Field lab: Evaluating Bokashi manure treatment in housed cattle systems

Final report

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Author: Dr Audrey Litterick

Summary

Take home messages: Odours in the housing were clearly more pleasant and less dominated by ammonia where Bokashi sprays were used, although this was far more noticeable at Mains of Fincastle than at Lochhill. Costs vary widely between farms, so it is important that farmers calculate the costs of using Bokashi for their own farm, and try it on a small scale to weigh up the benefits before choosing to use it on their whole farm. Further work is clearly required in order to better define the impact on carbon and nutrient losses and gaseous emissions of using Bokashi on manures on UK farms.

Context: Bokashi manure treatment was trialled with housed cattle on a mixed organic hill farm in the Scottish Highlands and a regenerative dairy farm in Ayrshire. Previous studies have suggested that Bokashi manure treatment can reduce emissions of ammonia and greenhouse gases, reduce odours in the housing and improve the quality of finished manures. However, there have been no UK studies which have compared Bokashi manure treatment with typical manure management methods used by UK farmers (i.e. the production of outdoor stacks of strawy cattle manure). Despite the fact that thousands of UK farmers are now using Bokashi, this study was the first of its kind in the UK.

Trial design: Farmers Andrew Barbour of Mains of Fincastle and Andrew Taylor of Lochhill sprayed Actiferm® onto the bedding in their cattle housing on several occasions over two winter seasons. They cleared the sheds in spring and stacked the manures under cover for the same length of time that they normally stacked their standard (uncovered) manures. They compared animal health, odours in the housing and manure quality after treatment. Manures were also comprehensively tested in the lab before and after treatment.

Findings:

- Odours in the cattle housing were reduced with Bokashi manure treatment, particularly at Mains of Fincastle.
- The cost of Bokashi manure treatment varied widely between farms, so it's important to work out the cost of using Bokashi on your own farm when looking at using it on a big scale.
- Andrew Barbour felt that Bokashi manure treatment made the manures more consistent and easier to spread. Andrew Taylor agreed with this, although felt that simply covering the manure stacks or composting brought similar benefits.
- Manure quality (nutrient and organic matter conservation) – Although there is evidence that Bokashi manure treatment can reduce carbon and nutrient losses, we were unable to demonstrate these benefits in this project, probably because the trials involved relatively small quantities of manure and because manures are inherently variable.
- Bokashi manure treatment has the potential to form part of a broader solution to some of the most important challenges facing agriculture today.
    - It could help reduce ammonia emissions in accordance with the UK Government's Clean Air Strategy and with goals aimed at meeting European targets for cutting ammonia emissions under the Gothenburg Protocol;
    - It could help reduce greenhouse gas emissions and aid meeting UK Net Zero targets;

- It could help farmers conserve carbon (in the organic matter) in manures, thereby maximising their value when applied to land;
- It could help farmers retain nutrients in the manures, thereby helping to maximise their fertiliser value and thereby reduce the requirement for bagged fertilisers.
- Even the simple act of covering manure heaps will help farmers move towards a better manure management strategy.

- Although there is sufficient evidence to show that Bokashi manure preparation has considerable potential in a UK context, there is also a requirement for further work, including a detailed comparison of the relative advantages and disadvantages of Bokashi manure preparation with those associated with creation of stacked, uncovered farmyard manures (currently the most common UK practice). In particular, there is a need to look at greenhouse gas emissions, ammonia emissions, manure quality and nutrient/carbon conservation.
- If further research were to confirm the benefits of Bokashi manure treatment in the UK, agricultural support schemes could encourage farmers to adopt covered Bokashi systems as a low-emission, multi-benefit manure management practice

Recommendations & next steps for farmers:

Bokashi manure treatment is clearly worth trying. If you plan to try it on your farm, the following key points are worth bearing in mind.

- Plan a simple comparison where you continue with your standard manure management techniques and use Bokashi on a proportion of your animal housing/manures. Compare the systems and keep notes on any clear differences that you find.
- If you can weigh your manures before and after treatment, then it is very much worth doing, since this gives the clearest idea of potential carbon and nutrient losses.
- Get advice from the manufacturer of Actiferm® as to how best to try Bokashi on your own farm setting.
- You must cover your manure stacks during fermentation. Although fermentation will work to some extent in compacted manure piles, there is clear evidence that it works best in anaerobic conditions within covered heaps.
- Keep in touch with others already using Bokashi.

Useful resources:

All resources relating directly to this project, which include meeting presentations, case studies, links to guidance on the use of Actiferm® and the final report are available on the Innovative Farmers Bokashi web page (Evaluating Bokashi manure treatment in housed cattle systems.).

Farmer comments

Andrew Barbour – Mains of Fincastle The Innovative Farmers project gave us the chance to put a bit of science behind our on-farm experiments with Bokashi. After a couple of years, we felt there were enough benefits from the technique for us to take things a step further and we bought a brewer to start our own farm-based fermentation. We see benefits from Bokashi both in the cattle housing, where the ammonia smell is much reduced, and in the manures themselves. After Bokashi fermentation, manures are more crumbly and easier to spread. The cost of preparing Bokashi manures seems to us to be worth the effort, but we are still keen to know more about how successful our own fermentation methods are in producing a high-quality spray and whether we really are reducing greenhouse gas and ammonia emissions and conserving nutrients in our manures." Andrew Barbour (farmer), Mains of Fincastle, Pitlochry, Perthshire.

Andrew Taylor – Lochhill The Innovative Farmers project gave us the opportunity to try something different with our manure management process. Funding from both Innovative Farmers and our co-operative, First Milk, as well as Agriton allowed us to try using Actiferm sprays and then look at the impact on the cattle bedding in the housing, and manure quality after treatment. To be honest, the jury is still out. There is quite a lot of work and expense involved with Bokashi manure treatment, and we feel we lack the evidence to justify it, certainly at the moment. We did see a benefit through simply covering our manures with an impermeable sheet though and are likely to continue to do that. Sheeted manures seemed to decompose better, had reduced weight losses and were easier to spread. We are still interested in the Bokashi technique, but need more scientific evidence on the environmental benefits, such as reduced nutrient losses and reduced ammonia and greenhouse gas emissions, before we would be prepared to go to the expense of using Bokashi every year." Andrew Taylor, Lochhill Farm, Mauchline, Ayrshire.

Main report

1 Field lab aims

This project aims to determine the value of Bokashi manure treatment in terms of:

- practical benefits to animal husbandry (e.g. does Bokashi manure treatment result in any differences in bedding quality over the season, animal health, odours, incidence and severity of flies);
- the nutrient content, organic matter content, *E. coli* numbers and financial value of manures produced, compared to those produced by the two host farmers prior to the project (using simple outdoor stacking and turning of uncovered heaps);
- the time and cost spent on manure treatment prior to use (compared to that spent by the two host farmers prior to this on their manure treatment (simple outdoor stacking and turning of uncovered heaps);
- the ease of handling and spreading Bokashi manure compared to manures otherwise made at the two host farms;
- its carbon footprint compared with that associated with more typical manure management practices.

2 Project background

Bokashi is the Japanese word for "well-fermented organic matter". The organisms responsible for the Bokashi fermentation process thrive in anaerobic (oxygen-free) conditions and for that reason, the process MUST take place inside sealed bags or vessels. It is similar to the process used to create silage. Although the term "Bokashi composting" is being used by some practitioners in this country and abroad, this is misleading, because composting is an aerobic process (which requires oxygen), whereas fermentation (which occurs in Bokashi treated organic wastes) is not. For that reason, the term Bokashi manure treatment is used in this project.

Bokashi manure treatment involves spraying animal bedding (prior to, during [and in some cases after] the housing period) with a liquid mixture of active microorganisms (sold in the UK as Actiferm®). This product, which is sold in the UK by a single company (Agriton) is effectively an activated "starter culture" based on Effective Microorganisms® (otherwise known as EM®). The microorganisms present in the starter culture gradually colonise the bedding and dung mixture in the animal housing and begin to break it down during the housing period. Once the animals have been removed from the housing, the bedding and dung are taken out, mixed and covered with an impermeable membrane (usually plastic) and left for at least 6 to 8 weeks. The resulting dung can be used in the same way as dung produced by other means (e.g. outdoor stacking, covered stacking and turning or composting).

