European Innovation Partnership (EIP) Wales

Ammonia reduction from broiler chicken production

Final Report

March 2022

GENERAL NOTES

Title: Ammonia reduction from broiler chicken production

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Date:	March 2022

BACKGROUND

About EIP-AGRI

The European Innovation Partnership for Agricultural Productivity and Sustainability (EIP-AGRI) was launched by the European Commission in 2012. It aims to foster a competitive and sustainable agriculture and forestry sector that "achieves more from less". It contributes to ensuring a steady supply of food, feed and biomaterials, and to the sustainable management of the essential natural resources on which farming and forestry depend, working in harmony with the environment.

EIP Wales

Menter a Busnes delivers the EIP Wales scheme on behalf of the Welsh Government and has received funding through the Welsh Government Rural Communities – Rural Development Programme 2014-2020, which is funded by the European Agricultural Fund for Rural Development and the Welsh Government. For Welsh farm and forestry businesses to remain competitive, profitable and resilient, they will need to work on a continuous programme of improving both business and technical practices.

The aim of EIP Wales is to solve common agricultural and forestry problems by bringing people from practical and scientific backgrounds together. It is an opportunity for farmers and foresters to put their ideas into practice by testing new technologies or techniques. Each project that is approved has access of up to £40,000 (incl. VAT) and can run for 3 years or until March 2023.

Project Outline

An inevitable consequence of poultry farming is the production of ammonia, through the natural breakdown of urates within poultry manure. As a result of environmental concerns over ammonia emissions, future reductions are being targeted through government policy. This project measures ammonia emissions from conventional poultry meat (broiler) systems in two pairs of houses on two farms.

On each farm, a control system in one house is compared with the use of three different additives intended to reduce ammonia emissions in the other house. The project therefore extends over three production cycles with each additive being used once on each farm. Comparisons are also made of bird welfare and flock performance (physical and economic). Overall, the objective is to identify best practice which could then be used on other farms.

EIP Operational group

The businesses represented in the operational group and other members of the project are set out in Tables 1 and 2 below. The names of the farmers involved are being kept confidential in this report at their request (see section 2.5.2).

Table 1 Operational group for the project

Organisation	Name	Farm/Location	Role
Farmer 1	Confidential	Farm 1 South Wales	Lead Farmer and principal contact
Farmer 2	Confidential	Farm 2 North Wales	Farmer
Ian Pick Associates Ltd	Ian Pick	Station Farm Offices, Wansford Road, Nafferton, Driffield, East Yorkshire, YO25 8NJ	Actor

Table 2 Other members of the project

Organisation	Name	Farm/Location	Role
RSK ADAS Ltd	Jason Gittins	Cefn Llan Science Park, Aberystwyth SY23 3AH	Project manager
RSK ADAS Ltd	Will John	Henstaff Court Business Centre, Groesfaen, Cardiff CF72 8NG	Innovation Broker

EXECUTIVE SUMMARY

Broiler production has been a growth area in Welsh agriculture in recent years but ammonia emissions from poultry production have led to concerns over environmental impacts. Aerial emissions of ammonia can damage sensitive habitats and react with other atmospheric acids to impact adversely on human health. In 2019, the poultry sector was responsible for 14% of all UK ammonia emissions and under international agreements, the UK government has agreed to reduce emissions by 16% by 2030, compared to 2005.

The environmental permitting regime for intensive farming requires the adoption of Best Available Techniques to reduce emissions. Additional guidance emphasises the need for appropriate feed formulation (to reduce nitrogen excretion) and the adoption of management practices that keep manures and litters as dry as possible. Both of these are widely understood by farmers, although it can be difficult to keep litter dry in some cases.

Additional means of reducing ammonia emissions are being sought by farmers since in addition to environmental concerns, there are implications for bird welfare and performance. One option is the use of additives supplied in the drinking water. These are currently used by some broiler growers to maintain health but there are suggestions that these products may also reduce ammonia emissions, although there is little independent evidence for this at present.

This project set out to investigate the effects of three different additive products, through a study conducted on two commercial broiler farms in Wales. Two similar broiler houses on each farm were assigned as either the 'treatment' or a 'control' house. In the treatment house, three different additive products were used in turn with three different flocks. In the control house no additives were used in any of the flocks. Visiting restrictions due to coronavirus and avian influenza concerns led to delays and the work was undertaken in the autumn of 2020 and the summer of 2021.

For both the treatment and control houses and for each of the three flocks, ammonia levels in the houses and the volume of air throughput were recorded using specialist equipment installed. The data recorded were collated remotely and transferred to an environmental modelling specialist who calculated the ammonia emission factor. This allowed a comparison between the houses with additives and those without. In addition, specialist veterinary visits were made three times during each flock cycle so that flock welfare assessments could be made. At the final visit, a litter sample was collected for analysis of moisture and nitrogen content. Finally, performance data for each flock was examined, based on a combination of farm and processor records.

The results showed few substantial differences between the treatment and the control flocks. Ammonia emission factors were actually numerically lower (i.e. better) in the control houses, but the difference was minimal, and the overall levels were very high, compared to current published figures. The reasons for this have been considered but no clear explanation can be provided. The study therefore does highlight the difficulties of measuring ammonia emissions in commercial settings and further studies may be needed to resolve methodology issues.

The average feed conversion ratio (FCR) for the treatment flocks was lower than it was for the control flocks. It has been suggested that the products improve the FCR and if proven, this would have a beneficial effect on production costs, particularly at times when feed costs are high but further work is required to validate this finding.

Analytical results suggested a higher litter dry matter content in the treatment houses than in the control houses. If this difference is real, then the use of products would be consistent with the aim of keeping litter as dry as possible. For other assessments, there appeared to be no clear differences between the houses in this study. This may have been due to the impact of other external factors which can inevitably arise in largescale commercial studies.

With monitoring equipment now in place on both farms, additional studies may be undertaken to explore other new developments, although this will not be funded through the EIP scheme. The two farmers involved remain interested in exploring other ways of reducing ammonia emissions and additional testing has been taking place using misting systems and in-feed product administrations.

Wider knowledge transfer activities are now planned to increase awareness and discussion amongst broiler growers of the importance of ammonia and the main control methods available.

CONTENTS

1 INTRODUCTION

1.1 Background

Broiler production has been a growth area in Welsh agriculture in recent years. The growing demand for chicken has provided viable diversification opportunities for a number of Welsh farmers but concerns have been raised over possible environmental impacts.

