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CONTRACT REPORT
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Measuring effects of addition to pig slurry of EPIZYM-AW

undertaken for
Epizym Biosystems Ltd.

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Authentication

I declare that this work was done under my supervision according to the procedures described herein and that this report represents a true and accurate record of results obtained.

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Executive summary

EPIZYM-AW is a concentrated broad spectrum biological / biochemical complex in combination with selected ancilliary organic chemicals which is designed to deodourize and liquefy animal wastes.

An experiment to evaluate the efficacy of addition of EPIZYM-AW to the slurry produced by groups of finishing pigs was conducted within hermetically isolated rooms with a high level of environmental control.

EPIZYM-AW significantly reduced the depth of sludge left after removal of slurry at the end of the experiment, which shows an increase in liquefaction of the sedimented solids. An increase in liquefaction of sedimented solids, which results in an increase in flow and potential to pump more sludge out of below-slat stores, will be of considerable benefit to the producer. Increased capability to empty stores will increase the effective storage capacity under slats for successive groups of finishing pigs and, potentially, reduce the frequency of emptying required. In addition, an increase in liquefaction and ease of emptying stores will be likely to reduce the need to agitate slurry to promote emptying. Mixing or recirculating slurry, for example to remove sediments, can give off dangerous gases that can be lethal to both humans and stock.

An increase in liquefaction of the sludge would also benefit the producer to maximise storage capacity in above ground store slurry tanks where there is need to comply with the requirement for four months' storage as specified in the Control of Pollution (Silage, Slurry, Agricultural, Fuel, Oil) Regulations 1991.

Measurements of ammonia concentrations in the exhaust ventilation air, taken at weekly intervals from the rooms, showed a significant reduction in ammonia concentration in the third week of the experiment and cumulative ammonia emission up to the end of the third week was also significantly reduced.

The reduction of ammonia concentration in week 3, following high levels of ammonia in the second week of the experiment, showed the addition of EPIZYM-AW promoted a more rapid response in reducing ammonia than could be achieved by naturally occurring bacteria in slurry.

Subjective assessments of ammonia concentrations within rooms, by ADAS and Epizym Biosystems Limited Staff and others, more positively identified a benefit of reduction in ammonia concentrations in EPIZYM-AW treated rooms.

Introduction

Complaints from the public about odours caused by agriculture are recorded and reported every year by the Institution of Environment Health Officers. In the years 1987/88 to 1989/90, there were on average 1,382 justifiable complaints annually of which pigs were the cause of 650 complaints (47%). In the same years the spreading of slurry or manure was the major source of justifiable complaint (44%) followed by farm buildings (25%) and slurry and manure stores (21%).

Ammonia emission to the atmosphere has been implicated with both malodours and acid rain. In The Netherlands it has been estimated that ammonia emission contributed approximately 40% to the acidifying deposition in rainfall and that 85% of the emitted ammonia originates from volatilization from animal manure. For these reasons, the Dutch Government aims at a reduction in ammonia emission of 50% by 1995 and 70% before the year 2000.

Sedimentation of slurry in stores reduces the effectiveness of emptying and thereby reduces the storage capacity for subsequent refilling with slurry.

An effective slurry additive for odour control and reduction of ammonia emission would be of considerable public and environmental good. Increased liquefaction of slurry would increase the efficiency of slurry removal from buildings and reduce slurry sedimentation and could be of considerable financial benefit to the pig farmer.

EPIZYM-AW is a highly concentrated, broad-spectrum, biological/biochemical complex, in combination with selected ancillary organic chemicals for the positive deodourisation and liquefaction of all types of animal wastes.

This experiment protocol was designed to test the efficacy of the slurry additive EPIZYM-AW on a commercial scale in pig finishing pens with independent slurry stores and a high degree of environmental control.

The objectives of the experiment were to:

1. Determine ammonia emission from within buildings following application of EPIZYM-AW to slurry during production by finishing pigs.

2. Determine the effect of EPIZYM-AW on the liquefaction of slurry whilst in store.

3. Assess ammonia emission from slurry at spreading on grassland after storage.

Materials and methods

Four fully-slatted, hermetically isolated rooms in a controlled environment building, were thoroughly cleaned to remove all sediment from the below-slat store. The outlet from each store was then sealed to prevent loss of any liquid. Each room contained two pens capable of housing fourteen pigs per pen. Rooms were paired, and the water delivery rate of pig drinkers within room pairs was adjusted to be balanced between room pairs.

One hundred and twelve pigs of approximately 50 kg live weight were weighed and allocated to pens within rooms. Total pig live weight was also balanced between room pairs at the start of the experiment.

Each pair of rooms represented one replicate within a randomised block experiment design with room as a blocking factor. The experiment used four replicates in total, with the first two replicates run concurrently with pigs from 50 to approximately 85 kg live weight.

After slaughter of pigs and removal of slurry from the first two replicates, the rooms and slurry stores were thoroughly cleaned and resealed. For the third and fourth replicates, a further 112 pigs of approximately 50 kg live weight were weighed and allocated to rooms within room pairs, again so that total pig live weight within rooms was balanced between room pairs.

For each of the first two replicates, rooms within pairs were allocated at random to one of two treatments:

1) Control, no additive
2) EPIZYM-AW applied to pen floor and slurry store after one week and weekly thereafter until pigs were selected for slaughter.

For each of the last two replicates, rooms within pairs were allocated to the alternative treatment from that allocated in replicates 1 and 2, to account for any possible room effects in the experimental design.

EPIZYM-AW was reconstituted in lukewarm water and applied at the concentration and rate specified by Epizym Biosystems Limited (455 g / 4.55 l water / pen [week 1; purge dose] and 60 g / 4.55 l water / pen [subsequent weeks; preventative maintenance treatment], based on the slurry store capacity of approximately 18,200 litres).

From the starting live weight of approximately 50 kg to the slaughter live weight of approximately 85 kg, pigs were offered *ad libitum* a pelleted compound diet containing approximately 13.6 MJ/kg digestible energy and 20% crude protein (Appendix I). Final live weight of pigs at slaughter and food offered and refused between start and slaughter were recorded. Water consumption by pigs was recorded each week for all rooms.

The ventilation rate of each room was set at 0.1 m^3 / s / room (10% of typical maximum ventilation rate for a commercial building housing pigs of 50 to 85 kg live weight) throughout the experimental period. For replicates 3 and 4, ventilation rate of each room was set at 0.1 m^3 / s / room from the start until the end of the third week and 0.3 m^3 / s / room (30% maximum ventilation rate) from week 4 until the end of the experiment. Room temperature was maintained at 18°C throughout the whole of the experiment.