Bokashi waste management techniques (and the associated Effective Microorganisms® or EM® technology) are much more widely used in Asia Pacific countries, where they were originally developed by Professor Teruo Higa (University of the Ryukyus in Okinawa, Japan) and his team in the 1980s (EM Research Organisation: https://emrojapan.com/).

Bokashi manure treatment of solid manures can result in:

- improved health of housed animals;
- lower odours;
- drier bedding;
- reduced incidence of flies;
- reduced nutrient losses from the finished manure and improved carbon retention;
- reduced manure management costs;
- reduced carbon footprint associated with manure management.

The potential for Bokashi manure treatment is clear, but there has been very little work done to evaluate that potential in a European context and very few relevant peer-reviewed publications. Through a review of the literature (Appendix 1) and two simple, farm-based trials, this project will address some of the information gaps and will further highlight the potential for Bokashi manure treatment in the UK and for further investigation to better understand that potential.

3 Methodology and data collection

Two farmers (Andrew Barbour of Mains of Fincastle near Pitlochry and Andrew Taylor of Lochhill, near Mauchline) have looked at the potential for Bokashi manures over a 2-year trial. The farms and the methods used on each were slightly different. The trial details are therefore reported separately below.

Mains of Fincastle

Farming system - A mixed, organic family-run hill farm with beef, sheep and woodland pastures Plates 1, 2 and 3). Much of the grazing is species-rich grassland which sits within designated sites. The farm is home to a herd of 70 suckler cows. These are made up of a small fold of Highland cattle crossed with Whitebred Shorthorn, which form the basis for the suckler herd. These cows are crossed with Limousin to produce 8 month-old weaned calves. Cattle kept on the farm over winter are housed. Hard feed is bought in and silage is produced on the farm. The farm also has 600 Texel and Cheviot cross sheep producing finished and store lambs, mainly from rough grazing.

Plate 1. Farmer Andrew Barbour with his wife and daughter at Mains of Fincastle

Plate 2. Sampling untreated, covered manure at Mains of Fincastle

Plate 3. Covered manure at Mains of Fincastle

<u>Management of the bedding and housing</u> - Straw is often in short supply in this area and Andrew therefore uses farm-produced and locally-sourced wood chip along with straw as bedding for the cattle. The farm uses a shallow bedding system, which is cleared out every 6 weeks (December to May) with straw/woodchip laid at 15 cm depth and then topped up every 3 to 4 days with straw until cleaning out.

<u>Application of Actiferm</u> – Actiferm® (sourced from Agriton) was diluted with water (1 part in 20) and applied weekly using watering cans at approximately 1 l/m^2. It was applied to bedding in only one side of the housing, with the other side remaining untreated. Actiferm was applied approximately four times during the housing period from December through to May over the 22/23 and 23/24 seasons. The system has now changed slightly and costings for the 25/26 season are based on the purchase of EM® and molasses in order to produce ferments on the farm in a brewer (see Section 4).

<u>Preparation of the Bokashi manures</u> – Manures were removed from the housing every 6 weeks and were stacked outdoors for 12 months before use. The Bokashi manures were covered in heavy black plastic sheeting, which was weighed down with tyres. The standard manure, prepared according to normal farm practice, was also covered, although that had not been standard farm practice in the past.

<u>Application of the Bokashi manures</u> – The manures were spread on a permanent grass field in April in both years, using a top discharge dung spreader at around 10 t/ha. The two types of manure were spread on the same separate parts of the same field in both years.

Lochhill Farm

<u>Farming system</u> - A lowland, regenerative family-run dairy farm with a beef enterprise running alongside (Plates 4, 5 and 6). The farm runs 110 dairy cattle (Holstein x Fleckveih x Norwegian Red) and 45 suckler cows (Aberdeen Angus x Simmental). Replacements are bred on the farm and all animals not kept for milking or suckler cows are finished and sold for meat. There are around 450 cattle in total on the farm during the year. Cattle are housed in the winter.

Plate 4. Farmer Andrew Taylor (left) with his father and grandfather at Lochhill

Plate 5. Cattle on Bokashi-treated bedding at Lochhill

Plate 6. Cows enjoying the manure sampling process at Lochhill!

Around 20 t of barley is produced on the farm, but the remaining hard feed is bought in. Silage is produced on the farm.

Lochhill Farm is part of "First Milk", a co-operative organisation owned by its (approximately) 700 members. First Milk aim to have a positive impact on the world, whilst producing nutritious, tasty dairy products to feed a growing population. As a co-operative business, this starts with the member farmers, who all follow regenerative farming practices. Lochhill Farm won the First Milk Regenerative Farming Award (Scotland) in 2025, which recognised the extent to which the family are innovatively and practically addressing the challenges of regenerative dairy farming. Andrew Taylor, who has been leading the Bokashi work at Lochhill, is constantly on the lookout for new technologies and methods which might help the environmental and economic performance of the farming system as a whole.

Management of the bedding and housing – Straw was used for bedding during the housing period which lasted from mid-September until early May. The straw was blown into the sheds with a bedding machine and was then topped up daily as required.

Application of Actiferm® – Actiferm® (sourced from Agriton) was diluted with water (1 part in 20) and applied weekly from 1st October until 1st May (i.e. approximately 30 times) using watering cans at approximately 1 l/m^2. It was applied to two marked bays (6 m x 8 m) in the housing, with two bays remaining untreated.

Preparation of the Bokashi manures – Manures were removed from the housing in the first week of August and were stacked outdoors for 6 weeks before use. The Bokashi manures were covered in heavy black plastic sheeting, which was weighed down with tyres. The standard manure, prepared according to normal farm practice, was not covered.

Additional work in the 2024/25 season – Three additional manure treatments were set up at Lochhill once the manures were removed to the field in August 2025. The five treatments in the second of the 2-year trial all ran for just over 6 weeks, outdoors, as before. Treatments were as follows, with the additional testing and labour required being funded by First Milk:

- Standard strawy cattle manure, uncovered
- Standard strawy cattle manure, covered with impermeable black polythene
- Standard strawy cattle manure, uncovered and composted (turned thoroughly four times)
- Bokashi-treated strawy cattle manure, uncovered
- Bokashi-treated strawy cattle manure, covered with impermeable black polythene

During the second year's work at Lochhill, the weight of manures in each treatment were recorded before and after treatment.

Application of the Bokashi manures – The standard strawy cattle manure and the Bokashi-treated, covered manure were spread on a permanent grass field in late September, using a rear discharge dung spreader at around 15 t/ha. The two types of manure were spread on different parts of the same field in both years.

Evaluation of the time and cost of manure preparation methods

Both farmers made estimates of the time and cost taken in preparing Bokashi manures compared with their standard manure preparation method. In year 2, Andrew Taylor compared the time and cost of making the five types of manure listed above.

Testing of manures - both farms

Bokashi manures and the "farm standard" manures were tested at the start and finish of manure preparation in each of the two trials on both farms. Given the innate variability of organic manures, great care was taken to obtain a sufficient number of representative samples from each manure heap. When sampling, at least 24 sub-samples were taken from different areas and depths in each pile, using a soil auger. These were combined and thoroughly mixed before sub-sampling in order to prepare samples to send to the lab. Each manure was sampled three times to get three replicate samples on each sampling date.

Manure samples were tested for the following parameters:

- dry matter
- total nutrients (P, K, Mg and S)
- total C and C:N ratio
- nitrate and ammonium
- *E.coli* numbers

Farmer assessments

A key part of this project involved gathering information from farmers on the practicality, costs, challenges, problems and benefits from using Bokashi in their farming system. Each farmer was therefore asked to consider this as the trials progressed.

Given the short duration of the project, it was not thought useful to test soils both before and after manure application, because soil properties change slowly and would not change in a significant way after only two manure applications. However, both farmers were asked for their opinions on ease of spreading and whether they had observed any differences in soils or grass crops to which the two types of manures had been applied.

Project output

In addition to this project final report, which includes a literature review (Appendix 1) and a simple cost/benefit comparison of five key manure management systems (Appendix 2), a range of resources have been prepared and are now available on the dedicated Innovative Farmers web page (https://www.innovativefarmers.org/field-labs/evaluating-bokashi-manure-treatment-in-housed-cattle-systems/). These are listed under Section 7 (Further reading) in this report and include case studies on the preparation of Bokashi manures at each of the two host farms and links to information on preparing and using Actiferm in Bokashi systems on UK farms.