An inevitable consequence of any form of poultry farming is the production of ammonia, through the natural breakdown of urates within poultry manure. Ammonia emissions from poultry production can have a number of impacts as set out below.

- ***Environmental impacts:*** Aerial emissions of ammonia can damage sensitive habitats and can react with other atmospheric acids to form secondary particulate matter which can significantly impact upon human health.
- ***Bird welfare:*** The main impacts are respiratory impairment, damage to eyes, increased prevalence and severity of footpad dermatitis (FPD) and hock marks. There are also health and safety implications for poultry workers operating in high-ammonia environments.
- ***Bird performance and economics:*** These include reduced liveweight, poorer feed conversion and reduced feed and water intake, due to impaired mobility arising from FPD, higher mortality and increased use of medications.

1.2 Ammonia emissions and emission factors

Agriculture is a major source of ammonia compared to other sectors, accounting for 87% of UK emissions in 2019[1]. In Wales, ammonia emissions represent around 9% of the UK total and 93% of all ammonia emissions are from agriculture[2]. For the UK as a whole, the poultry sector was responsible for around 14% of all agricultural ammonia emissions in 2019[3].

The UK is committed to ammonia emissions reductions. Under international agreements, UK Government has agreed to reduce ammonia emissions by 16% by 2030, compared to emissions in 2005[4]. In Wales, Natural Resources Wales (NRW) wish to see reductions in ammonia emissions so that farmers can achieve environmental compliance. Almost all broiler farms in Wales have more than 40,000 bird places and they must therefore hold an environmental permit which requires adoption of Best Available Techniques (BAT) to reduce emissions. High levels of ammonia emissions are cited by farmers as one of the main reasons for permits being refused or for planned expansion being prohibited.

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[1] Beis.gov.uk. (2017). NAEI, UK National Atmospheric Emissions Inventory - [online] Available at: https://naei.beis.gov.uk/.

[2] https://businesswales.gov.wales/farmingconnect/news-and-events/technical-articles/air-pollution-reducing-ammonia-emissions-adapting-livestock-management-approaches

[3] https://uk-air.defra.gov.uk/assets/documents/reports/cat07/2103191000_UK_Agriculture_Ammonia_Emission_Report_1990-2019.pdf

[4] Defra. 2018. *Code of Good Agricultural Practice (COGAP) for Reducing Ammonia Emissions*. [online] Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/729646/code-good-agricultural-practice-ammonia.pdf

In order to assess the likely extent of ammonia emissions from poultry farms, typical ammonia emission factors have been published by the Environment Agency and by Natural Resources Wales for different livestock types and production systems. These are based on published studies, but it is accepted that variations exist in practice for a variety of reasons, including seasonality, cycle length, housing type and a range of different management factors.

At present, the standard, accepted ammonia emission factor for a typical broiler production system in Wales and England is 0.034 kg of ammonia per bird place per year. In this context, a 'bird place' is in effect the area of flooring available to each bird and the weight of ammonia produced takes account of multiple crop cycles (typically around seven) per year and thus any differences due to seasonality. Previous studies by ADAS have concluded that the current emission factor is based on a comparatively small number of published studies.

A separate EU document[5] provides a range of between 0.01 and 0.08 kg of ammonia per bird place per year as the Best Available Technique Associated Emission Level (BAT-AEL) for broilers up to a final weight of 2.5kg.

The Defra Code of Good Agricultural Practice for Reducing Ammonia Emissions applies in England and there is a separate Code in Wales[6]. The Defra Code includes a section on poultry sector-specific measures with two main housing-related measures for reducing ammonia emissions, together with guidance on storage and spreading of manures. The main housing measures are:

- ***Diet:*** Reducing the amount of nitrogen excreted by poultry through carefully matching the feed formulations to the nutrient requirements of the birds at all stages of production.
- ***Housing***: Keeping poultry manures and litters as dry as possible because poultry manure and litter emit more ammonia when wet.

Dietary management measures are already widely implemented by the poultry industry. As a matter of standard practice, feed formulations are based on birds' amino acid requirements rather than on total crude protein alone. This is normally achieved through the addition of synthetic amino acids and enzymes which increase amino acid digestibility. Feed formulations are also matched to the nutritional requirements of the birds at all stages of production. This is achieved through the implementation of sequential (or 'phase') feeding programmes, which normally include a 'starter' a 'grower' and a 'finisher' feed for flocks of different age.

The importance of **keeping the litter dry** is also well understood throughout the poultry industry although it can be difficult to achieve at all times. Modern housing is now capable of maintaining precise humidity and temperature levels using automated control systems. In addition, there has been a drive to improve ventilation and heating systems. Such developments are consistent with improved litter condition, but further improvements may still be possible. A comparatively recent development for example is the use of ammonia scrubbing systems which are designed to reduce ammonia emissions to air, outside the house. In some cases, the installation of such systems has been stipulated as part of the planning consent or permitting processes, but the capital costs are high and the operating costs represent an ongoing expense thereafter.

The Code of Good Agricultural Practice guidance on reducing ammonia losses from agriculture in Wales[7] also contains similar guidance in relation to housing and manures.

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[5] https://op.europa.eu/en/publication-detail/-/publication/968ab1da-f807-11e6-8a35-01aa75ed71a1/language-en

[6] https://gov.wales/sites/default/files/publications/2019-04/code-of-good-agricultural-practice-guidance-on-reducing-ammonia-emissions.pdf

[7] https://gov.wales/sites/default/files/publications/2019-04/code-of-good-agricultural-practice-guidance-on-reducing-ammonia-emissions.pdf

1.3 Use of drinking water additives

The use of additives that reduce ammonia emissions offers an additional means of further reducing ammonia production 'at source'. These products are typically supplied to the birds via the drinking water and are already used by some broiler growers mainly to improve flock health and performance. However there is little independent data at present on their effects on ammonia or on their interactions with other key production drivers.

Different additives may have different modes of operation and if proven to be successful with regard to ammonia, they could offer a valuable extra tool for poultry producers to use to further reduce ammonia emissions over and above existing measures.

1.4 Farmer interests and project participants

The farmers and the actor in the operational group were keen to study the possible ammonia-suppressing qualities of additives supplied in the drinking water. This is partly due to the need to reduce current environmental impacts but also the expectation that further mitigations may be required in the future, particularly if new developments or further expansion is being considered on a farm. This could be particularly important from a planning and permitting perspective.