Ammonia concentration of inlet air (one sample point) and exhaust air (three sample points) was determined by micro meteorological mass balance techniques using acid flasks over the 24 hrs. preceding stocking of the rooms with pigs and at weekly intervals until slaughter thereafter. Ammonia was absorbed into 0.1 molar orthophosphoric acid through which a recorded volume of either inlet or exhaust air was drawn. Ammonia absorbed in the orthophosphoric acid was determined by flow injection analysis by the salicylate method. Samples were heated with salicylate and hypochlorite in an alkaline phosphate buffer to prevent precipitation of calcium and magnesium salts. The density of the colour produced, which is proportional to the ammonia concentration, was measured absorptiometrically at 660 nm. The total ventilation for each room over the 24 hr. sampling period was recorded, and ammonia emissions over each 24 hr. period were calculated.

After removal of pigs from pens for slaughter, both pens within each room were cleaned by pressure washing, and the volume of water used recorded. After cleaning, the depth of slurry in each room was measured using 35 grid reference points (Appendix II). For each room in turn, slurry was removed using a submersible pump at the outlet from the store which transferred slurry to a reception tank. A 5 litre sample of slurry was taken before the slurry in the reception tank was drawn into a vacuum slurry tanker. The depth of settled sludge remaining in the slurry store after the initial slurry emptying was measured at the same 35 grid reference points used for initial slurry depth. After measurement of settled sludge depth, the seal between the slurry store and an external channel was broken, and the settled sludge was manually removed to the external channel. The sludge was then pumped, from the external channel into the reception tank and a 5 litre sample was taken before the sludge was drawn into the vacuum tanker. The contents of the vacuum slurry tanker were discharged back to the reception tank, re-drawn into the vacuum slurry tanker and then discharged once again into the reception tank to ensure thorough mixing of the initial slurry and the settled sludge. One 5 litre and one 200 litre sample of the mixed slurry and sludge were taken before the remaining slurry was re-drawn into the vacuum slurry tanker and taken for disposal through slurry handling facilities at ADAS Terrington. The reception tank was thoroughly cleaned by pressure washing and the vacuum slurry tanker was charged with clean water and emptied (to clean the tanker interior) before the whole procedure for slurry removal was repeated on the next room. For replicates 1 and 2 and replicates 3 and 4, both control treatment slurry stores were emptied before the EPIZYM-AW treatment slurry stores, to ensure no cross contamination of micro-organisms occurred between control and EPIZYM-AW treated slurry.

The viscosities of the 5 litre samples of slurry, sludge and mixed slurry and sludge were measured in centipoise units and the mixed sample was also analysed for total solids. pH, Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), total nitrogen and ammonium nitrogen. The 200 litre samples of mixed slurry and sludge from replicates 1 and 2 were stored under aerobic conditions for four months. The 200 litre samples from replicates 3 and 4 were stored under aerobic conditions for two months and ammonia emissions after spreading on grassland were measured using small wind tunnels through which known volumes of air were drawn. Loss of ammonia to the atmosphere, from small plots (2 m x 0.5 m) spread with 5 kg slurry, was calculated from the product of the volume of air (drawn at 1 m / sec^{-1}) which flowed through the wind tunnel and the difference between the concentration of ammonia in air entering and leaving the tunnel (Lockyer *et al.*, 1989). Ammonia concentrations were measured by micro meteorological mass balance technique using acid flasks, containing 0.01 molar orthophosphoric acid, through which air was drawn at 5 l /minute $^{-1}$. Flasks were changed eight times, over approximately four days to give cumulative loss of ammonia over 24, 48, 72 and 102 h.

Statistical analysis

The statistical analysis was undertaken by the ADAS Biometrics Unit. Data for ammonia concentrations in exhaust ventilation, and slurry and sludge depths were analysed by analysis of variance with rooms as a blocking factor. Subset of data for replicates 1 & 2 and 3 & 4 for slurry and sludge depths were also analysed by analysis of variance with blocking by room omitted and variability due to blocks transferred to the residual error term.

Differences between the treatment means of pig live weights, food conversion ratios, water usage, slurry volumes and chemical and physical properties of slurry samples were compared by 'Student' *t* test.

A glossary of statistical terms is presented in Appendix III.

Results

Raw data for pig performance parameters, ammonia concentrations and volumes of air sampled, and depths of slurry and sludge are listed in Appendices IV, V and VI respectively.

Pig performance, measured as live weight at start and at slaughter, and food conversion ratio from start to slaughter, was similar for both treatments (Table 1). There were no differences between treatments in water usage by pigs in any week, the water used for pressure washing, total water usage or final volume of slurry produced (Table 2).

The concentration of ammonia in the exhaust ventilation before pigs were introduced to EPIZYM-AW or control rooms (week 0) was low (Table 3). Ammonia concentration increased with time although there was a peak in ammonia concentration during week 2. During week 1, the concentration of ammonia in exhaust ventilation from EPIZYM-AW treated rooms was lower and although there were no differences between rooms (P = 0.085) the difference was approaching the conventional P<0.05 level of significance. Ammonia concentration in exhaust ventilation was significantly lower from EPIZYM-AW treated rooms in week 3 (P = 0.002) but there were no differences between treatment rooms in other weeks.

Ammonia emissions from rooms on the day of sampling throughout each week of the experiment are shown in Table 4. As ventilation rates for all rooms were constant, differences in daily ammonia emission rates are similar to differences in ammonia concentrations. However, the cumulative ammonia emission (calculated by assuming ammonia emission for each week to be constant at the rate of the respective daily emission rate) was significantly lower from EPIZYM-AW rooms for the periods 0-2 weeks and 0-3 weeks (P = 0.004 and 0.003 respectively). For further cumulative ammonia emission, weeks 0-4, 0-5 and 0-6, whilst total ammonia emission was lower from EPIZYM-AW treated rooms, the differences were not significant.

Ammonia emission rate after spreading slurry on grassland and emissions as a percentage of total ammoniacal nitrogen spread, were similar for both EPIZYM-AW and control slurries (Table 5).

The viscosity of slurry, sludge and remixed slurry and sludge and the characteristics of the mixed slurry (Total solids, pH, BOD_5, COD, total nitrogen and ammonium nitrogen) and slurry as spread (Total solids, pH, total nitrogen and ammonium nitrogen) was similar for both EPIZYM-AW and control treatments (table 6).

Although there were no significant differences in the slurry volume measured from EPIZYM-AW or control treatment rooms (4.97 m^3 and 4.36 m^3 respectively), the analysis of variance of slurry depth with rooms as a blocking factor showed the depth of slurry was greater in EPIZYM-AW treated rooms ($P<0.001$; table 7). The depth of sludge in EPIZYM-AW treated rooms was also less than in control rooms ($P = 0.056$) and sludge, as a proportion of slurry, was lower in EPIZYM-AW treated rooms ($P<0.001$).

The analysis of variance of the sub sets of data for replicates 1 & 2 and 3 & 4, which omitted the blocking by room (with variability due to blocks transferred to the residual error term), showed further significant differences between treatments (Table 7). For replicates 1 and 2, slurry depth in EPIZYM-AW treated rooms was significantly greater ($P>0.001$) than control treatment rooms whilst sludge depth and sludge as a proportion of slurry was significantly less than the control treatment rooms ($P>0.001$). However, for replicates 3 and 4, although slurry depth in EPIZYM-AW treatment rooms was greater than control treatment rooms ($P>0.001$), sludge depth was greater in EPIZYM-AW treated rooms although there were no differences in the proportion of sludge.