4 Results

Time and cost of manure preparation – Mains of Fincastle

Work at Mains of Fincastle began in 2022, with the purchase of Actiferm (at about £3/l) which was diluted (1 part in 20 l of water) and applied once per month at around 0.4 l/m^3 of manure and bedding over the 6 month housing period using a knapsack sprayer. In order to try to reduce costs and the difficulties of reliably getting Actiferm up to this relatively remote location, the system was changed in 2025. EM1® (which is used rather than Actiferm in "farm-produced-brews") is now being mixed with molasses and fermented in a domestic brewer twice per month before being applied as before. 1 l of EM® is mixed with 1 l of molasses and 20 l of water for the fermentation process, which lasts 14 days. A continuous culture system is then run, with molasses and water being topped up after each drawdown of ferment. The EM1® costs £40/l, the molasses costs £5.40/l and the finished ferment costs £0.85/l. Given that there is around 450 m^3 of manure and bedding requiring treatment, the total cost for the ingredients is around £206 for the season. The labour cost is estimated at no more than 1 hour per month at a cost of £15/hour, therefore the total cost of preparing the Bokashi manures is just under £300. Given that manures are already sheeted at Mains of Fincastle, the extra cost of producing Bokashi manures was estimated at around £0.66/m^3 or £0.85/t.

The manure and bedding mixture is removed from the sheds in spring and stacked, covered in impermeable black plastic for a year before use. Initially, silage plastic was used to cover the manure heaps, but it did not survive the winter gales on this exposed upland farm, even in a single year. The farm has now invested in a heavier (185 g/m^2) tarp at £0.95/m^2. Its longevity is unknown, but it has so far lasted 2 years and is still looking OK. Perhaps a better option would be to use a heavy tarp within a silage pit, but there is no silage pit on the farm and AgBags are not a feasible option for this farm either.

Time and cost of manure preparation – Lochhill

Application of Actiferm took around 30 minutes per week over 30 weeks. This time included diluting and mixing the product, then watering the dilute product onto an area of approximately 100 m^2 at 1 l/m^2. (It would take longer for a bigger area, but the cost per tonne of manure would go down.) The labour cost was around £7.50 per application (based on a standard labour cost of £15/hour). The Actiferm costs around £3/l of undiluted product (including delivery) and 60 l were used over the season to treat approximately 100 m^2. The total cost for producing around 30 t of Bokashi manures prior to sheeting was around £405, which equates in this case to £13.50/t).

Used silage covers were employed to cover smaller tonnages of the different manure types, so there was no cost for them. It took around half an hour to cover each manure pile in the second year of the trial (which were each around 5 to 7 t in weight. Although larger piles would take more time, the cost per tonne of covering of manure would go down as the heap size increases. Given that all the manures at Lochhill have to be moved outside and stacked for several weeks prior to spreading, the costs for removal and stacking have not been calculated, only the extra cost per tonne of manure when it was covered, or Actiferm®-treated and then covered. Compared with standard, stacked, uncovered strawy cattle manure, It was calculated that it cost about £1.25/t extra to sheet manure during its outdoor storage period. The total cost for producing and sheeting the bokashi manures was therefore around £14.75/t).

Nutrient and carbon content of manures – Mains of Fincastle

Manures at Mains of Fincastle were tested immediately after they had been removed from the cattle housing and stacked in the field in spring, then again, immediately prior to spreading, 1 year later. The results presented are average values obtained from three replicate samples from each manure (Tables 1 and 2).

There were few clear differences between the standard and Bokashi manures tested from Mains of Fincastle in year 1 (Table 1). Manure pH was the same in standard and Bokashi manures and did not change during the processes. Ammonium nitrogen content decreased during manure treatment, regardless of whether Bokashi or standard manure treatment was used. The percentage of readily-available nitrogen (N) present decreased markedly during manure treatment, but again, the same decrease was seen in both manure management systems.

There was no clear pattern to the apparent changes in total nutrient content between the start and finish of manure preparation, regardless of whether standard or Bokashi manure

Table 1. Nutrients and carbon (kg/tonne of fresh manure), readily-available N (RAN), carbon:nitrogen (C:N) ratio and *E. coli* (colony-forming units/g of fresh manure) in farm standard and Bokashi manures at Mains of Fincastle before and after treatment (trial year 1).				
	Standard manure		**Bokashi manure**	
Parameter	**Start**	**Finish**	**Start**	**Finish**
pH	9.2	9.1	9.2	9.2
Total N	4.2	5.5	4.5	4.8
Ammonium-N	0.4	0.1	0.4	0.0
% RAN	9.5	1.8	8.9	0.0
Total P	1.3	1.9	1.3	2.1
Total K	4.8	10.7	5.3	8.0
Total Mg	0.4	1.7	0.4	1.9
Total S	0.8	1.8	0.9	1.5
Total C	103	86	122	78
C:N ratio	25	16	28	16
E. coli	1500	<10	1500	<10

management was used. The high value for total potassium (K) content was thought to be an anomaly and has not been seen in manure samples tested after that date. There was a lot of variation between values from which the average total nutrient contents were calculated and for that reason, care must be taken not to over-interpret the total nutrient data presented in this and subsequent tables. Values for individual (total) nutrients were broadly those of extensively produced beef cattle, in that the values were generally lower than standard values published for strawy cattle manures in FAS Technical information (FAS, 2020).

The Carbon to nitrogen (C:N) ratio decreased considerably during manure treatment, regardless of whether Bokashi or standard manure treatment was used.

E. coli numbers decreased to below the detection limit following during manure treatment, but again, this happened in both standard and Bokashi systems.

Again, there were few clear differences between the standard and Bokashi manures tested from Mains of Fincastle in year 2 (Table 2).

Table 2. Nutrients and carbon (kg/tonne of fresh manure), readily-available N (RAN), carbon:nitrogen (C:N) ratio and *E. coli* (colony-forming units/g of fresh manure) in farm standard and Bokashi manures at Mains of Fincastle before and after treatment (trial year 2).				
	Standard manure		**Bokashi manure**	
Parameter	**Start**	**Finish**	**Start**	**Finish**
pH	8.6	8.6	8.6	8.5
Total N	3.4	3.5	3.6	3.5
Ammonium-N	0.1	0.1	0.1	0.1
% RAN	2.9	3.2	2.8	2.9
Total P	1.1	1.2	1.1	1.2
Total K	5.3	4.8	6.4	6.6
Total Mg	1.0	0.8	1.2	0.9
Total S	1.0	1.2	1.1	1.2
Total C	99	66	94	71
C:N ratio	29	19	26	20
E. coli	1500	<10	263	<10

Manure pH was almost identical in standard and Bokashi manures and did not change during the processes. Ammonium nitrogen content remained similarly low in both manures tested before and after treatment. The percentage of readily-available nitrogen (N) was also similar in both manures tested before and after treatment.

There was no clear pattern to the apparent changes in total nutrient content between the start and finish of manure preparation, regardless of whether standard or Bokashi manure management was used. Again, there was a lot of variation between values from which the average total nutrient contents were calculated and for that reason, care must be taken not to over-interpret the total nutrient data presented in this and subsequent tables. Values for individual (total) nutrients were again broadly those of extensively produced beef cattle, in that the values were generally lower than standard values published for strawy cattle manures in FAS Technical information (reference).

The Carbon to nitrogen (C:N) ratio decreased considerably during manure treatment, regardless of whether Bokashi or standard manure treatment was used.

E. coli numbers decreased to below the detection limit following during manure treatment, and again, this happened in both standard and Bokashi systems.

Nutrient and carbon content of manures – Lochhill

Manures at Lochhill were tested immediately after they had been removed from the cattle housing and stacked in the field in spring, then again, immediately after the 6-week Bokashi manure treatment process was considered complete, prior to spreading. The results are average values obtained from three replicate samples from each manure (Tables 3 and 4).

Table 3. Nutrients and carbon (kg/tonne of fresh manure), readily-available N (RAN), carbon:nitrogen (C:N) ratio and *E. coli* (colony-forming units/g of fresh manure) in farm standard and Bokashi manures at Lochhill before and after treatment (trial year 1).