Furthermore, identifying possible correlations between ammonia reductions and improved flock performance could lead to increased use of additives, because it may be cost effective to do so. Environmental improvements could then be a useful additional benefit.

This study has involved inputs from a company specialising in poultry ventilation and ammonia monitoring (Draper Ventilation[8]), an environmental modeller (AS Modelling and Data[9]) and a poultry veterinary practice (St. David's Poultry Team[10]). It was hoped that the results of this study may help to develop best practice recommendations for reducing ammonia emissions from broiler chicken production and could help to achieve targets for ammonia reduction with a view to continued sustainable expansion of the poultry sector in Wales.

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[8] www.drapervent.com

[9] https://asmodata.co.uk/

[10] www.stdavids-poultryteam.co.uk

2 METHODOLOGY

2.1 Experimental Design

This project evaluated the performance of three different additive products (administered in the water) on two commercial broiler sites in Wales, one in the north and one in the south. The three products, in alphabetical order were:-

- Biocomplex[11] (Ekogea), a product derived from marine algae which is also intended to improve microbial health and to improve liveweight gain and feed conversion ratio.
- Herban[12] (Herban UK) a product based on oreganum essential oil which is primarily intended to maintain gut health, reduce mortality and improve growth rate and feed conversion ratio.
- Searup[13] (Olmix) a product based on marine sulphated polysaccharides (MSPs), vitamins and amino acids, intended to build a stronger immune response, so that animals are better able to withstand stresses.

At present, there are some suggestions and claims that the use of such products can also reduce levels of ammonia emissions, in addition to having other beneficial effects.

The farms are contracted to two different major broiler processing companies. The individual farms taking part in the trial have two similar, modern-style poultry houses on the same site, which already follow BAT standards with environmental permits in place. This allowed a ‘control’ and a ‘treatment’ study to be set-up in the two houses on each farm using the three products in turn. As far as possible, it was important that the two houses chosen on each farm had similar dimensions, stocking rate, ventilation system, litter, feed and heat supply. These conditions were generally met, although the farm in north Wales used different heat sources in the two houses.

On each farm, the pairs of houses were monitored across three complete chicken production cycles, so that the three different products could be used in turn in one of the houses. This was initially intended to take place on consecutive flocks, over the course of approximately six months which would take some account of seasonal effects. However the impacts of coronavirus meant that the planned start date (spring 2020) had to be delayed until late-summer with only one cycle of birds on each farm monitored at that time. There was then a further delay in the winter of 2020/2021 due to the re-introduction of coronavirus visit restrictions, coupled with concerns over avian influenza. It was not until the summer of 2021 that the two remaining flock cycles could be completed on each farm. The results therefore mainly reflect summer growing conditions, rather than winter flocks.

Whilst coronavirus and avian influenza affected the timing and completion of the project, it did not impact upon the approach and the procedures followed. Comprehensive risk assessments were made so that the on-farm inputs by members of the project team could be undertaken as safely as possible.

During each monitoring period, ammonia levels within the houses and a range of environmental, animal welfare and performance parameters were monitored and measured. On each farm, the same house was designated as the ‘control’ and as the ‘treatment’ (i.e. with additive product) throughout the three cycles. This allowed the best comparison of the three products, enabling the same ‘control versus product’ comparison to be made each time.

By using houses on each farm that are as similar as possible, together with a carefully designed and executed trial protocol, the findings of the work were designed to provide a clear and valuable insight

[11] www.ekogea.co.uk/what-is-biocomplex/

[12] www.herban.co.uk/poultry/

[13] www.olmix.com/animal-care/searup

into the performance of each product and a comparison between 'products' and 'control'. However given the low number of farms involved (two) and that each product was only used once on each farm, a full statistical analysis – of the type that could be done with more replicates - was not possible.

2.2 Project initiation meetings

Project initiation meetings were undertaken on both farms, led by the ADAS project manager. This ensured that there was full agreement on the project aims and the approach at the outset. Practical issues were addressed e.g. in relation to ways in which the products could be accurately administered in the two trial houses and additional equipment for product administration and environmental monitoring was fitted where necessary. The houses and systems in place were checked to ensure equivalence and the control and the treatment house on each farm was assigned.

Diets used on each farm were reviewed to ensure that they were the same in each house, with specifications set by feed compounders and poultry nutritionists. This ensured that the specifications and the programme were consistent with the goal of nitrogen optimisation.

2.3 Trial Design

Three different production cycles were followed (August 2020 to June 2021). Each ammonia reducing product was tested for one complete production cycle on each of the two farms. The order in which the products were used was different on each farm. This was intended to ensure that none of the products were used on 'winter flocks' on both farms, since the results for that product may partly reflect seasonal differences. In practice however, the trial avoided winter flocks as described above.

For reasons of commercial confidentiality, the names of the three products used are anonymised in this section and in the results and discussion that follows. They are referred to here as products A, B and C but it is emphasised that these have been assigned randomly. **They do not necessarily follow the same order as the products named in alphabetical order in section 2.1 above.** Tables 3 and 4 below set out the order of product testing on each farm and in each house. For the purposes of this report, farms are referred to as north and south Wales and the houses on each site as 1 and 2.

Table 3 Order of product testing – north Wales farm

North Wales		
House 1	Cycle 1	Product C
House 2	Cycle 1	Control
House 1	Cycle 2	Product A
House 2	Cycle 2	Control
House 1	Cycle 3	Product B
House 2	Cycle 3	Control

Table 4 Order of product testing – south Wales farm

South Wales		
House 1	Cycle 1	Product A
House 2	Cycle 1	Control
House 1	Cycle 2	Product B
House 2	Cycle 2	Control
House 1	Cycle 3	Product C
House 2	Cycle 3	Control

The treatment products were applied according to the manufacturers' instructions, with guidance being provided by the suppliers as necessary. The control and treatment houses were managed identically by the farm staff as far as possible, although it was accepted that there may be a need to react to specific flock requirements in each house and change management inputs accordingly. Daily records were maintained on-farm of key performance indicators throughout each cycle and these, together with any unusual occurrences were reviewed at the end of each flock.

2.4 Data Collection

The following were monitored and recorded for each control and treatment house.