Throughout replicates 1 and 2 of the experiment, subjective assessment by ADAS Terrington staff of the environment within rooms, consistently identified that perceived ammonia levels in the EPIZYM-AW treated room (replicate 2) were lower than the control room. However, in replicate 1, although ammonia levels in the EPIZYM-AW treated room were generally perceived to be lower, differences were neither felt to be as great nor as consistent as for replicate 2. Further subjective assessments conducted "blind" by an ADAS Maidstone staff member and two Epizym Biosystems Limited staff, similarly perceived differences between rooms in replicate 2 but less distinct differences between rooms in replicate 1.

Ongoing subjective assessment of the environment within rooms throughout replicates 3 and 4, by ADAS Terrington staff, gave similar results with a consistent impression of lower ammonia in the EPIZYM-AW treated room (replicate 4) but a less consistent difference between replicate 3 treatment rooms. This subjective assessment of differences between rooms in replicate 4 was also identified during a "blind" assessment by an Epizym Biosystems staff member and his guest at a visit two weeks prior to slaughter of pigs from the last two replicates. However, as with replicate 1, no differences between treatment rooms in replicate 3 were identified during this assessment.

Table 1. Performance of pigs finished in control and EPIZYM-AW treatment rooms and reasons for removal of pigs from experiment

	EPIZYM-AW	Control	t	P
No. of pigs at start	112	112		
No. of pigs at slaughter	108	105		
Average live weight at start (kg)	51.7 (1.95)	51.5 (1.77)	0.083	NS
Average live weight at slaughter (kg)	83.8 (1.53)	81.8 (1.82)	0.833	NS
Food conversion ratio (start - slaughter)	2.77 (0.071)	2.90 (0.094)	1.059	NS
Reason for removal:				
rectal prolapse	3	4		
pneumonia	1	1		
died	-	2		

( ) ± s.e.

Table 2. Water usage by pigs and for pressure washing rooms and final slurry volume

	Epizym-AW Replicate 1	2	3	4	Control Replicate 1	2	3	4	*t*	*P*
Drinker flow rate (l/min)	0.877	0.860	0.892	0.882	0.872	0.865	0.892	0.897	0.368	NS
Water usage week (l): 1	696.0	659.5	809.0	1048.0	758.0	637.0	950.5	822.0	0.103	NS
2	1046.0	1173.0	851.0	1142.5	998.0	1017.5	957.5	801.0	1.251	NS
3	1048.0	1161.0	804.5	1205.0	1012.0	1025.0	982.0	846.0	0.896	NS
4	1076.0	1260.0	666.0	1039.5	1017.5	1032.0	968.0	721.0	0.526	NS
5	1132.0	1239.0	829.5	1241.0	1167.5	1064.0	1154.5	836.5	0.443	NS
6*	1479.5	1301.0	1277.5	2142.5	1487.0	1406.0	1637.0	1192.5	0.203	NS
Water used for pressure washing (l)	676.5	652.0	665.5	720.5	668.5	364.5	589.5	573.0	1.948	NS
Total water usage (l)	7154.0	7445.5	5903.0	8539.0	7108.5	6546.0	7239.0	5792.0	0.929	NS
Slurry volume (Cu^3)	5.17	4.44	6.17	4.10	4.19	4.19	4.06	5.02	1.176	NS

* 9 and 8 days to removal for slaughter, replicates 1 & 2 and 3 & 4 respectively.

Table 3. Ammonia concentration (ppm) in exhaust ventilation of EPIZYM-AW and control treatment rooms

	EPIZYM-AW	Control	s.e.d.	f pr.
Ammonia concentration (ppm) week:				
0	0.66	0.63	0.131	0.772
1	12.75	20.77	4.406	0.085
2	39.32	41.92	3.407	0.455
3	13.30	16.63	0.937	0.002
4	15.69	16.63	0.769	0.236
5	19.78	21.61	4.785	0.707
6	22.51	21.15	5.155	0.795

Table 4. Ammonia emissions from rooms

	EPIZYM-AW	Control	s.e.d.	f.pr.
Ammonia emission (m^3)				
Daily during week:				
0	0.01	0.01	0.001	0.772
1	0.12	0.19	0.041	0.085
2	0.36	0.39	0.032	0.455
3	0.12	0.15	0.009	0.002
4	0.37	0.37	0.102	0.979
5	0.36	0.36	0.042	0.879
6	0.37	0.32	0.037	0.166
Cumulative for week:				
0	0.04	0.04	0.008	0.772
0-1	0.87	1.39	0.289	0.089
0-2	3.42	4.11	0.211	0.004
0-3	4.32	5.18	0.250	0.003
0-4	7.06	7.78	0.803	0.384
0-5	9.60	10.27	1.055	0.532
0-6	12.26	12.50	1.306	0.861

Table 5. Cumulative loss of ammonia after spreading on grassland

	EPIZYM-AW	Control	*t*	*P*
Ammonia loss (NH_4-N g/m^2) after:				
24 h	1.653	1.290	0.872	NS
48 h	2.173	1.910	0.476	NS
72 h	2.623	2.233	0.619	NS
102 h	2.998	2.50	0.864	NS
Ammonia loss as % of NH_4-N spread after:				
24 h	10.5	7.8	1.302	NS
48 h	13.8	11.67	0.806	NS
72 h	16.7	13.6	1.002	NS
102 h	19.1	15.2	1.203	NS

Table 6. Viscosity of slurry, sludge and mixed slurry and characteristics of mixed slurry and slurry as spread after storage

	Epizym-AW		Control		t	P
No. of samples	4	± s.e.	4	± s.e.		
Viscosity (centipoise) of:						
Slurry	92.8	31.28	75.0	38.74	0.356	NS
Sludge	4900	793.7	2945	766.8	1.771	NS
Mixed slurry and sludge	312.5	76.85	402.5	62.90	0.882	NS
Total slurry volume (m^3)	4.97	0.4580	4.36	0.221	1.776	NS
Mixed slurry and sludge:						
Total solids (%)	8.7	0.60	10.4	0.94	1.496	NS
pH	7.2	0.06	7.1	0.03	0.361	NS
BOD_5 (mg/l)	15750	2696.4	11625	2163.9	1.193	NS
COD (mg/l)	72600	8465.8	68100	14126.9	1.638	NS
Total nitrogen (g/l)	6.8	0.40	7.23	0.431	0.722	NS
Ammonium nitrogen (mg/l)	4828	527.3	5358	570.7	0.682	NS
Slurry as spread:						
Total solids (%)	8.1		8.2		0.18	NS
pH	7.0		7.0		0.13	NS
Total nitrogen	2.8		2.9		0.91	NS
Ammonium nitrogen (mg/l)	3113.		3224.		0.59	NS

