BIOREDUCTION OF FALLEN STOCK

An evaluation of in-vessel bioreduction for containment of sheep prior to disposal

Final report

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Evaluating the science practicality, cost and science of in-vessel bioreduction for containment of sheep prior to disposal

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ABSTRACT

The Animal By-Products Regulation (EC No. 1774/2002) that forbids the burial of fallen stock has caused widespread concern across the livestock industry on both economic and environmental grounds. Consequently, more biosecure and economically viable alternatives for dealing with fallen stock need to be developed and validated for use by the livestock sector. The European Commission (EC) may allow novel alternative methods to be permitted as a means of treating fallen stock after consultation with the European Food Safety Authority (EFSA) and provision of robust scientific data. Bioreduction has been proposed as one possible mechanism of storing fallen stock prior to disposal.

Through joint funding from Hybu Cig Cymru and the Welsh Government, bioreduction was evaluated under controlled, replicated conditions; and under conditions which simulated those typical 'on-farm'. The trial was run over two phases and was based at Bangor University's research farm. The trial found that numbers of pathogens inoculated into the vessels decreased over time, often to below detection levels. In addition, no pathogens were detected in gaseous emissions from the system. It was found that the bioreduction system could satisfactorily cope with the volume of carcasses normally associated with a sheep flock numbering 1600, so that none had to be disposed of via any other option. On a weight basis, cost of waste disposal was considerably less than costs of disposing of fallen stock via the conventional method, although running costs would likely be prohibitive to smaller farms unless there's an improvement in the technology. Our findings indicate that in-vessel bioreduction could potentially offer livestock farmers a sustainable, practical, cost-effective, and biosecure method of containing fallen stock prior to disposal by an approved collector. We believe that the findings provide sufficient evidence for bioreduction to obtain legislative approval for use within the EC.

Contents

1 INTRODUCTION

1.1 Current options for disposal of fallen stock

Traditionally, most fallen stock was disposed of by burial in soil. However, due to BSE and Foot & Mouth Disease, this practise was banned throughout Europe when the Animal By-Products Regulation (EC No. 1774/2002) (ABPR) was implemented in 2003 (amended in Wales in September, 2005). This regulation limits disposal of fallen stock to three options:

1. Collection and heat-treatment (incineration or rendering) via an approved company;
2. A knackers' yard or hunt kennel; or
3. Small-scale (usually on-farm) incineration in an approved incinerator.

Although three options exist, most farmers are restricted to disposing of their fallen stock through the first option: collection and heat-treatment. The regulations have caused widespread concern within the livestock industry on the grounds of practicality (how to store and handle fallen stock prior to collection), the increasing cost of disposal, and concerns about biosecurity due to collection vehicles travelling between farms whilst laden with dead animals.

Alternative methods for dealing with fallen stock therefore need to be developed and validated for use by the livestock sector. However, before any new system can be used by industry, it must be approved by the European Commission. The EC bases its decision following consultation with the European Food Safety Authority (EFSA), who needs robust scientific data on particular aspects of new methods, mainly in relation to biosecurity. This is achieved by looking at the fate of specific bacterial and viral pathogens within the system, the various stages of the process, whether it represents any risk to human or animal health and the environment, and how the end material is disposed of.

1.2 Bioreduction

For the purpose of this report, bioreduction is defined as:

"*The aerobic degradation of animal by-products in a partially sealed vessel, where the contents are heated and aerated*".

Bioreduction has been proposed as one possible mechanism of storing fallen stock prior to disposal. However, to date there has been insufficient scientific evaluation and reporting of the system to enable its formal evaluation.

Bioreduction should not be mistaken for biodigestion or composting. Biodigestion tends to be an anaerobic process typically designed for the production of methane for burning as a source of renewable energy. Composting involves the regular mixing of carcasses with other feedstuffs (e.g. straw, woodchip) in a relatively dry, aerobic environment. The physical integrity is maintained within a bioreduction system, with an air-vent being the only opening to the atmosphere. The contents of a vessel used for bioreduction would still have to be eventually disposed of following the normal procedure for Category 1 material in accordance to the ABPR (i.e. via incineration or rendering). However, if bioreduction is successful, the volume of waste and hence its associated disposal cost should be considerably reduced.

1.3 Project history

This project was jointly funded by Hybu Cig Cymru and the Welsh Government in two phases: Phase 1 started in 2007 to look at the practicality and costs of bioreduction together with an overview of the science; whilst Phase 2 started in 2009 to look at the science of bioreduction in greater depth.