2.4.1 Ammonia emissions

Ammonia levels were continuously monitored in each poultry house on both farms throughout each entire production cycle. The approach was based on VERA protocols[14] as recognised by NRW in Wales. Ammonia monitoring was based on systems supplied by Draper Ventilation[15]. The ammonia content in a house is affected by the prevailing ventilation rate e.g. high ventilation rates mean that ammonia is extracted from the houses more rapidly than at low ventilation rates. Therefore, it was important to also measure air throughput from each house and again this was undertaken by recording systems supplied and installed by Draper Ventilation.

Draper Ventilation specialists attended each farm to calibrate equipment during the house set-up stage between flocks (i.e. when the houses were empty). They downloaded the data on ammonia levels and air throughputs remotely and then forwarded this to AS Modelling to undertake calculations on ammonia emission factors.

AS Modelling calculated average hourly ammonia concentrations and house ventilation rates using the one-minute data from the logging files.

Average ammonia emission rates were calculated by multiplying the hourly ventilation rate by the reported ammonia concentration. In cases where no data were available for either ammonia concentration or ventilation rate, the hour was excluded from the calculation, it

[14] www.veracert.eu

[15] www.drapervent.com

was not counted as a zero value. The average value obtained was expressed in units of kilogrammes of ammonia per bird per year (kg-NH_3/bird/year) as initially stocked.

The average figure above was then reduced by a factor of (crop length/(crop length + 10)) whereby 10 is the assumed number of days when each house is empty between crops for cleaning and preparation. After this adjustment had been applied, the figure calculated represents the kilogrammes of ammonia per bird place per year (kg-NH_3/bird-place/year), again as initially stocked. As set out in section 1.2, this is the unit in which ammonia emission factors are customarily expressed.

2.4.2 Bird welfare

Poultry veterinary specialists from the St. David's practice undertook a routine welfare assessment of the birds in each house (control and trial) on both farms three times during each crop. These were scheduled for the time when the birds were aged 14, 25 and 35 days of age, so that comparable assessments could be made. Where these ages were reached at a time when a visit was not possible (e.g. over the weekend) the nearest available date was selected.

The following veterinary assessments were carried out during each farm visit:

- **Foot pad condition and hock marks** of a sample of 100 birds per house (taken as four sub-sets across the house). Foot and leg health are useful indicators of litter condition and ammonia levels. Foot pads and hocks were scored on a recognised scale of 0-3, whereby the higher score denotes higher levels of damage[16]. A score of zero (0) indicates no evidence of foot or hock issues. **Gait** was also scored on a scale of 0-3, whereby the higher score denotes poorer walking ability.
- **Feather condition scoring** on a random sample of 100 birds per house. Feather condition (in particular the degree of soiling) is a useful indicator of litter condition i.e. whether it is wet or dry. A scale of 0 (best) to 3 (worst) was used for scoring[17].
- **Litter condition scoring** for friability. This was done using a pre-determined sampling plan to cover all parts of the house. A scale of 0 (best) to 3 (worst) was used for scoring.

In addition, during the final veterinary visit to each flock, the vet collected a litter sample (based on sub-samples) from each house for analysis to determine the moisture level and nutrient content. Analytical work was undertaken by NRM Laboratories, part of Cawood Scientific[18]. Moisture and nitrogen in the litter are both important factors for ammonia emissions and they have been shown in previous studies to be correlated with animal welfare indicators such as pododermatitis and hock marks.

2.4.3 Performance indicators

Apart from the potential environmental and welfare benefits of reduced ammonia levels, there may also be differences in physical performance and thus financial returns between treatments. In order to determine this, key information was collected for each flock. The

[16] For details of gait scoring method, see www.assurewel.org/broilers/walkingability.html

[17] A feather scoring guide is given in https://edepot.wur.nl/233471

[18] https://cawood.co.uk/nrm/

data were obtained either from farm records or from information provided by the processor following receipt of the birds. The key items recorded were as follows:

- **Mean bird liveweight** at the end of the growing period. This was based on processor records, and it includes the liveweight and the proportion of birds at thinning or partial depopulation and at final depopulation (approximately seven days later). Processor co-operation in supplying these figures is acknowledged.
- **Flock mortality and processor rejects.** The mortality percentage was taken from farm records. Data were gathered on the percentage of birds that were rejected by the processor for any reason, both at the time of thinning and at final depopulation.
- **Feed intake** for each flock, to calculate feed conversion ratios (FCR) based also on the above liveweight information.

Any *ad hoc* medicine use prescribed was recorded for each flock.

2.5 Other considerations

The study was undertaken with full regard for considerations such as biosecurity, confidentiality and procurement as outlined below.

2.5.1 Biosecurity

When visiting farms, contractors operated within their biosecurity Standard Operating Procedures (SOP) to ensure that the risk of disease transfer to or from the trial farms was reduced to an absolute minimum. Key visits (with birds in place) were undertaken by poultry veterinarians, who followed high biosecurity procedures whereas Draper Ventilation specialists were able to attend the farms to calibrate equipment when there were no birds in place. Data were generally collected remotely, whether from the farm or from the processor.

The need for good biosecurity and a precautionary approach were also appropriate given coronavirus restrictions which began at around the time the project was first scheduled to begin (spring 2020) and continued to varying degrees throughout the project. Risk assessments were prepared in respect of visits; social distancing procedures were in place when visits needed to be undertaken. Project meetings were generally conducted remotely by telephone or on MS Teams to avoid the need for face-to-face contact.

Outbreaks of avian influenza late in 2020 resulted in a housing order being announced in Wales on 14 December 2020 and this was not lifted until the end of March 2021. Whilst this Order did not directly affect housed broilers, it emphasised increased concerns at the time and meant that only essential farm visits were typically scheduled. Any visits deemed 'non-essential' were generally postponed.

2.5.2 Confidentiality and commercial considerations

The poultry sector has sometimes been targeted by campaigns which may pose risks to both animal welfare and site biosecurity precautions. Therefore it has not been considered appropriate to include the names of the farmer participants or their locations in this report. Similarly, whilst the three products assessed in the study have been named at the start, the results shown are anonymised. This is because the overall aim was to determine whether such products could have an impact upon ammonia emissions. It was not possible to carry out a direct comparison between products, due to the scale of the study and the possibility of confounding factors in a commercial setting.

2.5.3 Procurement

Contractors were procured in line with Welsh Government protocols to assist in generating and collating data during the study.