Table 7. Depth of slurry and settled sludge in EPIZYM-AW and control treatment rooms

	EPIZYM-AW	Control	s.e.d.	f pr.
All replicates:				
Slurry depth (mm)	226.8	197.8	3.122	<0.001
Sludge depth (mm)	84.3	89.3	2.59	0.056
Sludge as a proportion of slurry	0.37	0.46	0.011	<0.001
Replicates 1 and 2:				
Slurry depth (mm)	220.4	189.4	2.41	<0.001
Sludge depth (mm)	73.4	99.6	3.12	<0.001
Sludge as a proportion of slurry	0.34	0.53	0.017	<0.001
Replicates 3 and 4:				
Slurry depth (mm)	233.1	206.3	6.94	<0.001
Sludge depth (mm)	95.1	78.9	4.54	<0.001
Sludge as a proportion of slurry	0.40	0.39	0.016	0.219

Discussion

The ammonia concentration of exhaust ventilation air during week 0, after thorough cleaning of rooms was very low (0.66 and 0.63 ppm for EPIZYM-AW and control treatments respectively) and confirms that emission characteristics of rooms, before stocking with pigs, were similar. During week 1, after stocking rooms with pigs but prior to the first addition of EPIZYM-AW treatments, ammonia concentration was greater in the exhaust ventilation of control rooms, although the differences were not significant. The higher concentration in control rooms was attributable to results for rooms in replicates 3 and 4, as ammonia concentration of control room exhaust ventilation air was lower than that of EPIZYM-AW rooms for replicates 1 and 2. Such variability is an inherent problem in experiments on biological systems, and illustrates the need for replication. Increasing replication will mitigate against such variability but can only be achieved at extra cost.

The ammonia concentration of exhaust ventilation air was mostly below the level required for compliance with regulatory legislation (Control of Substances Hazardous to Health [COSHH]; 8 hr. Time Weighted Average Maximum = 25 ppm) throughout the experiment. However during week 2, exhaust ventilation air from both EPIZYM-AW and control treatment rooms (both replicates 1 & 2 and 3 & 4) exceeded the COSHH regulatory level for Occupational Exposure Standard (35 ppm). During this period, the ventilation rate for both replicates 1 & 2 and 3 & 4 was restricted to 10% of maximum rate and higher ammonia concentration levels might have been expected. The reason for ammonia concentration levels as high as 39.3 and 41.9 ppm during week 2 for EPIZYM-AW and control treatment rooms respectively, is unclear. However, it is possible that bacterial populations capable of utilising ammonia, released from the breakdown of urine produced by pigs over the first two weeks, had not been established in either EPIZYM-AW or control treatment rooms at this stage.

The significant reduction of ammonia concentration in exhaust ventilation air from EPIZYM-AW treated rooms during week 3, following the previously high ammonia levels, shows a more rapid return to ammonia levels within the COSHH limits. The broad spectrum biological / biochemical complex of EPIZYM-AW is therefore likely to have established a favourable microbial population in slurry more rapidly than was achieved by naturally occurring organisms in the control treatment rooms.

The subjective assessments by ADAS staff and Epizym Biosystems Limited staff and their guests more positively suggested a benefit of reduction in ammonia concentrations within rooms in EPIZYM-AW treated rooms. However, ADAS Terrington staff conducting the experiment were not presented "blind" to treatment rooms and any subjective assessment may have been biased by prior knowledge of treatments within rooms.

Subjective assessments conducted "blind" may be considered more reliable but on each occasion that such assessments were completed, only one pair of replicate rooms were correctly identified as EPIZYM-AW treated or control rooms. It is interesting to note that these room pairs were not the same rooms in replicate 1 and 2 (September 1993 to November 1993) or replicates 3 and 4 (November 1993 to January 1994).

Whilst the objective assessments of ammonia concentrations in exhaust air only showed one week in which concentrations were lower for EPIZYM-AW treated rooms, it must be remembered that sampling was only completed over one 24 hr. period each week to be representative of emission characteristics for that week. Emissions over the remaining six days of the week may have differed between treatments although this is unlikely in view of the high degree of environment control imposed within the hermetically isolated rooms.

The ammonia emissions from rooms, calculated from the concentration of ammonia in exhaust ventilation and total ventilation for each 24 h sampling period within each week, shows similar differences between treatments as for ammonia concentration in exhaust air, since all rooms were controlled to achieve the same ventilation. However, the cumulative ammonia emission (which assumes ammonia emissions for each week to be constant at the rate of each respective daily emission rate) showed a significant reduction in total ammonia emission to the end of both the second and third weeks of the experiment. Ammonia emission from slurries spread onto grassland after two to four months storage was similar for both EPIZYM-AW and control treatments.

Whilst analysis of slurry and measurements of viscosity showed no differences between the EPIZYM-AW and control treatments, the reduced proportion remaining as sludge, after slurry removal, shows that EPIZYM-AW increased the liquefaction of slurry whilst in the below-slat store.

The depth of sludge in control treatment rooms was almost one half of the total slurry depth (46%) whilst that of the EPIZYM-AW treated rooms was just over one-third of the total slurry depth (37%) which represents a 20% reduction in sedimented solids.

The reduction in sludge as a proportion of slurry was largely attributable to the highly significant reduction in sludge depth in replicates 1 and 2 as shown by the analysis of variance where blocking by room was removed to restrict the analysis to replicate pairs.

An increase in liquefaction, which results in an increase in flow and potential to pump more sludge out of below-slat stores, will be of considerable benefit to the producer. Increased capability to empty stores will increase the effective storage capacity under slats for successive groups of finishing pigs and, potentially, reduce the frequency of emptying required. In addition, an increase in liquefaction and ease of emptying stores will be likely to reduce the need to agitate slurry to promote emptying. Mixing or recirculating slurry, for example to remove sediments, can give off dangerous gases that can be lethal to both humans and stock.

An increase in liquefaction of the sludge would also benefit the producer to maximise storage capacity in above ground store slurry tanks where there is need to comply with the requirement for four months' storage as specified in the Control of Pollution (Silage, Slurry, Agricultural, Fuel, Oil) Regulations 1991.

Conclusions

The concentration of ammonia in exhaust ventilation, measured at weekly intervals by micrometerological mass balance techniques, showed a significant reduction during the third week of the experiment in EPIZYM-AW treated rooms but at no other time.

Cumulative ammonia emission, based on the ammonia concentration of exhaust ventilation air measured on one day in each week, was significantly lower from EPIZYM-AW treated rooms up to the end of the third week of the experiment. Addition of EPIZYM-AW promoted a more rapid response in reducing ammonia than could be achieved by naturally occurring bacteria in slurry.

Subjective assessments of ammonia concentrations within rooms, by experimental workers and non-experimental personnel throughout the finishing period, identified a perceived reduction in ammonia concentration in some rooms where slurry was treated with EPIZYM-AW, but this was not consistent for all replicates in the experiment.