For Phase 1, two fibreglass bioreduction vessels were installed vertically at Henfaes Research Station[1]. Each was of 6500 litre capacity, measuring approximately 2.5 m in diameter, and 3.0 m length. For Phase 2, an additional three vessels were also installed at Henfaes, being of the same dimensions but horizontally-orientated.

Following arrival at Henfaes, the vessels were placed in a thick visqueen as protection and placed on a bed of sand in the ground in a suitable location. The necessary grounds and electrical work was conducted, and then the area was fenced off to restrict unauthorised access by people and animals (Appendix 1).

1.4 Project aim

The aim of the project was:

"*To evaluate the effectiveness and biosecurity of in-vessel bioreduction as an on-farm containment system for fallen stock from sheep farms prior to disposal*".

This would be done by testing whether bioreduction provides a secure method of on-farm containment for fallen stock prior to disposal without increasing any biological or chemical risk i.e. it reduces pathogen loads, does not expel large volumes of harmful or odorous gases, and that the final product can be safely removed and disposed.

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[1] Henfaes Research Station is owned by Bangor University and is where the University farm is based. It comprises 46 ha of lowland, 203 ha of upland grazing and 1750 ha of common grazing rights.

2 METHODS

2.1 Trial management

Prior to adding carcasses, each bioreduction vessel was half-filled with water, which was then heated to 40 ± 2 °C by an oil-filled heating element running the length of the vessels. The internal temperature was maintained by a thermostat that regulated the degree of heating required. Air was automatically pumped to the base of the vessels and sparged at a pressure of approximately 0.5 bars, for 45 min $hour^{-1}$. An electricity meter recorded the amount of power (kWh) required per day to run the vessels.

A small incision was made to the abdomen of each adult sheep just prior to placing it in the vessel. The water level was maintained so that ⅔ of each carcass was submerged throughout the trial period. In Phase 1, the air from the exhaust pipes was vented into the open, whilst in Phase 2 they were vented into a biofilter bed (a mixture of woodchip and compost) to reduce the occurrence of smell.

For Phase 1, both vessels were managed differently:

- The first vessel had 300 kg of carcasses inputted on a single day and it was emptied after 3 months. This was repeated three times in total.
- The second vessel was managed as it would on-farm, i.e. fallen stock was inputted as and when they occurred from the farm's flock of 1600 sheep. This amounted to 2816 kg of carcasses over twelve months; with the greatest input over the lambing period.

For Phase 2, the three new vessels had 300 kg of carcasses added to them in one day, and were then inoculated with a high concentration of bacterial pathogens (*Salmonellae* spp., *Enterococcus faecalis* and *E. coli* O157) and a virus (porcine parvovirus) on the same day. The two existing vessels had the same amount of carcasses added, but no pathogens (to act as 'Controls'). This trial was repeated but with the vessels switched off (no heating or aeration) so that it could be seen how effective vessels were under a 'breakdown' scenario or when a farmer may have switched the vessels off to save on electricity.

2.2 Appraisal of bioreduction

Samples were collected over a period of up to five months in both Phases. All samples were analysed using approved, proven methods (see 'Further reading') and tested for the following:

- Liquor samples for the presence of bacterial and viral pathogens, and in Phase 1 also for their chemical properties.

- Gases (sampled from the opening hatch of the vessels and from the exhaust pipes) for bacterial and viral pathogens, and for greenhouse gas emissions in Phase 1.
- The biofilter for bacterial and viral pathogens (Phase 2 only).

The rate of carcass breakdown, issues encountered, and the economics of bioreduction were also noted (mainly in Phase 1).

3 RESULTS

3.1 Scientific aspects

3.1.1 Liquor and biofilter

In Phase 1, no *Salmonellae* or *Campylobacter* spp. were recovered from any sample throughout the trial period, even though they are commonly found in sheep. *E. coli* O157 is a pathogenic *E. coli* present in approximately 5% of sheep, and only once was it detected during the whole trial, and at very low numbers. Coliform bacteria (bacteria from the ruminant gut) were only recovered at initial stages. After initially high numbers, total bacteria numbers decreased in all samples, then stabilised.