2.6 Reporting

All data and results from the various sources have been collated by ADAS in order to prepare this final project report. Results for the control treatments have been compared with those for each of the three additives used, so that a series of ammonia emission factors have been calculated on the basis of 'kilogrammes of ammonia per bird place per year' for each product and for the control. This allows an overall assessment of evidence for ammonia-reduction capability to be made.

The final report is being utilised by all participants in the project so that any wider implications can be considered and areas for further study identified.

3 RESULTS

3.1 Crop cycles, products and dates

The date of bird placement (month, year) for each of the three products tested on each farm is set out in Table 5 below.

Table 5 Date of bird placement for products A, B and C on both farms

	Farm 1 North Wales	Farm 2 South Wales
Product A	April 2021	September 2020
Product B	May 2021	May 2021
Product C	September 2020	June 2021

3.2 Issues arising

Since this was a trial undertaken on two commercial farms, it was not always possible to mitigate against atypical occurrences. The main issues which were encountered during the study are listed below:

Farm 1 North Wales

- Incorrect numbers of day-old birds were placed in the two houses when Product C was being tested (September 2020). Rather than both houses being stocked with the same number, the control house contained some 38,000 and the trial house around 42,000 due to an error at the time of delivery. This affected stocking density and it is likely to affect a number of indicators including ammonia, flock performance and welfare.
- Flock 2 (using Product A, house 2) had to be treated for three days with amoxicillin starting at 25 days, due to a problem with enteritis and wet litter.

Farm 2 South Wales

- The birds in the first flock (Product A) had to be medicated for enterococcus and septicaemia for five days after arrival. Product A could not be used until the end of this period of medication and therefore it was added for the first time on day 5 (note that the day of arrival on-farm is referred to as 'day zero').
- A 35 day veterinary visit was not possible on the second flock in south Wales because this coincided with very hot weather conditions. Carrying out an assessment was not considered appropriate for bird welfare at that stage.
- The 14 and 25 day veterinary visits were missed in the third flock in south Wales. This was due to a misunderstanding with the veterinary practice which was not identified at the time. A final visit was made at around 35 days, after the earlier oversights had been identified.

The key results for each additive product (A, B and C) on each farm are set out in the following sections. This includes the results of the 35 day veterinary visits which were likely to show the biggest differences and were considered the most important. The findings of earlier veterinary visits (14 and 25 days) are provided in the Appendix section.

3.3 Key results for Product A

Table 6 below shows a summary of the physical performance for both farms, based on flocks using product A, compared to the control house.

Table 6 Physical performance summary (Product A)

	Farm 1 North Wales April 2021		Farm 2 South Wales September 2020	
	Control	Product A	Control	Product A
Average liveweight (kg)	2.18	2.10	2.19	2.19
Average age at depopulation (days)	34.7	34.1	34.6	34.5
FCR	1.441	1.398	1.512	1.492
Mortality (%)	2.65	3.67	3.76	6.86

Table 7 below shows a summary of key welfare indicators, litter analysis and ammonia emission factors for both farms, based on flocks using product A. In terms of welfare assessments, hock and foot pad scores are presented here, based on the final veterinary assessment for the flock which showed the greatest differences between the control and treatment flocks.

Table 7 Welfare, litter analysis and ammonia (Product A)

	Farm 1 North Wales		Farm 2 South Wales	
	Control	Product A	Control	Product A
Final hock score 0 (% of birds assessed)	75	80	70	84
Final footpad score 0 (% of birds assessed)	90	84	90	92
Reject birds at thin (%)*	0.75	0.99	1.43	1.25
Reject birds, final depopulation (%)	1.2	0.97	1.25	1.15
Litter dry matter (%)	60.3	72.7	73.7	73.1
Total litter nitrogen (%)	5.27	4.99	4.30	4.41
Litter ammonium nitrogen (mg/kg)	3,641	2,971	3,819	4,485
Ammonia emission factor (kg per bird place per year)	0.066	0.052	0.106	0.093

*Reject birds at thin refers to the number of birds rejected at the slaughterhouse when the flock is thinned at approximately 30 days of age.

Key results for Product B

Table 8 below shows a summary of the physical performance for both farms, based on flocks using product B compared to the control house.

Table 8 Physical performance summary (Product B)

	Farm 1 North Wales September 2020		Farm 2 South Wales May 2021	
	Control	Product B	Control	Product B
Average liveweight (kg)	2.162	2.198	2.450	2.354
Average age at depopulation (days)	33.8	34.7	34.9	35.0

FCR	1.419	1.447	1.54	1.55
Mortality (%)	4.51	3.92	7.75	6.74

Table 9 below shows a summary of key welfare indicators, litter analysis and ammonia emission factors for both farms, based on flocks using product B. Again, hock and foot pad scores are based on the final veterinary assessment for the flock.

Table 9 Welfare, litter analysis and ammonia (Product B)

	Farm 1 North Wales		Farm 2 South Wales	
	Control	Product B	Control	Product B
Final hock score 0 (% of birds assessed)	85	96	96 (23d)[19]	97 (23d)
Final footpad score 0 (% of birds assessed)	99	98	100 (23d)	100 (23d)
Reject birds at thin (%)	0.817	0.619	2.10	1.63
Reject birds, final depopulation (%)	1.49	1.97	1.50	1.35
Litter dry matter (%)	71.0	72.6	67.5	74.2
Total litter nitrogen (%)	4.70	4.50	4.49	4.08
Litter ammonium nitrogen (mg/kg)	2,047	2,671	3,954	2,671
Ammonia emission factor (kg per bird place per year)	0.109	0.144	0.0667	0.0660

3.4 Key results for Product C

Table 10 below shows a summary of the physical performance for both farms, based on flocks using product C compared to the control house.

[19] Note that a 35 day veterinary visit could not be made due to hot weather conditions at the time and the risks to bird welfare. The flock owner requested no veterinary visit. The data presented here is for 23 days.

Table 10 Physical performance summary (Product C)

	Farm 1 North Wales		Farm 2 South Wales	
	Control	Product C	Control	Product C
Average liveweight (kg)	2.250	2.303	2.62	2.60
Average age at depopulation (days)	34.1	34.9	37.7	37.7
FCR	1.456	1.475	1.58	1.54
Mortality (%)	3.97	4.46	4.42	3.04

Table 11 below shows a summary of key welfare indicators, litter analysis and ammonia emission factors for both farms, based on flocks using product A. Again, hock and foot pad scores are based on the final veterinary assessment for the flock.