Subjective assessments by experimental workers may have been biased by fore-knowledge of treatment but similar perceptions were made by people assessing differences between rooms when presented "blind" with no fore-knowledge of treatments imposed on test rooms.

Analysis of samples of slurry did not show any differences in chemical or physical properties of slurry produced during the finishing period.

Measurements of sedimented sludge after removal of slurry from rooms showed a highly signficant reduction in the depth of sludge remaining. EPIZYM-AW treatment increased the liquefaction of the sedimented sludge which resulted in a 20% increase in removal of sedimented solids.

An increase in liquefaction of the sedimented sludge would be of benefit to the pig producer, both in terms of efficiency of building management and reduction in potential health hazards.

Recommendations

The increase in slurry liquefaction could be of signficant benefit to pig producers utilising slurry based housing systems. However, diversity of housing facilities and management practices may determine the extent to which individual producers benefit. It is recommended that a market survey of pig producers using slurry based systems is conducted to determine the marketing potential for EPIZYM-AW to these customers.

Further work with EPIZYM-AW in large-scale above ground slurry stores is also needed to identify the potential to increase liquefaction and reduce sludge sedimentation over prolonged (up to four months) storage.

Recent advances in the determination of odourants (eg indole and skatole) in head space gases from small samples of slurry, may be useful in small, exploratory investigations to determine the potential of EPIZYM-AW to reduce production of malodours from slurry.

Acknowledgements

Thanks are due to staff of ADAS Analytical Chemistry Laboratory, Wolverhampton, for the analysis of ammonia samples and slurry, to the staff of ADAS Terrington for the care of experimental animals and management of the waste handling facilities and also to ADAS Biometrics Unit for statistical analysis of data.

The author thanks Epizym Biosystems Limited for funding the experimental work at ADAS Terrington.

References

Control of pollution (Silage, Slurry and Agricultural Fuel Oil) Regulations 1991. SI 1991 No. 324. HMSO.

Lockyer, D.R., Pain, B.F. and Klarenbeek, J.V. 1989. Ammonia emissions from cattle, pig and poultry wastes applied to pasture. Environmental Pollution 56, 19-30.

Storage of data

The raw data will be stored by ADAS Terrington, Terrington St. Clement, King's Lynn, Norfolk PE34 4PW for a period of ten years. Epizym Biosystems Limited will be consulted before data are disposed of.

APPENDIX IV

PIG PERFORMANCE PARAMETERS.

Raw data presented in polythene pocket.

Standard deviation.	The standard deviation of a group of observations is the positive square root of the mean of the squared deviations from the mean value of the group of observations and is a measure of how the individual observations cluster about their arithmetic mean value.
Standard error (s.e.).	The standard deviation of a sampling distribution of a statistic or observation.
Standard error of difference (s.e.d.).	The standard deviation of a distribution of differences between two mean values for samples of a given size. In simple terms, differences between two means need to be greater than 2 x s.e.d. for the two means to be considered as being significantly different.
Statistic.	A summary value calculated from the observations in a sample.
Test statistic.	A function of a sample of observations which provides the basis for testing a statistical hypothesis.
'*t*' test.	'Student' *t* test. A test statistic often used to test one difference between the means of two small samples. For the majority of tests in this report, the value of '*t*' would have needed to be greater than 2.447 to confirm statistical significance to a *P* value of 0.05.

APPENDIX III.

Glossary of statistical terms

Arithmetic mean.	This is a measure of location that is calculated as the sum of all the observations divided by the number of observations.
Block.	A group of experimental units that are chosen such that they respond in a consistent manner to different treatments.
Control treatment.	A null or standard treatment.
Experiment unit.	The smallest group of experimental material to receive a single treatment or treatment combination.
Probability (*P*).	The quantitative measure assigned to situation where uncertaintly occurs. Conventionally P<0.05, 0.01, 0.001 means 95, 99 and 99.9% certainty.
Randomisation.	The allocation of treatments to experimental units in an unbiased manner.
Replication.	The application of a treatment of interest to one or more experimental units.
Residual error.	The inherent variability between samples regardless of the treatment applied. It measures the variability due to unexplained causes or experimental error.
Significance level of test.	The probability of rejecting the null hypothesis when it is correct.

APPENDIX II.

35 grid reference points at which slurry and sludge depths were measured

OUTLET

1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31	32	33	34	35

APPENDIX V

AMMONIA CONCENTRATION OF VENTILATION AIR AND VOLUMES OF AIR SAMPLED

Variates	Category
1 to 7	Laboratory result of ammonium nitrogen (NH_4-N) in mg/l in 100 mls acid - OUTLETS.
8 to 14	Laboratory result of ammonium nitrogen (NH_4-N) in mg/l in 100 mls acid - INLETS.
15 to 21	Volume of air sampled to give results for variates 1 to 7.
22 to 28	Volume of air sampled to give results for variates 8 to 14.
29 to 35	Ammonia concentration in OUTLETS (ppm).
36 to 42	Ammonia concentration in INLETS (ppm).

Raw data presented in polythene pocket.

Experiment Title - EFFICACY_OF_THE_SLURRY_ADDITIVE_EPIZYM

Code reference - 04/C098003/11/1993/94/04/4001

Site Address - ADAS_TERRINGTON
TERRINGTON_ST_CLEMENT
KING'S_LYNN
NORFOLK

Officer i/c - R.M.KAY

Crop harvested - SLURRY

Plot dimensions - UNEQUAL (see note below)

No of experimental units - 24

Block factors

No	Name	No of levels
1	SAMPLE_POINT	3
2	ROOM	4
3	REP	4

Treatment factors

No	Name	No of levels	Level No	Name
1	SLURRY_ADDITIVE	2	1	CONTROL
			2	EPIZYM

Variables recorded or to be recorded

No	Description
1	NH4N_WEEK_0_(MG/L)
2	NH4N_WEEK_1_(MG/L)
3	NH4N_WEEK_2_(MG/L)
4	NH4N_WEEK_3_(MG/L)
5	NH4N_WEEK_4_(MG/L)
6	NH4N_WEEK_5_(MG/L)
7	NH4N_WEEK_6_(MG/L)
8	INLET_NH4N_WEEK_0_(MG/L)
9	INLET_NH4N_WEEK_1_(MG/L)
10	INLET_NH4N_WEEK_2_(MG/L)
11	INLET_NH4N_WEEK_3_(MG/L)
12	INLET_NH4N_WEEK_4_(MG/L)
13	INLET_NH4N_WEEK_5_(MG/L)
14	INLET_NH4N_WEEK_6_(MG/L)
15	SAMPLED_AIR_VOLUME_WK_0_(CUMETRES)
16	SAMPLED_AIR_VOLUME_WK_1_(CUMETRES)
17	SAMPLED_AIR_VOLUME_WK_2_(CUMETRES)
18	SAMPLED_AIR_VOLUME_WK_3_(CUMETRES)
19	SAMPLED_AIR_VOLUME_WK_4_(CUMETRES)

