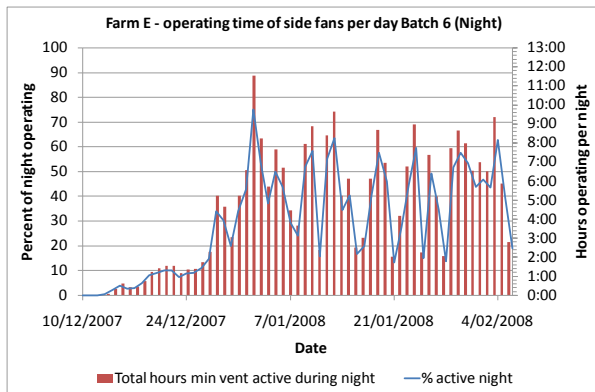
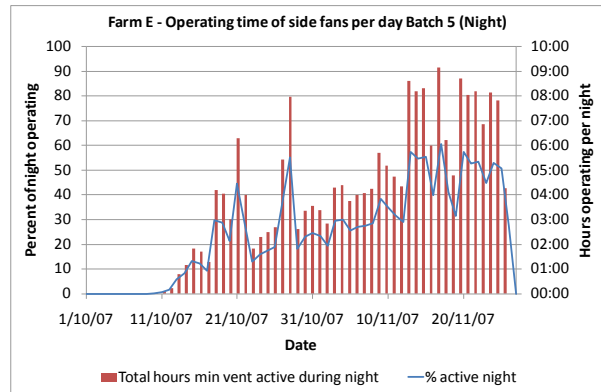
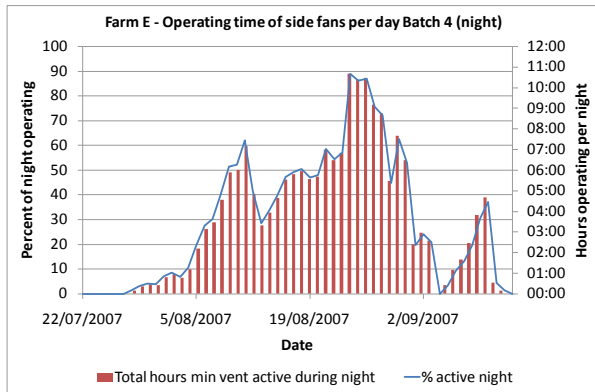
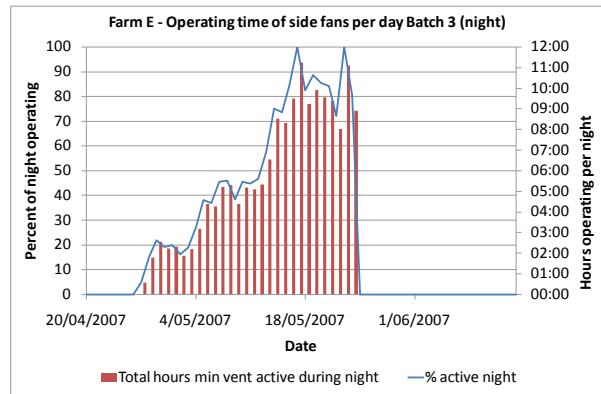
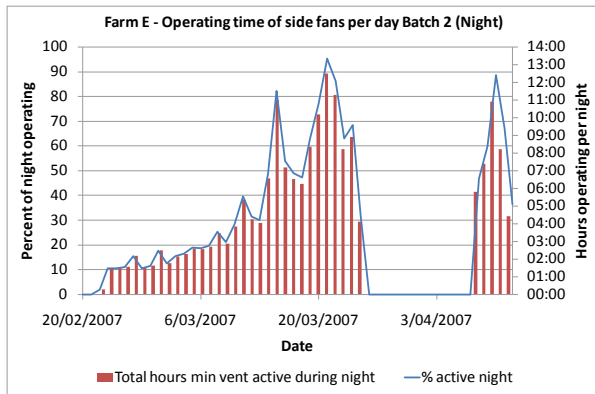
Appendix 12.3 Farm C side fan operating hours and percentage of 'Night' - All batches excluding batch 7 (sensors failed)



Appendix 12.4 Farm D side fan operating hours and percentage of ‘Night’ - All batches excluding batch 1 due to batch commencing prior to equipment commissioning) and batch 4 (due to equipment malfunction



Appendix 12.5 Farm E side fan operating hours and percentage of 'Night' - All batches



Monitoring Mechanical Ventilation Rates in Poultry Buildings

By Mark Dunlop and David Duperouzel

Pub. No. 13/O24

Increasing pressure is being placed upon the chicken meat industry to reduce odour and dust emissions from poultry sheds. Recent research has identified that ventilation rate significantly influenced the odour emission rate from meat chicken sheds.

The information provided in this report will enable producers, consultants and regulators to improve their knowledge of ventilation requirements for tunnel ventilated poultry sheds.

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