In Phase 2, results were slightly different when the vessels were switched on or off. When switched on, numbers of all bacterial pathogens declined in both the inoculated and the Control vessels (Fig. 1). Some declined at a greater rate than others, but this is to be expected as some bacteria are hardier under such conditions. A number of pathogens declined by 5 log values per ml (100,000 per ml), which EFSA see as desirable when determining whether a system dealing with animal byproducts is biosecure. Indeed, by the end of the trial, many pathogens couldn't be detected at all. The metabolic activity of *E. coli* O157 was also detected during the trial; the greater its metabolic activity, the increased likelihood for it to cause infection. Metabolic activity also declined considerably during the trial period (Fig. 1). Levels of porcine parvovirus decreased by 3 log values per ml (1000 per ml), which again is seen as desirable by EFSA when determining whether a system is biosecure.

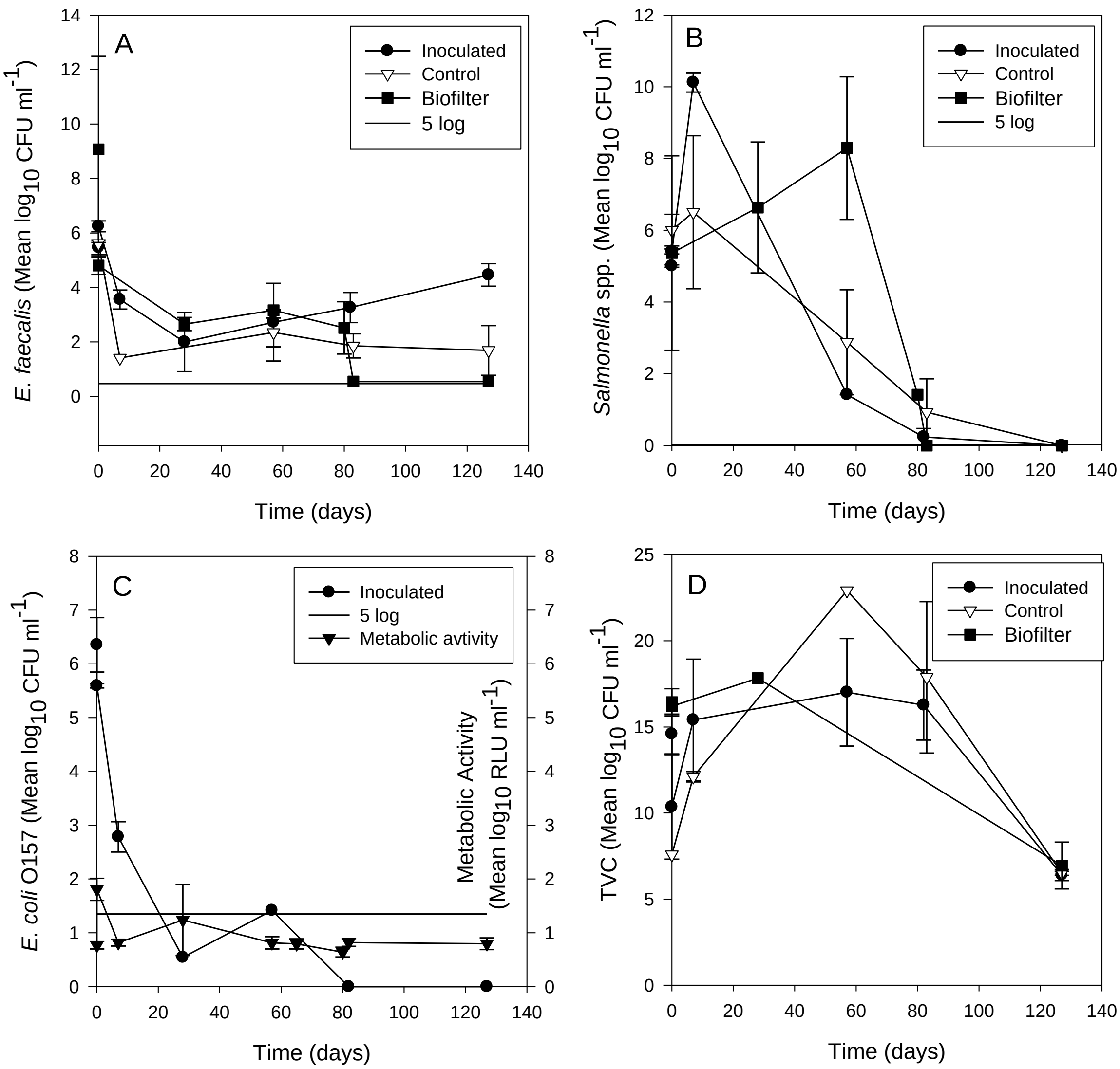

Figure 1: Numbers of *E. faecalis* (A), *Salmonella* spp. (B), *E. coli* O157 (C) and total bacteria numbers (TVC) (D) in inoculated and Control vessels and the biofilter when vessels were switched on. The continuous line represents a 5 log reduction (100,000) from starting concentrations. Values represent means ± standard error.