0	SAMPLED_AIR_VOLUME_WK_5_(CUMETRES)
21	SAMPLED_AIR_VOLUME_WK_6_(CUMETRES)
22	SAMPLED_INLET_AIR_VOLUME_WEEK_0_(CUMETRES)
3	SAMPLED_INLET_AIR_VOLUME_WEEK_1_(CUMETRES)
24	SAMPLED_INLET_AIR_VOLUME_WEEK_2_(CUMETRES)
25	SAMPLED_INLET_AIR_VOLUME_WEEK_3_(CUMETERS)
6	SAMPLED_INLET_AIR_VOLUME_WEEK_4_(CUMETRES)
27	SAMPLED_INLET_AIR_VOLUME_WEEK_5_(CUMETRES)
28	SAMPLED_INLET_AIR_VOLUME_WEEK_6_(CUMETRES)
29	NH3_WEEK_0_(PPM)
30	NH3_WEEK_1_(PPM)
31	NH3_WEEK_2_(PPM)
32	NH3_WEEK_3_(PPM)
33	NH3_WEEK_4_(PPM)
34	NH3_WEEK_5_(PPM)
35	NH3_WEEK_6_(PPM)
36	INLET_NH3_WEEK_0_(PPM)
37	INLET_NH3_WEEK_1_(PPM)
38	INLET_NH3_WEEK_2_(PPM)
39	INLET_NH3_WEEK_3_(PPM)
40	INLET_NH3_WEEK_4_(PPM)
41	INLET_NH3_WEEK_5_(PPM)
42	INLET_NH3_WEEK_6_(PPM)
43	NH3_EMMISSION/DAY_WEEK_0_(CUMETRES)
44	NH3_EMMISSION/DAY_WEEK_1_(CUMETRES)
45	NH3_EMMISSION/DAY_WEEK_2_(CUMETRES)
46	NH3_EMMISSION/DAY_WEEK_3_(CUMETRES)
47	NH3_EMMISSION/DAY_WEEK_4_(CUMETRES)
48	NH3_EMMISSION/DAY_WEEK_5_(CUMETRES)
49	NH3_EMMISSION/DAY_WEEK_6_(CUMETRES)
50	NH3_EMMISSION_WEEK_0_(CUMETRES)
51	NH3_EMMISSION_WEEKS_0-1_(CUMETRES)
52	NH3_EMMISSION_WEEKS_0-2_(CUMETRES)
53	NH3_EMMISSION_WEEKS_0-3_(CUMETRES)
54	NH3_EMMISSION_WEEKS_0-4_(CUMETRES)
55	NH3_EMMISSION_WEEKS_0-5_(CUMETRES)
56	NH3_EMMISSION_WEEKS_0-6_(CUMETRES)

Analyses required

No	Description
1	ANOVA

Experiment Title - EFFICACY_OF_THE_SLURRY_ADDITIVE_EPIZYM

Code reference - 04/C098003/11/1993/94/04/4001

Block Factors

1 SAMPLE_POINT
2 ROOM
3 REP

Treatment Factors

1 SLURRY_ADDITIVE

Variables fully or partly entered

1 NH4N_WEEK_0_(MG/L)
2 NH4N_WEEK_1_(MG/L)
3 NH4N_WEEK_2_(MG/L)
4 NH4N_WEEK_3_(MG/L)
5 NH4N_WEEK_4_(MG/L)
6 NH4N_WEEK_5_(MG/L)
7 NH4N_WEEK_6_(MG/L)
8 INLET_NH4N_WEEK_0_(MG/L)
9 INLET_NH4N_WEEK_1_(MG/L)
10 INLET_NH4N_WEEK_2_(MG/L)
11 INLET_NH4N_WEEK_3_(MG/L)
12 INLET_NH4N_WEEK_4_(MG/L)
13 INLET_NH4N_WEEK_5_(MG/L)
14 INLET_NH4N_WEEK_6_(MG/L)
15 SAMPLED_AIR_VOLUME_WK_0_(CUMETRES)
16 SAMPLED_AIR_VOLUME_WK_1_(CUMETRES)
17 SAMPLED_AIR_VOLUME_WK_2_(CUMETRES)
18 SAMPLED_AIR_VOLUME_WK_3_(CUMETRES)
19 SAMPLED_AIR_VOLUME_WK_4_(CUMETRES)
20 SAMPLED_AIR_VOLUME_WK_5_(CUMETRES)
21 SAMPLED_AIR_VOLUME_WK_6_(CUMETRES)
22 SAMPLED_INLET_AIR_VOLUME_WEEK_0_(CUMETRES)
23 SAMPLED_INLET_AIR_VOLUME_WEEK_1_(CUMETRES)
24 SAMPLED_INLET_AIR_VOLUME_WEEK_2_(CUMETRES)
25 SAMPLED_INLET_AIR_VOLUME_WEEK_3_(CUMETERS)
26 SAMPLED_INLET_AIR_VOLUME_WEEK_4_(CUMETRES)
27 SAMPLED_INLET_AIR_VOLUME_WEEK_5_(CUMETRES)
28 SAMPLED_INLET_AIR_VOLUME_WEEK_6_(CUMETRES)
29 NH3_WEEK_0_(PPM)
30 NH3_WEEK_1_(PPM)
31 NH3_WEEK_2_(PPM)
32 NH3_WEEK_3_(PPM)
33 NH3_WEEK_4_(PPM)
34 NH3_WEEK_5_(PPM)
35 NH3_WEEK_6_(PPM)
36 INLET_NH3_WEEK_0_(PPM)
37 INLET_NH3_WEEK_1_(PPM)
38 INLET_NH3_WEEK_2_(PPM)
39 INLET_NH3_WEEK_3_(PPM)
40 INLET_NH3_WEEK_4_(PPM)
41 INLET_NH3_WEEK_5_(PPM)
42 INLET_NH3_WEEK_6_(PPM)
43 NH3_EMMISSION/DAY_WEEK_0_(CUMETRES)
44 NH3_EMMISSION/DAY_WEEK_1_(CUMETRES)

45 NH3_EMMISSION/DAY_WEEK_2_(CUMETRES)
46 NH3_EMMISSION/DAY_WEEK_3_(CUMETRES)
47 NH3_EMMISSION/DAY_WEEK_4_(CUMETRES)
48 NH3_EMMISSION/DAY_WEEK_5_(CUMETRES)
49 NH3_EMMISSION/DAY_WEEK_6_(CUMETRES)
50 NH3_EMMISSION_WEEK_0_(CUMETRES)
51 NH3_EMMISSION_WEEKS_0-1_(CUMETRES)
52 NH3_EMMISSION_WEEKS_0-2_(CUMETRES)
53 NH3_EMMISSION_WEEKS_0-3_(CUMETRES)
54 NH3_EMMISSION_WEEKS_0-4_(CUMETRES)
55 NH3_EMMISSION_WEEKS_0-5_(CUMETRES)
56 NH3_EMMISSION_WEEKS_0-6_(CUMETRES)