	Standard (uncovered) manure		Bokashi manure	
Parameter	**Start**	**Finish**	**Start**	**Finish**
pH	8.7	8.8	8.7	9.0
Total N	6.1	5.4	6.1	5.9
Ammonium-N	0.5	0.1	0.7	0.1
% RAN	8.2	1.9	11.5	1.7
Total P	3.0	3.4	3.2	3.6
Total K	12.7	8.9	12.9	12.1
Total Mg	1.6	1.8	1.7	1.9
Total S	2.8	2.6	2.6	3.0
Total C	99	81	101	67
C:N ratio	16:1	15:1	16:1	11:1
E. coli	10	10	10	10

There were few clear differences between the standard and Bokashi manures tested from Lochhill in year 1 (Table 3). Manure pH was similar in standard and Bokashi manures and did not change markedly during the processes. Ammonium nitrogen and the percentage RAN content also decreased during manure treatment, regardless of whether Bokashi or standard manure treatment was used.

Again, there was no clear pattern to the apparent changes in total and carbon nutrient content between the start and finish of manure preparation, regardless of whether standard or Bokashi manure management was used. Again, there was a lot of variation between values from which the average total nutrient contents were calculated and for that reason, care must be taken not to over-interpret the total nutrient data presented in this and subsequent tables. Values for individual (total) nutrients were broadly similar or slightly higher than standard values published for strawy cattle manures in FAS Technical information (FAS, 2020).

The Carbon to nitrogen (C:N) ratio remained similar in both types of manures between the start and finish of treatment, which was different to the situation at Mains of Fincastle.

E. coli numbers were very low in both manures tested before and after treatment.

In the second year of trials at Lochhill, the Bokashi-treated and untreated manures and bedding were tested as before, but manures from three additional treatments were tested, including covered standard manure, uncovered Bokashi manure and composted (turned, uncovered) manure.

Manure pH was more variable than in the previous year, but it was always between 8.6 and 9.3, so fairly similar throughout (Table 4). Ammonium nitrogen content and the percentage RAN content decreased during all types of manure treatment, and the decrease in % RAN content was greatest in both Bokashi manures at the end of the process.

Table 4. Nutrient and carbon (kg/tonne of fresh manure), readily-available N (RAN), carbon:nitrogen (C:N) ratio and *E. coli* (colony-forming units/g of fresh manure) in covered and uncovered farm standard (stan'd) and Bokashi manures and composted manures at Lochhill before and after treatment in trial year 2. All manures were based on similar volumes and proportions of straw and dairy cattle manure.

	Start of manure preparation process		End of manure preparation process				
			Covered		Uncovered		
Parameter	**Bokashi manure**	**Stan'd manure**	**Bokashi manure**	**Stan'd manure**	**Bokashi manure**	**Stan'd manure**	**Composted**
pH	8.9	8.8	8.7	8.6	9.3	9.2	9.2
Total N	6.1	6.5	6.1	3.4	4.8	5.9	5.7
Ammonium-N	0.4	0.4	0.1	0.1	0.1	0.1	0.1
% RAN	6.3	6.3	1.7	4.1	2.9	1.6	1.9
Total P	3.0	3.2	3.7	1.1	3.1	4.2	1.9
Total K	11.6	11.1	14.2	5.3	11.7	10.5	4.1
Total Mg	1.9	2.0	2.3	1.0	1.9	2.7	12.3
Total S	2.5	2.5	3.2	1.0	2.5	3.0	2.6
Total C (%inFM)	96	93	75	102	71	83	87
C:N ratio	16	14	12	12	15	14	15
E. coli	6933	277	44	213	N/A	N/A	N/A

Again, there was no clear pattern to the apparent changes in total and carbon nutrient content between the start and finish of manure preparation, regardless of whether standard or Bokashi manure management was used. Again, there was a lot of variation between values from which the average total nutrient contents were calculated and for that reason, care must be taken not to over-interpret the total nutrient data presented in this and subsequent tables. Values for individual (total) nutrients were again broadly similar or slightly higher than standard values published for strawy cattle manures in FAS Technical information (FAS, 2020).

The Carbon to nitrogen (C:N) ratio remained fairly similar in all types of manures between the start and finish of treatment, which was different to the situation at Mains of Fincastle.

E. coli numbers were high at the start, particularly in the Bokashi manures and remained above the detection limit in the covered standard manure. Numbers were reduced after covered Bokashi treatment but *E.coli* was not tested in the other manures after treatment.

Mass losses at Lochhill as a result of manure preparation

The actual weight of manure used for each manure treatment method differed slightly and ranged between 5.6 and 6.4 tonnes. To simplify presentation of the results, they are expressed as a percentage of the initial mass lost during treatment (Figure 1).

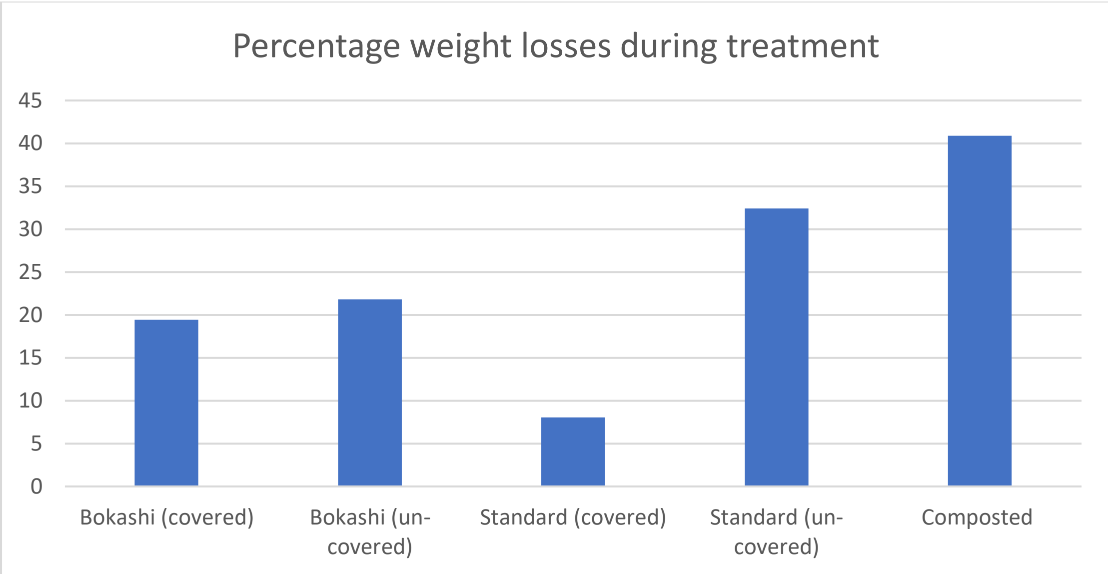

Figure 1. The percentage weight loss from small (5.6 to 6.4 t) batches of manure undergoing five different treatments.

The covered standard manure lost the smallest amount of weight over 6 weeks (around 13% whereas the composted manure lost the most (just over 40%). The standard uncovered manure also lost over 30 %. Both types of Bokashi manures lost around 20% of their weight over a 6 week period.

Discussion

Drawing firm conclusions about the nutrient and carbon content of manures produced using different methods in very small, simple, farm-based trials is difficult, because manures are inherently variable, both over time and within heaps. The standard values for the nutrient content of different types of manure published in SAC or FAS Technical notes are based on many hundreds of samples (rather than just three, as in this work) and it is usually the case that the nutrient content in samples from individual farms will vary from these standard values, sometimes by a great deal, depending mainly on the feeding strategy for the beasts in question. It is also the case that three different, replicate samples taken from the same heap can have widely different nutrient contents. That natural variability has made it very difficult to show whether changes in manure properties have taken place between the beginning and end of manure treatment.

Bokashi manure treatment has been widely reported to result in reduced nutrient losses (through reduced ammonia volatilisation and reduced leaching of nitrate and other nutrients) and reduced carbon losses when compared to other manure management systems, particularly composting.