When the vessels were switched off, the rate of pathogen decline wasn't as great; however, all showed a significant decrease in numbers (Fig. 2). Again, some pathogens declined at a greater rate than others, whilst metabolic activity of *E. coli* O157 declined to below detection limits after approximately three weeks. Virus levels also decreased, but not as greatly as when the vessels were switched on.

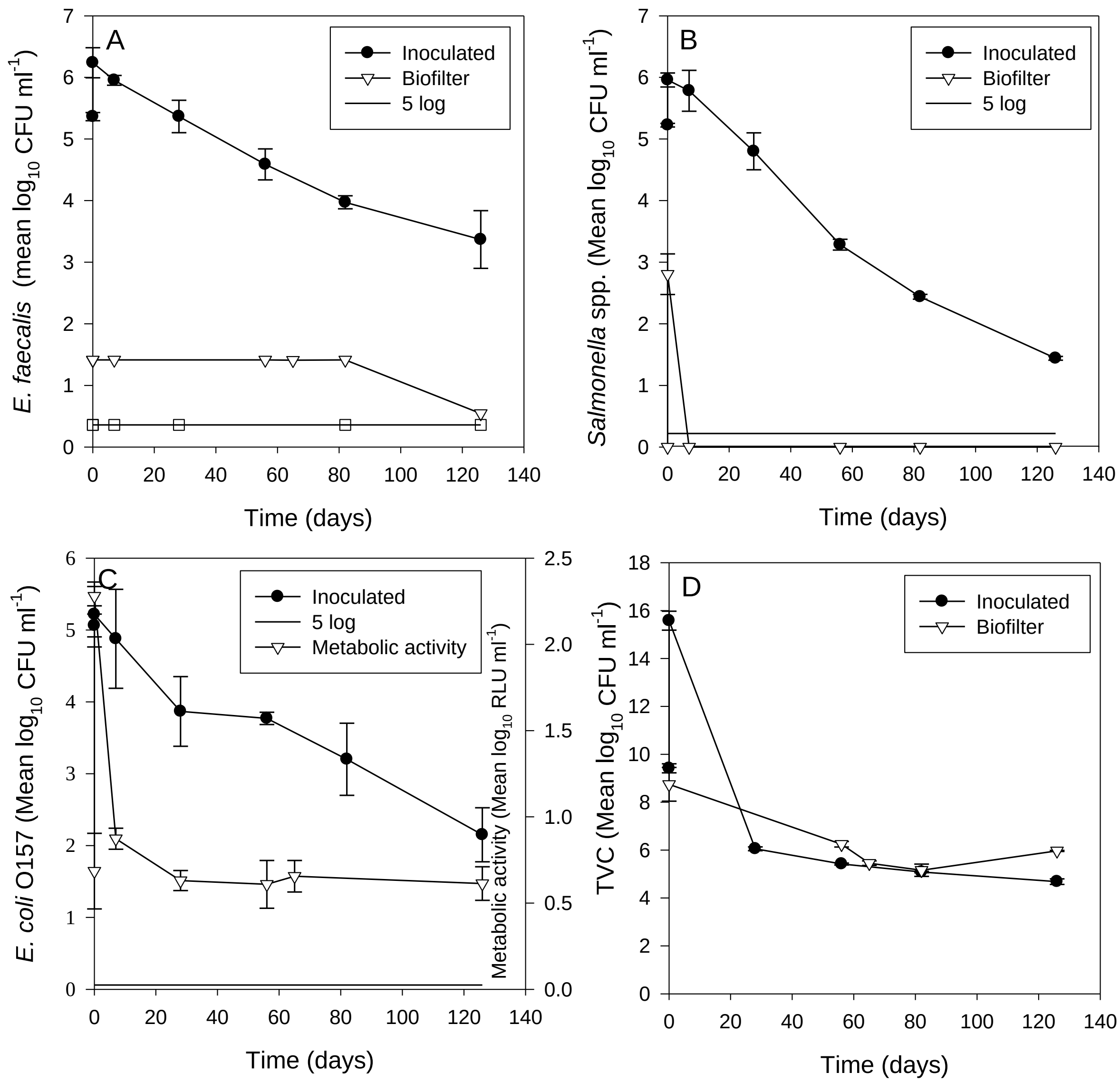

Figure 2: Numbers of *E. faecalis* (A), *Salmonella* spp. (B), *E. coli* O157 (C) and total bacteria numbers (TVC) (D) in the inoculated vessels and the biofilter when vessels were switched off. The continuous line represents a 5 log reduction (100,000) from starting concentrations. Values represent means ± standard error.