UNIT LABEL	B 1	B 2	B 3	T 1	VAR 1	VAR 2	VAR 3	VAR 4	VAR 5	VAR 6	VAR 7
1	1	2	2	1	5.4	263	775	356	335	722	620
2	2	2	2	1	5	139	736	296	328	616	590
3	1	4	1	1	3.8	133	700	228	256	463	441
4	2	4	1	1	4.2	121	730	265	229	435	313
5	1	1	1	2	11	222	845	289	298	414	579
6	2	1	1	2	11.5	162	864	209	269	471	421
7	1	3	2	2	7.6	270	701	207	203	551	286
8	2	3	2	2	4.9	156	589	230	146	614	705
9	3	1	1	2	28.2	234	900	260	341	402	480
10	3	2	2	1	13.5	177	926	372	276	516	600
11	3	4	1	1	8.5	154	851	292	215	355	361
12	3	3	2	2	5.9	155	661	*	127	*	610
13	1	2	3	2	17.6	115	668	292	366	255	296
14	2	2	3	2	12.7	114	878	293	311	261	214
15	1	4	4	2	6.6	114	485	101	259	169	201
16	2	4	4	2	11.2	114	491	158	146	104	*
17	1	1	4	1	10.2	597	702	299	296	191	115
18	2	1	4	1	11.3	342	648	248	246	179	200
19	1	3	3	1	18.8	606	690	261	270	213	197
20	2	3	3	1	16.8	587	667	278	215	213	132
21	3	1	4	1	12.2	730	543	247	313	280	207
22	3	2	3	2	13.4	609	522	331	387	300	264
23	3	4	4	2	10	499	410	167	219	156	154
24	3	3	3	1	21.5	496	532	190	258	110	*

UNIT LABEL	VAR 14	VAR 15	VAR 16	VAR 17	VAR 18	VAR 19	VAR 20	VAR 21	VAR 22
1	13.5	2.949	3.271	2.914	2.956	2.592	3.093	2.818	5.873
2	13.5	2.864	2.918	2.861	2.863	2.78	2.704	2.68	5.873
3	8	2.9	2.949	2.889	2.563	2.943	2.695	2.746	5.935
4	8	2.791	2.877	2.78	2.831	2.617	2.71	2.366	5.935
5	10.3	2.809	3.156	2.776	2.889	2.797	2.732	2.746	5.995
6	10.3	2.867	2.846	2.817	2.894	2.755	2.771	2.73	5.995
7	8.5	3.25	3.278	3.114	2.832	2.483	2.494	2.756	5.314
8	8.5	3.212	2.97	2.801	2.972	1.754	3.281	2.995	5.314
9	10.3	3.388	3.425	3.11	2.844	3.113	2.687	2.668	5.995
10	13.5	3.318	3.271	2.997	3.153	2.226	2.662	2.808	5.873
11	8	3.21	3.152	2.828	2.871	2.392	2.36	2.666	5.935
12	8.5	3.106	3.236	2.755	1.166	1.674	2.799	2.768	5.314
13	15	3.136	3.288	2.91	3.153	3.231	3.166	3.263	3.803
14	15	2.774	2.908	2.834	2.909	2.884	3.18	2.914	3.803
15	8.2	2.728	2.955	2.902	2.881	3.017	2.902	3.164	4.604
16	8.2	2.728	2.781	2.82	2.771	3.001	2.943	3.001	4.604
17	8.9	2.8	2.801	2.793	2.794	2.816	2.747	2.919	4.545
18	8.9	2.74	2.875	2.877	2.822	3.056	2.911	3.093	4.545
19	6.3	2.85	2.899	3.074	2.904	2.845	3.007	3.062	4.283
20	6.3	2.786	2.829	2.832	2.799	2.575	3.126	2.606	4.283
21	8.9	3.366	3.249	2.766	2.645	3.745	3.673	3.631	4.545
22	15	2.981	3.157	3.155	3.013	3.229	3.169	3.072	3.803
23	8.2	2.888	2.898	2.837	2.928	2.962	3.04	2.953	4.604
24	6.3	3.137	2.922	2.985	2.868	2.965	3.035	3.109	4.283

UNIT LABEL	VAR 29	VAR 30	VAR 31	VAR 32	VAR 33	VAR 34	VAR 35	VAR 36	VAR 37
1	0.3124	13.71	45.36	20.54	22.04	39.81	37.52	0.0958	0.105
2	0.2977	8.126	43.87	17.64	20.13	38.86	37.55	0.0958	0.105
3	0.2235	7.693	41.33	15.17	14.84	29.3	27.39	0.0776	0.121
4	0.2567	7.174	44.79	15.97	14.92	27.37	22.56	0.0776	0.121
5	0.6679	12	51.91	17.06	18.17	25.85	35.96	0.0882	0.117
6	0.684	9.71	52.31	12.32	16.65	28.99	26.3	0.0882	0.117
7	0.3988	14.05	38.39	12.47	13.95	37.68	17.7	0.0834	0.153
8	0.2601	8.958	35.87	13.2	14.2	31.92	40.14	0.0834	0.153
9	1.419	11.65	49.36	15.59	18.68	25.52	30.68	0.0882	0.117
10	0.6939	9.228	52.7	20.12	21.15	33.05	36.44	0.0958	0.105
11	0.4517	8.333	51.33	17.34	15.33	25.65	23.09	0.0776	0.121
12	0.3239	8.17	40.92	*	12.94	*	37.58	0.0834	0.153
13	0.9571	5.966	39.15	15.79	19.32	13.74	15.47	0.3005	1.056
14	0.7808	6.685	52.83	17.18	18.39	14	12.52	0.3005	1.056
15	0.4126	6.581	28.51	5.979	14.64	9.932	10.83	0.1445	0.950
16	0.7003	6.991	29.7	9.726	8.297	6.027	*	0.1445	0.950
17	0.6214	36.35	42.87	18.25	17.93	11.86	6.72	0.3415	1.338
18	0.7035	20.29	38.42	14.99	13.73	10.49	11.03	0.3415	1.338
19	1.125	35.65	38.28	15.33	16.19	12.08	10.97	0.2827	0.763
20	1.028	35.39	40.17	16.94	14.24	11.62	8.638	0.2827	0.763
21	0.6182	38.32	33.48	15.93	14.26	13	9.722	0.3415	1.338
22	0.7667	32.9	28.22	18.74	20.44	16.15	14.66	0.3005	1.056
23	0.5905	29.36	24.65	9.728	12.61	8.752	8.893	0.1445	0.950
24	1.169	28.95	30.39	11.3	14.84	6.181	*	0.2827	0.763