Table 11 Welfare, litter analysis and ammonia (Product C)

	Farm 1 North Wales		Farm 2 South Wales	
	Control	Product C	Control	Product C
Final hock score 0 (% of birds assessed)	69	56	92	88
Final footpad score 0 (% of birds assessed)	98	78	100	99
Reject birds at thin (%)	2.10	3.02	1.46	1.40
Reject birds, final depopulation (%)	1.79	2.49	1.39	1.35
Litter dry matter (%)	75.9	73.5	68.0	72.8
Total litter nitrogen (%)	4.81	4.79	4.67	4.58
Litter ammonium nitrogen (mg/kg)	2,975	3,157	3,862	4,191
Ammonia emission factor (kg per bird place per year)	0.143	0.135	0.048	0.065

4 DISCUSSION

The main objective of the study was to compare ammonia levels in the treatment houses (with additive) and the control houses. In addition though, the study set out to determine any effects on performance and on key welfare indicators. These three elements are discussed in turn in this section.

4.1 Did the products reduce ammonia?

Table 12 shows the results for three relevant indicators, namely total litter nitrogen, litter ammonium nitrogen and calculated ammonia emissions[20]. The results are summarised for each product and for the control house on each farm. The mean of the values for both farms combined is shown in brackets. The numbers in **bold font** are the mean values of all six results, allowing a comparison between the use of all three products (combined) and the control houses.

Table 12 Both farms' data and averages (products A, B, C and control) and averages for 'product' versus 'control'

	Product - both farms (with mean)			Control - both farms (with mean)		
Total litter nitrogen (%)	A	4.99/4.41 (4.7)	**4.56**	A	5.27/4.30 (4.8)	**4.71**
	B	4.50/4.08 (4.3)		B	4.70/4.49 (4.6)	
	C	4.79/4.58 (4.7)		C	4.81/4.67 (4.7)	
Litter ammonium nitrogen (mg/kg)	A	2971/4485 (3728)	**3358**	A	3641/3819 (3730)	**3383**
	B	2671/2671 (2671)		B	2047/3954 (3001)	
	C	3157/4191 (3674)		C	2975/3862 (3419)	
Ammonia (kg/bird place per year)	A	0.052/0.093 (0.073)	**0.093**	A	0.066/0.106 (0.086)	**0.090**
	B	0.144/0.066 (0.105)		B	0.109/0.067 (0.088)	
	C	0.135/0.065 (0.100)		C	0.143/0.048 (0.096)	

Based on the averages **in bold** in the table above, there was broad consistency between the control houses and those with products added. Both total litter nitrogen and ammonium nitrogen were numerically lower in the 'product' houses, but the differences were very marginal i.e. a 3% reduction for litter nitrogen and a 1% reduction for ammonium nitrogen. Ammonia emissions were actually slightly lower in the control houses than in those with products added. Again, the differences were very small, at only around 3%. Due to the small sample size, it impossible to know for sure whether the differences observed were due to chance or represented true effects from the additives. However, it is noted that the differences are very small.

[20] Note that litter dry matter (which is also relevant to ammonia emissions) is considered in section 5.3

It is notable that the ammonia emissions figures in this study are generally much higher than the currently accepted figure of 0.034 (see section 1.2). The means for all 'product' flocks (0.093) and for all 'control' flocks were similar and the calculated means for all 12 results (two farms x two houses x three flocks) was 0.0912. This is approaching three times higher than the current standard figure. Veterinary assessments would have identified if there was an actual problem with such high ammonia levels in the houses but this was not the case. The reasons for the anomaly are therefore unclear although views have been sought from various parties involved. No firm conclusions have been reached and separate studies may therefore be required.

AS Modelling report that there were no long periods of missing data that might adversely affect the results and on that basis, it was concluded that the figures are reasonably robust. At both farms, the reported ventilation rates were considered reasonable and as expected in modern broiler houses.

Drapers staff undertook some separate ammonia readings in the houses on occasions, using portable Draeger tubes to compare the results from these and the ammonia sensors installed. It was concluded that the findings were very similar, with possibly a difference of just one or two parts per million. This is unlikely to result in a substantial overall difference.

A possible consideration is the position of the ammonia sensors in the houses, since it is likely that the highest ammonia levels would be low-down, close to the litter. In this study, the sensors were placed around one metre above the ground. If the 'standard' emission factor was calculated from sensors positioned higher in the house than this, then it may result in the calculated ammonia emission figure being lower.

Finally, it should be noted that none of the studies were undertaken during winter conditions, therefore the averages calculated do not take full account of seasonality, which the standard emission factor would. Whilst ventilation rates (and air throughputs) would typically be lower in winter, it is not clear what effect this would have on the calculations.

4.2 Did products improve flock performance?

Table 13 shows the results for liveweight (with flock age) and feed conversion ratio (FCR). As before, the results are summarised for each product and for the control house on each farm. The mean of the values for both farms is shown in brackets. The numbers in **bold font** are the mean values of all six results, allowing a comparison between the use of all three products (combined) and the control houses.

Table 13 Both farms' data and averages (products A, B, C and control) and averages for 'product' versus 'control'

	Product - both farms (with mean)			Control - both farms (with mean)		
Liveweight (kg)	A	2.10/2.19 (2.15)	**2.29**	A	2.18/2.19 (2.19)	**2.31**
	B	2.20/2.35 (2.28)		B	2.16/2.45 (2.31)	
	C	2.30/2.60 (2.45)		C	2.25/2.62 (2.44)	
Average age (days)	A	34.1/34.5 (34.3)	**35.2**	A	34.7/34.6 (34.7)	**35.0**
	B	34.7/35.0 (34.9)		B	33.8/34.9 (34.4)	
	C	34.9/37.7 (36.3)		C	34.1/37.7 (35.9)	
FCR	A	1.398/1.492 (1.445)	**1.484**	A	1.441/1.512 (1.477)	**1.492**
	B	1.447/1.550 (1.499)		B	1.419/1.540 (1.480)	
	C	1.475/1.540 (1.508)		C	1.456/1.580 (1.518)	

Based on the numbers **in bold** in the table, the average liveweight in the houses with product was slightly lower than in the control houses, even though the average age at processing was very slightly higher. The differences are again marginal though.