Reduced nutrient and carbon losses might show up as higher nutrient and carbon content in the finished Bokashi manure, or they may become obvious as a result of reduced mass losses in the finished Bokashi manure. Whilst there is good scientific evidence to show that nutrient losses and carbon losses can be reduced through the use of Bokashi manure treatment in some circumstances, it was not possible to demonstrate loss reduction in this project. Some of the published information on reduced nutrient losses has been based on information gained from bench scale reactors rather than farms, and there have so far been no farm-scale studies which have compared the magnitude of nutrient and carbon losses from both Bokashi manure treatment and the types of manure management systems commonly used in the UK.

Despite the lack of evidence on reductions in nutrient and carbon losses, both farmers involved in this project have gained from it. Andrew Barbour remains convinced by the potential for Bokashi to reduce odours in the cattle housing and improve the handling characteristics of his finished manures. He believes it likely that nitrogen losses (through ammonia volatilisation) are being reduced. Andrew Taylor is less convinced by Bokashi, but is committed to covering his manures in future in order to reduce nutrient leaching and potentially reduce ammonia losses and he remains interested in the potential for Bokashi if further relevant evidence emerges.

There is some evidence from this project, and more than enough published scientific evidence to show that Bokashi manure treatment is worth further, more detailed study, using larger volumes of manure, careful weighing of manures before and after, and careful covering to ensure that truly anaerobic environments are created for fermentation, with no possibility of water or air getting into or out of the manure heaps. There is also scope to analyse the type and volumes of key gases being emitted from covered and uncovered, composted and Bokashi-treated manure heaps (in particular, ammonia and the three important greenhouse gases: carbon dioxide, methane and nitrous oxide). If Bokashi manure treatment could be shown to significantly reduce emissions of these gases and reduce losses of carbon, nitrogen and potentially other water-soluble plant nutrients, then there would be clear reasons for both government and farmers to look more closely at the technique as a way of tackling important challenges in agriculture today.

5 Conclusions

For a more detailed discussion of the points contained within it, and for references to back up the points made (to the extent that they currently exist) see the literature review (Appendix 1). A simplified comparison of the costs, advantages and disadvantages of the four main types of manure management systems is presented in Appendix 2.

The following key conclusions can be drawn from the practical work and literature review conducted in this project:

- ***Cost*** **-** Andrew Barbour at Mains of Fincastle found that it cost around £300/year to produce bokashi manures when brewing his own ferment. This cost around £0.85/t of manure. He felt that this cost was justified, given the reduced odours in the cattle housing and the improved quality in finished manures.
- ***Cost*** - Andrew Taylor at Lochhill found that it cost around £442.50 to produce 30 t bokashi manures based on purchase of Actiferm®. This cost around £14.75/t of manure. He felt that the cost was unlikely to be justified, despite the fact that the costs per tonne would reduce if the technique was to be used on all the manures produced.
- ***Odours*** - Andrew Barbour at Mains of Fincastle and his farming team were very pleased with the reduced odours in the cattle housing and felt that this was a major reason for choosing to continue with Bokashi manure treatment. They felt that the manures in the housing and manures following treatment smelt more like silage (which is fermented in a similar way to Bokashi manures) and less like typical strawy cattle manures.
- ***Odours*** - Andrew Taylor at Lochhill was less convinced that Bokashi sprays reduced the odours in the housing, but acknowledged that it was difficult to make a comparison with the two manure management methods tried, because the test areas were small (four areas of only 6 m x 8 m each) and very close to one another.
- ***Manure quality (ease of spreading)*** - Andrew Barbour felt that Bokashi manure treatment made the manures more consistent and easier to spread. Andrew Taylor agreed with this, although felt that simply covering the manure stacks or composting brought similar benefits.
- ***Manure quality (nutrient and organic matter conservation)*** – Although there is evidence that Bokashi manure treatment can reduce carbon and nutrient losses, we were unable to demonstrate these benefits in this project, probably because the trials involved small quantities of manure and because manures are inherently variable.
- ***Value of the technique – would you do it again?!*** – Andrew Barbour feels that the benefits of Bokashi manure treatment outweigh the costs and he plans to continue brewing his own ferment, spraying it onto the bedding as he has been doing and will continue to cover his manure stacks, despite the challenges of doing so. He intends to treat all bedding and is no longer producing untreated, uncovered manures stacked uncovered, outdoors in the way he used to.
- ***Value of the technique – would you do it again?!*** - Although Andrew Taylor remains interested in the potential for Bokashi manure treatment. He needs to see more evidence of the benefits before wanting to try it on a bigger scale. He is interested in the potential for impermeable covers for his manure stacks and feels that they are likely to reduce nutrient leaching and gaseous losses and is likely to use them in future, probably without the Bokashi sprays.
- ***Practical considerations*** - It is very important, when trying Bokashi manure preparation on farms, to exclude air during the main fermentation phase. The microorganisms present in EM® and Actiferm® work best in anaerobic (oxygen-free) environments and the evidence which does exist to support the use of bokashi fermentation techniques all relates to anaerobic environments.
- ***Practical considerations*** - This project has looked at the use of EM®/Actiferm® used according to the manufacturer's instructions to ferment wastes, then apply them to land. There is almost no evidence that EM® or Actiferm® work well in aerobic environments or applied to soil as amendments.

Overall project conclusions

- Bokashi manure treatment has the potential to form part of a broader solution to some of the most important challenges facing agriculture today.
    - It could help reduce ammonia emissions in accordance with the UK Government's Clean Air Strategy and with goals aimed at meeting European targets for cutting ammonia emissions under the Gothenburg Protocol;
    - It could help reduce greenhouse gas emissions in accordance with the UK's Net Zero targets;
    - It could help farmers conserve carbon (in the organic matter) in manures, thereby maximising their value when applied to land (in terms of their ability to maintain and enhance soil quality);
    - It could help farmers retain nutrients in the manures, thereby helping to maximise their fertiliser value and thereby reduce the requirement for bagged fertilisers.
    - Even the simple act of covering manure heaps will help farmers move towards a better manure management strategy.
- Although there is sufficient evidence to show that Bokashi manure preparation has considerable potential in a UK context, there is also a requirement for further work, including a detailed comparison of the relative advantages and disadvantages of Bokashi manure preparation with those associated with creation of stacked, uncovered farmyard manures (currently the most common UK practice). In particular, there is a need to look at greenhouse gas emissions, ammonia emissions, manure quality and nutrient/carbon conservation.
- There is no evidence based on long-term trials to determine the effects of Bokashi manures on soil health and quality, compared with standard manures.
- If further research were to confirm the benefits of Bokashi manure treatment in the UK, agricultural support schemes could encourage farmers to adopt covered Bokashi systems as a low-emission, multi-benefit manure management practice.

6 Tips and recommendations:

Bokashi manure treatment is clearly worth trying. If you plan to try it on your farm, the following key points are worth bearing in mind.

- Plan a simple comparison where you continue with your standard manure management techniques on a proportion of your animal housing/manures. Compare your standard system with Bokashi manure preparation and keep notes on any clear differences that you find.
- If you can weigh your manures before and after treatment, then it is very much worth doing, since this gives the clearest idea of potential carbon and nutrient losses.
- Get advice from the manufacturer of Actiferm® as to how best to try Bokashi on your own farm setting. The material can be applied in different ways to suit different farming systems.
- You must cover your manure stacks during fermentation. Although fermentation will work to some extent in compacted manure piles, there is clear evidence that it works best in anaerobic conditions, which will not occur uniformly unless air is excluded from the heaps, using an impermeable membrane, such as heavy plastic.

- Keep in touch with others: Agriton staff estimate that there are now several thousand farmers using Bokashi manure preparation. Many of these farmers are firmly convinced of the benefits and therefore choose Bokashi as their standard manure preparation method. It may be worth extending the networks created by this project in order to continue sharing knowledge and information.

7 Acknowledgements

This work would not have taken place without considerable effort from the two farmers involved and their contributions (including coffee-time farm kitchen conversations) are greatly appreciated. Thanks are also due to Agriton, for providing the Actiferm free of charge and to First Milk, who funded the additional treatments and associated testing and reporting conducted in year 2 of the trials at Lochhill. Thanks are also due to John Seed, a leading poultry farmer from Woodend Farm in Berwickshire, who provided enthusiastic and valuable constructive criticism of the literature review and helped compile the manure comparison table.