A summary of the chemical and microbiological characteristics of the wastes from both vessels in Phase 1 is presented in Table 1. Although there were variations with different sampling points, the liquor itself was slightly–moderately basic throughout the trial period (7.94–9.69), with low–moderate levels of nutrients such as nitrate, ammonium and phosphate. Levels of cations such as calcium were high, as expected (e.g. due to degradation of bone material).

Table 1. Average chemical properties of liquor waste samples from both bioreduction vessels in Phase 1. Values represent means ± standard error. Temperature values are those taken from individual samples immediately after collection. Values for chemical analyses are in mg l^{-1}, unless otherwise stated.

Parameter	Mean
Temperature (°C)	39.8 ± 0.7
pH	8.68 ± 0.03
Percentage solids (%)	3.1 ± 1.9
Total Carbon	5056 ± 1489
Total Nitrogen	1576 ± 434
Nitrate	0.23 ± 0.08
Ammonium	5.96 ± 1.94
Phosphate	143.8 ± 37.2
Calcium	261 ± 75
Potassium	421 ± 114
Sodium	266 ± 72

3.1.2 Gaseous emissions

Negligible emissions of greenhouse gases were detected throughout Phase 1.

No *Salmonellae* spp., *Campylobacter* spp., *E. coli* O157, *E. coli*, or coliforms were recovered from any samples of gaseous emissions throughout the trial period during Phase 1. When vessels were switch on during Phase 2, only very low levels of *E. faecalis* and *Salmonella* spp. were detected and only at initial stages; whilst none were detected when vessels were switched off. No porcine parvovirus was detected at all during Phase 2.

Although odour was occasionally an issue during Phase 1, the biofilter in Phase 2 resolved the issue and there were no negative comments during the trial by any staff working nearby.

3.2 Practical aspects

This has been discussed in detail in a previous report and published paper (see ‘Further reading’), so to summarise:

- One vessel was sufficient to take all the carcasses from Henfaes (flock of 1600 sheep) over a twelve month period, with the vessel requiring emptying only once. The frequency of emptying will depend on the frequency and volume of carcasses added. Carcasses began to degrade within a matter of days of placing into the vessels, with most having disappeared completely after three months (Appendix 2).
- Emptying the liquid portion of the vessel was relatively straightforward, with the liquid being sucked under vacuum for subsequent incineration.
- Relatively minor issues were noted during Phase 1 (e.g. ineffective filters); however most of these were resolved by Phase 2.

3.3 Economic aspects

This has been discussed in detail in a previous report and published paper (see 'Further reading'), so to summarise:

- Total cost of buying, importing, installing, and twelve months of usage of a bioreduction vessel was estimated to be £8000-9000. The payback period was estimated to be seven years.
- Excluding set-up and running costs, the disposal cost of liquid waste (bioreduction) was considerably cheaper than the cost of disposal of carcasses (conventional method) on a 'per weight' basis.
- Large farms could justify the costs of having a bioreduction system and it may reduce disposal costs for their fallen stock. The system may also be economically viable to smaller farms, should they share a vessel and associated cost.
- Improvements to the system design could significantly reduce running costs.

However, it should be remembered that these costs were based on figures gathered during Phase 1 in 2008 and that most, if not all, costs will have increased thereafter. In particular, the cost of electricity has significantly increased, and therefore so has the running cost of bioreduction. More accurate figures for electricity consumption gathered during Phase 2 also indicate that electricity consumption was higher than originally envisaged. These figures should therefore be taken with caution.

4 DISCUSSION

The concept of bioreduction is relatively simple, being based on containing fallen stock in a vessel which facilitates the microbial breakdown of carcasses in a biosecure environment. This reduces the volume of carcasses and hence the need for frequent disposal. These were the first trials to investigate the use of bioreduction as a containment method for dead sheep. The trial was managed so as to validate bioreduction under 'controlled experimental' conditions, and under 'on-farm' conditions, including conditions when the vessels had been switched off altogether.