The calculated average FCRs in Table 13 were comparatively low, both for the product and the control houses[21]. This is due in particular to low figures on the north Wales farm, as shown in Table 14 below.

Overall, the results indicate a lower (i.e. better) FCR with product use compared to the control, but this was due to differences on the south Wales farm. The FCR results on the north Wales farm were virtually the same. The calculations made for this report were often based on hand-written farm records of feed use and so recording or input errors are a possibility.

[21] In a report for the National Farmers Union (2019), ADAS used a typical FCR of 1.58 for an average liveweight of 2.26kg. This was based on views from industry stakeholders. It is noted that in this trial, the average final liveweights were lower than this and so the FCR is expected to be marginally lower (i.e. better) than this.

Table 14 Summary of FCR results for all flocks on both farms

	North Wales	South Wales
Product A	1.398	1.492
Product B	1.447	1.55
Product C	1.475	1.54
Mean	**1.440**	**1.527**
Control for Product A	1.441	1.512
Control for Product B	1.419	1.54
Control for Product C	1.456	1.58
Mean	**1.439**	**1.544**

To determine whether possible differences in FCR appeared attributable to a single product or equally to all products, the data are summarised by product in Table 15. This shows that both Product A and Product C had a lower FCR than the equivalent 'control' houses. It should be noted though that the use of Product C on the north Wales farm was in the flock when incorrect numbers of birds were placed in each house (see results, section 4.2). The additional birds in the treatment house may partly explain the very low FCR there.

Table 15 Comparison of FCR in test and control houses on both farms

	Test houses (both farms)	Control house (both farms)
Product A	1.445	1.477
Product B	1.499	1.480
Product C	1.508	1.518
Mean	1.484	1.492

The overall average difference in FCR between test and control houses was calculated as 0.008. Whilst seemingly very small, any real difference in FCR could have important financial implications. For example, the following calculations can be made from the data in Table 13.

- For **product houses,** the average feed intake is 3.398kg per bird (2.29 x 1.484)
- For **control houses,** the average feed intake is 3.447kg per bird (2.31 x 1.492)

The result is a calculated 49g difference in feed intake. Assuming a current average feed price of £400 per tonne, this difference in feed use would be worth around two pence per bird or some £784 (gross) per flock for a house with 40,000 birds. The cost of the additive product itself would have to be subtracted from this figure.

4.3 Did products improve welfare indicators?

Table 16 shows the results for five relevant indicators, namely mortality, % rejects, hock and footpad score and litter dry matter. As before, the results are summarised for each product and for the control house on each farm. The mean of the values for both farms is shown in brackets and the numbers in **bold font** are the mean values of all results, allowing a comparison between the use of all three products (combined) and the control houses.

Based on the numbers **in bold** in Table 16, the houses with product added performed numerically better only for the categories of hock score (assessed here in terms of the percentage of birds in the best score category) and litter dry matter. For litter dry matter, the mean of each product (average of 73.2%) was higher than the control mean (average of 69.4%). For other categories in the table, the control houses actually performed slightly better than the houses with product added.

Table 16 Both farms' data and averages (products A, B, C and control) and averages for 'product' versus 'control'

	Product - both farms (with mean)			Control - both farms (with mean)		
Mortality (%)	A	3.67/6.86 (5.27)	**4.78**	A	2.65/3.76 (3.21)	**4.51**
	B	3.92/6.74 (5.33)		B	4.51/7.75 (6.13)	
	C	4.46/3.04 (3.75)		C	3.97/4.42 (4.20)	
Final rejects (%)	A	0.97/1.15 (1.06)	**1.55**	A	1.2/1.25 (1.23)	**1.44**
	B	1.97/1.35 (1.66)		B	1.49/1.50 (1.50)	
	C	2.49/1.35 (1.92)		C	1.79/1.39 (1.59)	
Hock score 0 (% of birds sampled)	A	80/84 (82)	**84**	A	70/75 (73)	**82**
	B	96/97[22] (97)		B	85/96 (91)	
	C	56/88 (72)		C	69/92 (81)	
Footpad 0 (% of birds sampled)	A	84/92 (88)	**92**	A	90/90 (90)	**96**
	B	98/100[23] (99)		B	99/100 (100)	
	C	78/99 (89)		C	98/100 (99)	
	A	72.7/73.1 (72.9)	**73.2**	A	60.3/73.7 (67.0)	**69.4**

[22] At 23 days

[23] At 23 days

Litter dry matter (%)	B	72.6/74.2 (73.4)		B	71.0/67.5 (69.3)	
	C	73.5/72.8 (73.2)		C	75.9/68.0 (72.0)	

4.4 What did the farmers involved gain from the project?

Both farmers were proactive in the study and felt that they had benefitted from it and from the opportunity to liaise with environmental and veterinary specialists. With ammonia monitoring equipment now in place on both farms following the study, there is the opportunity to assess ammonia levels and fluctuations on a daily basis and to consider appropriate management responses as necessary.

One of the farmers reported that *'we have now progressed to looking at product applications through fogging systems. Initial results have suggested a quick 'knock-down' reduction in ammonia but we now need to see how long this persists and whether there are any other accompanying environmental benefits'*.

The other farmer participant concluded that *'whilst the use of additives is not a substitute for good practice, they may be able to offer a marginal gain for farmers and be seen as a means of fine-tuning, whether in terms of ammonia reduction or other aspects of performance. This may be particularly useful if flocks are stressed or challenged for any reason'.*

Both participants stated that the project highlighted the need to understand more about ammonia emission factors for poultry and they were interested in the possible links between the use of these products and the financial performance of flocks.

5 NEXT STEPS

Whilst the findings from this study do not provide strong evidence to show that the additives used have an impact upon ammonia emissions, the project has highlighted the importance of ammonia control and has encouraged debate amongst those involved which is already leading to new initiatives. Planned project publicity will encourage additional dissemination and a wider discussion of possible developments and solutions.

The project has highlighted possible variations in calculated ammonia emission levels in commercial production. Overall, the results obtained were higher than the standard broiler ammonia emission factor. Likely reasons have been suggested for this, including seasonality and the location (and height) of the ammonia sensors in the house but further studies are needed to improve understanding in this area. It is possible that this may aid the development of more detailed future guidance on methodologies. With equipment now in place for sensing ammonia and recording air throughputs on both farms, additional studies are planned (outside of EIP scheme funding) which will explore other developments and application methods, provide data for different times of the year and help to resolve methodology issues.