8 Further reading

All of the following information, which has been written specifically for this project can be found along with this report on the Bokashi web page on the Innovative Farmers website (Evaluating Bokashi manure treatment in housed cattle systems.).

- Bokashi in cattle systems (Video of webinar for the project's farmer group https://www.youtube.com/watch?v=_ek9tf7w0Ww)
- Treating manure with microorganisms – is Bokashi worth it? (https://www.innovativefarmers.org/knowledge-hub/treating-manure-with-microorganisms-is-bokashi-worth-it/)
- Case Study 1: Bokashi manures from housed dairy cattle at Lochhill Farm
- Case Study 2: Bokashi manures from housed beef cattle at Mains of Fincastle

The following links to publications on the Agriton website give practical information for farmers on how to use Actiferm®, how to develop and run a Bokashi manure management system and the benefits of Bokashi for manure management.

- FYM https://indd.adobe.com/view/8f55bb36-4e91-43a1-901e-ba2b82b39873
- Bokashi: https://indd.adobe.com/view/8a3f8644-b210-4866-b051-f96be0c33ba0
- Actiferm®: https://indd.adobe.com/view/2282c1a2-9b3f-428a-86c1-87980aab72d8
  https://indd.adobe.com/view/ed4d55b8-904f-42ae-96c3-50e674537df1

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Agriton website (https://www.agriton.co.uk/)

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Farmers Weekly (16th January 2026) How bokashi is helping a poultry farm's nutrient management.

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Merfield, C (2012) Treating food preparation 'waste' by Bokashi fermentation vs. composting for crop land application: A feasibility and scoping review. Report written for Gisborne District Council for The BHU Future Farming Centre, Lincoln, New Zealand.

Olle, M (2021) Review: Bokashi technology as a promising technology for crop production in Europe Journal of Horticultural Research and Biotechnology **96(2)**: 145–152.

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8. Appendices

Appendix 1 – Review of relevant literature on Bokashi and Bokashi manure treatment

Appendix 2 – Cost/benefit comparison of five key manure management systems

Appendix 1 Review of relevant literature on Bokashi and Bokashi manure treatment

Contents

Introduction

Bokashi waste treatment is used by a relatively small number of devotees in a range of commercial and domestic scenarios in the UK. It is thought that several thousand farmers in the UK are currently using it, with most of those concentrated in the south and southwest of England (Andrew Sincock, Agriton, personal communication). Agriton (a farming and garden supplies company based in Devon) is the only UK retailer currently selling the microorganism preparations required to kickstart large-scale, farm-based Bokashi processes. The patented preparation is sold to farmers in a liquid form, known as "Actiferm®". EM® a related microorganism preparation, which effectively forms part of Actiferm®, contains different suites of microorganisms depending on the country and situation it is to be used in, is also sold by Agriton. Advice on how to use Actiferm® and EM® is freely given by Agriton staff, who are keen to help and encourage to farmers adapt standard methods in order to use the product in their own farming systems.

Kitchen-scale Bokashi systems are also popular with some householders as an alternative (or an "add-on") to more traditional kitchen compost bins and home composting systems. The equipment and microorganism preparations are easily available from several UK retailers. Kitchen scale Bokashi systems are said to have various benefit over and above traditional compost caddies and are likely to be less smelly, which is clearly important in domestic settings.

Bokashi waste management techniques (and the associated Effective Microorganisms® or EM® technology, see below) is much more widely used in Asia Pacific countries, where it was originally developed by Professor Teruo Higa (University of the Ryukyus in Okinawa, Japan) and his team in the 1980s (EM Research Organisation: https://emrojapan.com/).

There are very few refereed scientific publications which evaluate and define the benefits from using Bokashi waste treatment and EM® in temperate climates, and a great deal of "grey" (non-refereed) literature and anecdotal evidence, again, much of which relates to tropical and sub-tropical climates. A key reason for the lack of published evidence is likely due to the fact that EM® is a relatively low cost product that has been developed by a philanthropic organisation which aims to put a great deal of the knowledge and power required to use it into the hands of farmers, many of whom are relatively poor and run subsistence and low-input holdings. The EM Research Organisation simply does not have significant sums of money to spend on extensive scientific research programmes, in the way that large agrochemical companies do. Instead, it has relied on word of mouth, presentations at practical conferences and farmer events and case studies published on its website to spread information about its work. The EM Research

Organisation has always, and still does, rely to a very large extent on farmers trying the products and techniques for themselves and talking about their experiences to interested parties (Sangakarra, 2023).

The current state of knowledge relating to the benefits of Bokashi in temperate climates is summarised in this section.

What is Bokashi and how does it relate to EM®

Bokashi is effectively a waste management technique. Bokashi systems can be used with a wide range of organic waste types, such as domestic and municipal food and garden wastes in order to help them decompose, thereby creating useful organic resources which can be applied beneficially to land.

Bokashi is the Japanese word for "well-fermented organic matter". The microorganisms responsible for the Bokashi fermentation process (sold as EM® and/or under several trade names including Actiferm®) thrive in anaerobic (oxygen-free) conditions and for that reason, the process occurs best inside sealed bags or vessels. It is similar to the process used to create silage and is a process which is used to break down organic wastes into materials which are safe, useful fertilisers and soil conditioners.

There are several types of EM®, but the most important is EM-1®, from which the other types are derived. EM-1® is a liquid containing dormant forms of the microorganisms required to kick-start Bokashi processes. The species of microorganisms present in EM-1® vary, with specific blends being manufactured from those species naturally prevalent in the soils and climate where the product is to be used (https://emrojapan.com/). EM-1® is manufactured under license in specialised labs in more than 50 countries around the world. It is often used to make products for sales into particular markets, such as farming, and is not something that farmers can make themselves.

EM-1® contains four main types of microorganisms including lactic acid bacteria, yeasts, actinomycetes and phototrophic bacteria. These microorganisms break down organic materials through fermentation, preventing generation of methane and foul odours, whilst conserving nutrients and organic matter within the mass (https://emrojapan.com/).

The fermentation process

The microorganisms which carry out fermentation processes are fundamentally different to those involved in (aerobic) composting processes and other types of anaerobic decomposition processes (such as anaerobic digestion) which produce methane as a natural by-product. Those that drive the decomposition process in composting are widely present in the environment and therefore there is no need for starter cultures. However, the microorganisms that drive fermentation are often much less common in natural environments, and for this reason, fermentation usually requires the addition of starter cultures (such as EM-1® to ensure that the correct species are present in sufficient quantity to ensure fermentation occurs as desired.

The fermentation microorganisms break down a relatively small proportion of the complex organic compounds and energy in the starting material to form a range of compounds such as organic acids, e.g., lactic acid, butyric acid and acetic acid (vinegar) and biologically 'active' compounds e.g., antibiotics e.g., streptomycin. These materials, along with the absence of oxygen, then stop other 'normal' decomposition processes (such as aerobic breakdown and anaerobic digestion). They also eventually stop the activity of the fermenting microbes too, i.e., the process is self limiting. From this point onwards the material cannot decompose any further without the reintroduction of oxygen i.e. air.

As fermentation can only proceed in the absence of oxygen, the fermenting material MUST be isolated from the atmosphere. This means that almost none of the C, O, H and N or any other elements present in the starting material can escape, and only a small amount of energy is liberated (unlike with aerobic composting, which can generate significant heat).

The microorganisms that conduct the fermentation process mostly use 'simple' compounds as their food source, such as sugars, starches and proteins. They generally do not use more complex compounds such as cellulose or lignin. This means that only relatively nitrogen-rich materials with a relatively low C:N ratio, e.g., 10:1 such as animal manures and food preparation wastes that also contain high levels of water, are suitable for fermentation. Woody and other high carbon materials such cereal straw will not ferment well and will still be visible at the end of a fermentation process.

A small amount water is produced during fermentation, which mixes with some of the soluble organic and inorganic compounds to form a leachate. Leachate may need to be collected and removed from the fermentation vessel, as fermentation will not proceed beneath the leachate layer. The leachate, which is similar to silage effluent, can contain significant levels of dissolved organic and inorganic compounds, which are both valuable and potentially polluting.

What Bokashi is not!