Installation of the bioreduction system was relatively straightforward. However, the trial showed that the system should not be sited too close to households due to the possibility of undesirable odours unless an effective filter (such as a biofilter employed during Phase 2) is used. Other aspects to consider prior to installation include accessibility for the operator and for waste disposal by a suitable tanker, whether the area is liable to flooding, or whether it is particularly stony. Although some minor issues arose during the trial period, the system in the main required only occasional maintenance.

The volume of both the liquid and solid waste considerably reduced with time. The 'on-farm' vessel was half-emptied only once and was capable of handling all fallen stock generated on a farm with 1600 ewes over a twelve month period that included two lambing cycles. Two major advantages were that fallen stock could be immediately removed and placed in the vessel rather than having to store them whilst awaiting collection via the conventional system, and the vessel could be emptied by a waste disposal company at a convenient time for the operator. Using the bioreduction system was straightforward and required only minimal guidance at the onset. As well as being practical and easy to manage, the work also suggests that the livestock sector could benefit economically from implementing a bioreduction system in some circumstances.

The trial involved monitoring basic chemical and microbiological properties of both the liquor within the vessels and the gaseous emissions. It was found that no harmful gases or pathogens were generated or dissipated during bioreduction. Although pathogen decline wasn't as significant when the vessels were switched off, the system was still deemed to be biosecure in that any pathogens within were contained and not spread to the wider environment. Moreover, it should also be remembered that the contents of bioreduction vessels are eventually incinerated, thus further reducing any risk within the waste.

5 ADDITIONAL WORK

Other work has also been undertaken in parallel to the main body of work outlined in this report. All studies add further to our knowledge of bioreduction. Support from other organisations is noted.

5.1 Fate of pathogens during laboratory-scale bioreduction

As preliminary work to the field trial in Phase 2, laboratory-scale bioreduction vessels were constructed to assess in detail the fate of a wide range of pathogens during bioreduction. The results were positive in that pathogen levels declined throughout the three month period and that the work helped to formulate a more refined field trial. The findings have also been published in a peer-reviewed scientific journal (see 'Further reading').

5.2 The efficacy of catalytic products (funded by BPEX)

A range of commercial catalytic products were tested to see if they accelerated the rate of bioreduction of pig/pork waste in a laboratory-scale system. None were found to affect the rate of degradation therefore such products could be considered an unnecessary expense if a bioreduction system were to be operated.

5.3 Fate of transmissible spongiform encephalopathies (TSEs) in fallen stock containment systems (study led by the Veterinary Laboratories Agency; funded by Welsh Government)

A desk-top study investigated the evidence of persistence of TSEs in waste and soil environments to try and predict their fate in a bioreduction vessel, should carcasses be scrapie-infected. It was concluded that the overall risk of TSE transmission to the operator was 'negligible' and that TSE particles would likely adhere to organic matter in the base of the vessel, which is ultimately incinerated. The findings have also been published in a peer-reviewed scientific journal (see 'Further reading').

5.4 Carbon Footprint of bioreduction (funded by NFSCo)

A carbon footprint approach was undertaken to determine the environmental effects of bioreduction versus the conventional system for disposal of fallen stock. For the scenario tested, the project found that bioreduction was likely to emit a greater amount of greenhouse gasses than the conventional system per unit weight of carcass, primarily due to the energy requirement of running the system. However, the study concluded that the reverse may occur under differing scenarios (e.g. where farms are at large distances to collectors).

6 CONCLUSIONS

The findings of these studies greatly contribute to our understanding of bioreduction. From these trials, it can be concluded that bioreduction could potentially offer livestock farmers a practical, cost-effective, and biosecure method of containing fallen stock prior to disposal by an approved collector. We believe that there is strong scientific ground for the legislation of bioreduction by the EC.

7 FURTHER READING

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Williams AP, Edwards-Jones G, Jones DL (2009) Bioreduction of fallen stock: An evaluation of in-vessel bioreduction for containment of sheep prior to disposal. Final report to Hybu Cig Cymru and Welsh Assembly Government.

Wood S (2007) On Farm Storage/Bio-reduction as an Alternative to Immediate Removal of Fallen Stock. Report for Welsh Assembly Government and Hybu Cig Cymru.

APPENDICES

APPENDIX 1. Location of bioreduction vessels: two used in Phase 1 (top) and the five vessels for Phase 2 (bottom).

APPENDIX 2. Sequential carcass breakdown during Phase 1.

Day 0.

Day 9.

Day 23.

Day 93 (pre-emptying).

Day 93 (post-emptying).