The farmers involved here remain interested in any developments that may reduce ammonia emissions. To this end, the next steps on these farms are likely to include additional testing on products applied through fogging systems in the house, in-feed administration and treatments applied to the litter. These studies will concentrate both on the impacts on ammonia and any other resulting environmental or animal welfare benefits.

The actor for this project, within the Operation Group has retained a close interest in the issues arising here and is currently working on a report on reducing ammonia emission levels which is currently at the peer-review stage. He is likely to remain involved and the findings from this study will add to the body of available knowledge. If appropriate, the facilities now available on these farms may be used for further on-farm studies.

Wider knowledge transfer activities are planned, so that the issues and the findings can be shared with other farmers. These activities will include a farmer discussion group meeting in mid-Wales (planned for March 2022) and an article for the farming press in Wales.

Acknowledgement

The project participants are grateful for the funding provided through the EIP scheme which has helped to prepare and deliver this project. Thanks are extended to Menter a Busnes for support and advice at all stages.

6 APPENDICES

In this section, the results of the veterinary assessments carried out at approximately 14, 25 and 35 days of age are summarised. In each table, the results for the treatment house with product added are shown in black font. The results for the control houses are shown in red. Details of the scoring system (0 to 3) used are set out in section 2.4.2 of the report, with 0 being the best. The numbers represent the percentages, based on a total of 100 birds sampled. For litter, the score for each house is denoted with an X.

6.1 Veterinary assessments for Product A and control – north Wales

	Score	0		1		2		3	
16 days Product A Control	Hock	84	100	16	0	0	0	0	0
	Footpad	99	100	1	0	0	0	0	0
	Feather	100	89	0	11	0	0	0	0
	Gait	95	99	5	1	0	0	0	0
	Litter			XX					

	Score	0		1		2		3	
25 days Product A Control	Hock	78	84	20	16	2	0	0	0
	Footpad	90	93	8	7	2	0	0	0
	Feather	100	90	0	10	0	0	0	0
	Gait	90	95	10	5	0	0	0	0
	Litter			XX					

	Score	0		1		2		3	
37 days Product A Control	Hock	80	75	20	22	0	3	0	0
	Footpad	94	90	4	8	2	2	0	0
	Feather	100	98	0	2	0	0	0	0
	Gait	92	89	8	11	0	0	0	0
	Litter			XX					

6.2 Veterinary assessments for Product A and control – south Wales

	Score	**0**		**1**		**2**		**3**	
15 days Product A Control	Hock	98	95	2	5	0	0	0	0
	Footpad	100	99	0	1	0	0	0	0
	Feather	100	100	0	0	0	0	0	0
	Gait	95	100	5	0	0	0	0	0
	Litter			XX					

	Score	**0**		**1**		**2**		**3**	
25 days Product A Control	Hock	94	88	5	9	1	3	0	0
	Footpad	98	94	2	4	0	2	0	0
	Feather	100	100	0	0	0	0	0	0
	Gait	96	100	4	0	0	0	0	0
	Litter			XX					

	Score	**0**		**1**		**2**		**3**	
35 days Product A Control	Hock	84	70	12	25	4	5	0	0
	Footpad	92	90	8	10	0	0	0	0
	Feather	100	100	0	0	0	0	0	0
	Gait	100	100	0	0	0	0	0	0
	Litter			XX					

6.3 Veterinary assessments for Product B and control – north Wales

	Score	0		1		2		3	
13 days Product B Control	Hock	100	99	0	1	0	0	0	0
	Footpad	100	100	0	0	0	0	0	0
	Feather	100	95	0	5	0	0	0	0
	Gait	98	75	2	14	0	9	0	2
	Litter			XX					

	Score	0		1		2		3	
26 days Product B Control	Hock	93	76	7	17	0	7	0	0
	Footpad	95	94	5	6	0	0	0	0
	Feather	94	90	6	10	0	0	0	0
	Gait	88	71	8	18	4	5	0	6
	Litter			XX					

	Score	0		1		2		3	
37 days Product B Control	Hock	96	85	4	15	0	0	0	0
	Footpad	98	99	2	1	2	0	0	0
	Feather	92	90	8	10	0	0	0	0
	Gait	91	95	5	3	4	2	0	0
	Litter			XX					

6.4 Veterinary assessments for Product B and control – south Wales

	Score	0		1		2		3	
14 days Product B Control	Hock	98	99	2	1	0	0	0	0
	Footpad	100	100	0	0	0	0	0	0
	Feather	100	100	0	0	0	0	0	0
	Gait	98	99	2	1	0	0	0	0
	Litter			XX					

	Score	0		1		2		3	
25 days Product B Control	Hock	97	96	3	4	0	0	0	0
	Footpad	100	100	0	0	0	0	0	0
	Feather	100	100	0	0	0	0	0	0
	Gait	97	99	3	1	0	0	0	0
	Litter			XX					

Note

No visit was made at 35 days due to hot weather conditions.

6.5 Veterinary assessments for Product C and control – north Wales

	Score	0		1		2		3	
13 days Product C Control	Hock	100	99	0	1	0	0	0	0
	Footpad	100	100	0	0	0	0	0	0
	Feather	100	100	0	0	0	0	0	0
	Gait	100	93	0	7	0	0	0	0
	Litter			XX					

	Score	0		1		2		3	
25 days Product C Control	Hock	65	58	27	34	8	8	0	0
	Footpad	92	94	8	6	0	0	0	0
	Feather	100	100	0	0	0	0	0	0
	Gait	100	90	0	10	0	0	0	0
	Litter			X		X			

	Score	0		1		2		3	
34 days Product C Control	Hock	56	69	34	28	10	3	0	0
	Footpad	78	98	15	2	7	0	0	0
	Feather	100	100	0	0	0	0	0	0
	Gait	100	99	0	1	0	0	0	0
	Litter			XX					

6.6 Veterinary assessments for Product C and control – south Wales

Note

No visits were made at 14 or 25 days due to an administrative error. Data are presented below for the final scheduled visit only, which was conducted at 37 days.

	Score	0		1		2		3	
37 days Product C Control	Hock	88	92	12	8	0	0	0	0
	Footpad	99	100	1	0	0	0	0	0
	Feather	100	100	0	0	0	0	0	0
	Gait	91	94	7	6	2	0	0	0
	Litter			XX					