Although many practitioners and sellers of EM® and related products often talk about "Bokashi compost" and "Bokashi Composting", these are misleading, often confusing and somewhat inappropriate terms. Composting can be defined as "a controlled, ***aerobic***, microbial decomposition process ***which involves self-generated heating***". In other words, the microorganisms which are responsible for the composting process create heat and they require oxygen in order to survive, thrive and break down organic matter. Bokashi waste management on the other hand, relies on microorganisms which live, thrive and break down wastes through fermentation in relatively cool, anaerobic environments (i.e. in the absence of oxygen). The most appropriate environments for true composting and Bokashi waste management are very different and the resulting products (compost and Bokashi manure) are also different in terms of their key properties. For that reason, the terms "compost" and "composting" have not been used in this project in relation to products made using Bokashi.

What are EM® and Bokashi used for?

EM® is used in an astonishingly wide range of applications, all of which were originally developed by Professor Teruo Higa and his team at the EM Research Organisation in Japan, which remains committed to supporting manufacturers and practitioners in its use (Higa, 1980; EMRO website). The EMRO is particularly committed to empowering subsistence, low-input, organic and regenerative farmers to develop and use low-tech solutions for pest and disease control and soil health management. There are applications for EM® and Bokashi in:

- agriculture, including animal health and animal husbandry
- field and glasshouse horticulture
- aquaculture
- water treatment

- waste treatment (including management of domestic, municipal and commercial organic wastes of all types)
- human health and medicine

The many practical applications for EM® and Bokashi are described in detail in Professor Higa's books (Higa, 1996; 1998), with hundreds of case studies also documented on the EMRO website (https://emrojapan.com/). This review concentrates only on applications for EM and Bokashi in manure management.

Potential benefits of Bokashi in relation to manure management

Advocates of Bokashi Manure preparation claim that the method is superior to other manure management methods for key reasons, which are summarised below then discussed in relation to available evidence.

- Odours, both in animal housing and around covered manure stacks are often said to be lower than where manures are not treated with EM® preparations.
- Ammonia emissions from Bokashi-treated manures have been reported to be lower from animal housing and from manures as they are being prepared for spreading.
- Greenhouse gas emissions from Bokashi-treated manures have been reported to be lower from animal housing and from manures as they are being prepared for spreading.
- Nutrients and organic carbon (in the form of organic matter) are thought to be conserved in covered Bokashi systems, thus the majority of these valuable commodities are preserved for use on the farm.
- The time taken to produce a "ready-to-use" manure is shorter with Bokashi than it is with more typical stacked manures or composts.
- The cost of Bokashi Manure preparation is lower than some other manure preparation methods, in particular composting.

Odours - While it makes sense that foul odours (probably due mainly to gaseous ammonia and sulphurous gases) are reduced in sealed Bokashi systems, many of the claims as to odour reduction relate to animal housing where bedding is regularly being sprayed with EM® (e.g. Actiferm). This is because the microorganisms present begin to ferment the mixture of manure and bedding *in situ* and reduce production of ammonia and other foul-smelling gases even as the animals are living on it. There is no scientific evidence to prove that treatment of animal bedding with EM® (e.g. Actiferm) reduces odours in the housing, but there are too many reports of it from too many different farmers, for this benefit not to contain an element of truth, at least for some.

Ammonia emissions – Ammonia emissions are a major problem in the UK, with the great majority (around 88%) of emissions coming from agriculture, and much of that coming from animal housing (Defra, 2024, Farming and Water Scotland website, 2025). Ammonia is not a greenhouse gas, but it presents a risk to the environment for other reasons. These include nitrogen deposition in natural environments, which can be a threat to biodiversity, as well as reactions with sulphur dioxide, nitrogen oxides and other pollutants in the air, which form small particles that can pose a risk to human health. It can be a particular risk to the health of farmers who regularly work in enclosed spaces such as animal housing. The UK government and devolved administrations are extremely concerned about ammonia emissions and have set out rules to help farmers minimise them (Defra, 2024, Farming and Water Scotland website, 2025).

Ammonia has a sharp, to many, unpleasant and distinctive smell and many farmers have reported that treating animal bedding with EM® (e.g. Actiferm) reduces ammonia smells in the housing. Although there is no scientific evidence to prove that this can happen, there are many anecdotal reports that it does. The fact that the Bokashi process should be completed in sealed units, means that ammonia emissions during manure preparation (for use) should also be reduced considerably when compared to other manure preparation methods such as stacking in uncovered heaps, or composting.

Given the national importance of reducing agricultural ammonia emissions, and the potential for Bokashi manure treatment to help reduce them, there is a clear reason to fund detailed work into this subject area.

Greenhouse gas emissions – Many researchers have concluded that Bokashi could help reduce greenhouse gas emissions associated with waste treatment and have underlined the need for future research funding in that area (Bosch *et al.*, 2017; Chavez-Rico *et al.*, 2022; Cooper *et al.*, 2026; Sangakarra, 2023; Sincock, personal communication, 2025).

The greenhouse gases associated with manure preparation, storage and application are nitrous oxide, methane and carbon dioxide. Given the global importance of reducing emissions of these gases, there have been surprisingly few studies to investigate the potential for different manure management strategies in this context. There is clear evidence that composting results in considerable carbon losses through carbon dioxide emissions in comparison with Bokashi manure management (Bosch *et al.*, 2017; Chavez-Rico *et al.*, 2022; Feed Innovation Services, 2013). (Composting also often results in additional carbon dioxide emissions during machinery operations associated with aerating and turning the material (Bosch *et al.*, 2017)).

A basic understanding of the fermentation process suggests that only small amounts of greenhouse gases should be emitted from it, compared with some other decomposition process types, for example, composting or uncontained anaerobic digestion (see section on the fermentation process). It also makes sense that gaseous losses (in general) are likely to be lower where manure is prepared for use in completely sealed systems (as should be the case with Bokashi systems) rather than stacked outdoors in open systems. However, there is limited evidence to support these theories other than to show that the weight of finished Bokashi manures is usually little changed compared to the starting weight (Feed Innovation Services, 2013; Merfield, 2012).

Merfield also said that methane is not produced in significant amounts during bokashi fermentation but he did not quote the source(s) of his information and he found no information on nitrous oxide emissions. Only three, small, detailed studies on nutrient losses during different waste management processes have been found. The first two relate to green wastes being treated through Bokashi fermentation or composting. Hillberg (2020) did not observe significant differences in greenhouse gas emissions between fermentation and composting waste treatment systems, whereas Bosch *et al.* (2017) found that the carbon footprint of a composted green waste was 27 times higher than that of a Bokashi-treated green waste. A third study compared the degradation of wastes using three composting system types, bokashi fermentation and vermicomposting (worm composting) in bench-scale trials (Cooper *et al.*, 2026). This study focussed mainly on the impact (and potential impacts) of the finished products on . However, it also concluded that carbon losses were considerably reduced where the wastes were treated using a Bokashi system rather than in any of the three types of composting system evaluated.

No studies have been found which compare the greenhouse gas emissions from Bokashi-treated manures with manures simply stacked and stored outdoors (as most currently are in the UK).

Great care must be taken to ensure that greenhouse gas emissions are minimised post-preparation/storage (i.e. during spreading) by following good agricultural practice (e.g. Scottish Executive, 2005) otherwise some or all of the benefits obtained from reducing emissions during preparation and storage could be lost.

Given the national importance of reducing greenhouse gas emissions in order to move towards "Net zero", there is a clear need for further work to investigate the potential for Bokashi waste treatment to reduce greenhouse gas emissions at all stages of manure treatment, preparation for use and spreading.

<u>*Reduced losses of nutrients and organic carbon*</u> - It makes sense that nutrient losses (in general) should be considerably lower (or almost eliminated) where manure is prepared for use in completely sealed systems (as should be the case with Bokashi systems) in comparison with systems which are open to the air (e.g. composting and stacked, uncovered manure heaps). Various sources have said that nutrient losses are minimised in Bokashi systems compared with other types of system (e.g. Chavez-Rico *et al.*, 2022; Merfield, 2012, Agriton website, Hillberg, 2020). Chavez-Rico *et al.* (2022) emphasised that waste management techniques that relied on reducing (anaerobic) conditions, including fermentation, tended to conserve more carbon, nitrogen and phosphate than those which took place in aerobic conditions (composting).

However, few studies have actually measured the extent of nutrient and carbon losses in different manure management systems. Feed Innovation Services (2012) clearly showed that losses of both carbon (and therefore organic matter) and nutrients were significantly higher in a composting process than in a Bokashi process where fresh green waste was being treated. A loss of only 3.2% of the original waste mass was lost in the Bokashi process, whereas 60.2% of the mass was lost in the composting process. Similar, high mass losses are usual with composting processes. Whilst much of the mass loss during composting will be down to CO_2 losses due to respiration of the aerobic microorganisms which mediate the composting process, some of these losses will also be due to losses of small amounts of other gases (e.g. nitrous oxide, ammonium and methane) and to leaching of nutrients (e.g. nitrate and potassium) and water.

Similarly, Bosch *et al.* (2017) when comparing composting and Bokashi treatment of fresh grass clippings, recorded average carbon and nitrogen losses of only 4.3 and 0.9% respectively following Bokashi treatment and average carbon and nitrogen losses of 64.0 and 12.8% respectively following composting.

No studies have been found which compare the losses of carbon and plant nutrients following Bokashi-treated manures with manures simply stacked and stored outdoors (as most currently are in the UK).

Of course, it is important to consider the potential for nutrient losses after manure preparation (i.e. during the movement, storage and application of manures). Such losses can be considerable if manures are inappropriately stored following treatment or applied in inappropriate ways. Although several workers have acknowledged the potential for post-manufacture nutrient losses, particularly during the spreading of Bokashi manures, no studies were found which quantified them.

Given the high, and increasing, cost of fertilisers and the importance of minimising nutrient losses to the environment (pollution), there is a clear case for further investigations into the potential for Bokashi manure management to help with these issues.

Reduced time and cost of manure preparation – Several workers have talked about the considerably greater amount of time and cost required to produce composts compared to Bokashi manures (Feed Innovation Services, 2013; Merfield, 2012). However, most of these studies related to treated of green/garden wastes rather than animal manures. Very few UK farmers take the time to make true compost from animal manures, and even those who say they do are usually just turning their manures a few times to introduce a bit more air than would otherwise be mixed with the manure and bedding. Animal manures do not compost well because they are typically too wet, too dense/airless and contain too much nitrogen in relation to carbon to compost easily or well. A more relevant comparison for farmers would be to consider the amount of time and money spent in preparing their standard manure for spreading (usually this means through stacking it outdoors, uncovered) with that taken to make a Bokashi manure. The relative costs and time spent would differ, depending on the farmer, the farm, the faming system and the available equipment. Despite the clear value in studies of this type, when evaluating the potential for Bokashi systems, no studies of this type have been published to date.

Evidence that Bokashi manure treatment can improve animal health and welfare

No published, refereed scientific evidence was found to demonstrate that the use of EM preparations in animal bedding used for housed animals can improve living conditions for livestock, working conditions for farmers or animal health, despite the fact that many farmers around the world are convinced that the benefits are clear. The lack of evidence does not mean that the benefits are not real, it may simply mean that no relevant research has been done and published.

Farmers in the UK and other European countries as well as those working in hotter climates have claimed that foot and respiratory health is better and that the atmosphere in the housing is more pleasant for both livestock and farmers (i.e. it is less odorous and has lower ammonia concentrations, Andrew Sincock, personal communication). A reduced incidence of flies has also been reported.

In addition to being used to treat animal bedding and manures, EM preparations are widely used as probiotic feed supplements for cattle, pigs, poultry, horses (and humans) and there is some published evidence from various countries worldwide to define the benefits of using it in this way (Sangakarra, 2023).

Despite the lack of refereed scientific papers, numerous case studies have been published on the EM Research Organisation website which demonstrated the benefits of using EM in animal production, including its use on bedding (https://emrojapan.com/em/case/).

Evidence that Bokashi can produce better manures

Many of the studies concerning Bokashi manures simply say that they improve soil health or soil quality in terms of soil structure, cation exchange capacity, fertility, porosity, water-holding capacity and microbial biomass (compared with situations where synthetic fertilisers are otherwise used). However, most forms of bulky organic matter would do similar things. More pertinent to this report are studies which compare Bokashi manures with other bulky organic materials typically used by UK farmers, including stacked strawy cattle manures, composts and fibre digestates: there are much fewer of those.

Advocates of Bokashi manures often say that they are superior to other types of manures in that they:

- Are easier to spread evenly
- Contain more nutrients and/or contain more nutrients in plant-available forms
- Contain beneficial microorganisms which will help improve soil health
- Contain bioactive compounds which can enhance plant growth and help protect crops from diseases.

The evidence for these claims is discussed below.

Ease of spreading – Several UK farmers have said anecdotally that Bokashi treatment makes manures "more consistent", "drier", "crumblier" and/or "easier to spread evenly" (Farmers Weekly, 2025; A. Sincock, personal communication). However, no scientific evidence was found to back up these claims. Again, this lack of scientific proof does not mean that the benefits are not real.

The form of nutrients in bokashi manures – It would not be correct to say that Bokashi manures are "better" than other types of manures (including true composts) in terms of their nutrient profiles, because the "best" manure (in terms of its nutrient concentrations and form of nutrients within it) will depend on the combination of soil, the production system and the nutrient requirements of the crop(s) in question. However, there is some evidence to show that Bokashi manures can be different from other types of manures made from the same wastes in terms of the form and amounts of nutrients present.

Various studies have shown that Bokashi manures (which should be produced in sealed spaces) contain more nutrients (including plant-available and unavailable forms) than other types, including stacked, uncovered strawy cattle manures and composts (e.g. Feed Innovation Services, 2013; Pandit *et al.,* 2020; Quiroz and Cespedes, 2019). This makes sense, since the sealed space minimises (and in most cases almost completely prevents) losses of nutrients through gaseous emissions and leaching.

Chavez-Rico *et al.* (2022) also reported, in their review, that bulky organic fertilisers produced by fermentation (such Bokashi manures) contained a higher proportion of nutrients (including nitrogen and phosphorus) which were in plant-available forms than those produced in oxidising conditions (such as uncovered, turned manures or composted manures). This effectively means that plants have better access to the nutrients within bokashi manures (when they are applied to soils) and therefore grow more quickly than when other manures containing lower concentrations of plant-available nutrients are applied. Other studies have not found the same though, and there is a general lack of definitive information on the impact of bokashi fermentation on the forms of nutrients in finished manures.

The impact (on soils) of beneficial microorganisms present in Bokashi manures – Whilst no studies were found that looked at the microbial profiles of Bokashi manures compared with composts or more typical stacked manures, many studies have focussed on the impact of Bokashi manures on crop health and disease suppression (Sangakarra, 2023; Subedi, 2025; Shin *et al.*, 2017). Some papers showed a clear reduction in crop disease (in for example, figs, tomatoes, lettuce, cucumber, aubergine and turf grasses) where Bokashi manures were used.

However, results were highly variable and most work has been conducted in warmer countries than the UK (Shin *et al.*, 2017).

Some studies have looked at possible mechanisms for disease suppression associated with Bokashi-treated wastes and it has been suggested that it can likely be attributed to the increased metabolic activity of the soil inherent microorganisms in response to Bokashi, which contains more easily decomposable compounds as compared to the other soil amendments (Van der Sloot *et al.*, 2023). These authors also suggested that Bokashi could promote the suppression of soil-borne diseases by stimulating the locally adapted soil microbiome but they acknowledge that that required further work.

There is a clear need for further investigations to be done in temperate climates in order to determine whether Bokashi manures are likely to reliably help prevent and control crop disease and to determine the mechanisms behind any disease suppression found.

<u>*Contain bioactive compounds*</u> – There are many anecdotal reports that the microorganisms present in Bokashi produce bioactive compounds such as enzymes, vitamins, antimicrobials, and phytonutrients (Agriton website, EMRO website). These substances are reported to enhance plant growth and help protect crops from diseases. However, there are no *in-depth* scientific studies which have compared concentrations of named bioactive compounds in Bokashi and other types of manure and no studies which have proved cause and effect of any of these bioactive compounds in plant disease prevention. Again, this does not necessarily mean that the bioactive compounds have no beneficial effects, it simply means that proof is lacking.

References

References used during production of this literature review are listed at the end of the Innovative Farmers final project report - Evaluating Bokashi manure treatment in housed cattle systems.