UNIT LABEL	VAR 44	VAR 45	VAR 46	VAR 47	VAR 48	VAR 49	VAR 50	VAR 51	VAR 52
1	0.1271	0.4203	0.1903	0.2042	0.3689	0.3477	0.0203	0.9097	3.852
2	0.0753	0.4065	0.1634	0.1865	0.3601	0.348	0.0193	0.5464	3.392
3	0.0713	0.383	0.1406	0.1375	0.2715	0.2538	0.0145	0.5135	3.194
4	0.0665	0.4151	0.1479	0.1383	0.2536	0.2091	0.0167	0.482	3.387
5	0.1112	0.481	0.1581	0.1684	0.2395	0.3332	0.0433	0.8215	4.189
6	0.09	0.4847	0.1141	0.1543	0.2686	0.2437	0.0444	0.6742	4.067
7	0.1302	0.3558	0.1155	0.1292	0.3491	0.164	0.0259	0.9372	3.428
8	0.083	0.3324	0.1223	0.1315	0.2958	0.372	0.0169	0.5979	2.925
9	0.108	0.4574	0.1445	0.1731	0.2364	0.2843	0.0921	0.8479	4.05
10	0.0855	0.4883	0.1865	0.196	0.3063	0.3376	0.045	0.6436	4.062
11	0.0772	0.4756	0.1607	0.1421	0.2377	0.214	0.0293	0.5698	3.899
12	0.0757	0.3791	*	0.1199	*	0.3482	0.021	0.551	3.205
13	0.0553	0.3628	0.1463	0.7304	0.5193	0.585	0.0621	0.449	2.989
14	0.0619	0.4895	0.1592	0.6954	0.5292	0.4735	0.0506	0.4843	3.911
15	0.061	0.2641	0.0554	0.5536	0.3755	0.4096	0.0268	0.4536	2.303
16	0.0648	0.2752	0.0901	0.3137	0.2279	*	0.0454	0.4989	2.425
17	0.3368	0.3972	0.1692	0.6778	0.4483	0.254	0.0403	2.398	5.179
18	0.188	0.356	0.1389	0.519	0.3965	0.4169	0.0456	1.361	3.854
19	0.3304	0.3547	0.1421	0.6119	0.4567	0.4148	0.073	2.386	4.869
20	0.3279	0.3723	0.157	0.5384	0.4394	0.3266	0.0667	2.362	4.968
21	0.3551	0.3102	0.1476	0.5389	0.4915	0.3675	0.0401	2.526	4.697
22	0.3048	0.2615	0.1736	0.7727	0.6104	0.5541	0.0497	2.184	4.014
23	0.2721	0.2284	0.0901	0.4768	0.3309	0.3362	0.0383	1.943	3.542
24	0.2683	0.2816	0.1047	0.5611	0.2337	*	0.0758	1.954	3.925

Experiment Title - EFFICACY_OF_THE_SLURRY_ADDITIVE_EPIZYM

Code reference - 04/C098003/11/1993/94/04/4001

Site Address - ADAS_TERRINGTON
TERRINGTON_ST_CLEMENT
KING'S_LYNN
NORFOLK

Officer i/c - R.M.KAY

Crop harvested - SLURRY

Plot dimensions - UNEQUAL (see note below)

No of experimental units - 16

Block factors

No	Name	No of levels
1	PEN	2
2	ROOM	4
3	REP	4

Treatment factors

No	Name	No of levels	Level No	Name
1	SLURRY_ADDITIVE	2	1	CONTROL
			2	EPIZYM

Variables recorded or to be recorded

No	Description
1	FEED_CONSUMED_(KGS)
2	TOTAL_START_WEIGHT_(KGS)
3	TOTAL_END_WEIGHT_(KGS)
4	TOTAL_LIVEWEIGHT_GAIN_(KGS)
5	FEED_CONVERSION_RATIO
6	AV._LIVE_WEIGHT_AT_START_(KG)
7	AV._LIVE_WEIGHT_AT_SLAUGHTER_(KG)
8	NO_DIED/REMOVED

Analyses required

No	Description
1	ANOVA

Experiment Title - EFFICACY_OF_THE_SLURRY_ADDITIVE_EPIZYM

Code reference - 04/C098003/11/1993/94/04/4001

Block Factors

1 PEN
2 ROOM
3 REP

Treatment Factors

1 SLURRY_ADDITIVE

Variables fully or partly entered

1 FEED_CONSUMED_(KGS)
2 TOTAL_START_WEIGHT_(KGS)
3 TOTAL_END_WEIGHT_(KGS)
4 TOTAL_LIVEWEIGHT_GAIN_(KGS)
5 FEED_CONVERSION_RATIO
6 AV._LIVE_WEIGHT_AT_START_(KG)
7 AV._LIVE_WEIGHT_AT_SLAUGHTER_(KG)
8 NO_DIED/REMOVED

UNIT LABEL	B 1	B 2	B 3	T 1	VAR 1	VAR 2	VAR 3	VAR 4	VAR 5	VAR 6	VAR 7
1	1	2	2	1	1187	642	1102	460	2.581	45.86	82.92
2	2	2	2	1	1346	676	1207	531	2.534	48.29	86.21
3	1	4	1	1	1038	656	1025	369	2.812	46.86	75.23
4	2	4	1	1	1054	650	1013	363	2.905	46.43	73.77
5	1	1	1	2	1291	643	1142	499	2.587	45.93	81.57
6	2	1	1	2	1291	677	1144	467	2.763	48.36	85.23
7	1	3	2	2	1288	648	1152	504	2.555	46.29	82.29
8	2	3	2	2	1129	650	1038	388	2.91	46.43	75.23
9	1	2	3	2	1035	798	1146	348	2.974	57	83.92
10	2	2	3	2	1125	833	1197	364	3.091	59.5	85.5
11	1	4	4	2	1235	776	1255	479	2.578	55.43	89.64
12	2	4	4	2	1225	766	1219	453	2.704	54.71	87.07
13	1	1	4	1	1025	782	1090	308	3.328	55.86	83.67
14	2	1	4	1	1075	780	1122	342	3.143	55.71	80.14
15	1	3	3	1	1225	797	1224	427	2.869	56.93	88.62
16	2	3	3	1	1174	784	1177	393	2.987	56	84.07

APPENDIX VI

SLUDGE AND SLUDGE DEPTHS

Raw data presented in polythene pocket.

Experiment Title - SLURRY_ADDITIVE

Code reference - EC/C098003/11/1994/04/1112

Block Factors

1 ROOM
2 REPLICATE
3 GRID_ROW

Treatment Factors

1 ADDITIVE

Variables fully or partly entered

1 SLURRY_DEPTH_(mm)
2 SLUDGE_DEPTH_(mm)
3 SLUDGE_AS_PROPORTION_OF_SLURRY

Experiment Title - SLURRY_ADDITIVE

Code reference - EC/C098003/11/1994/04/1112

Site Address - ADAS_TERRINGTON
TERRINGTON_ST_CLEMENT
KING'S_LYNN
NORFOLK_PE_34_4PW

Officer i/c - R.M.KAY

Crop harvested - SLURRY

Plot dimensions - UNEQUAL (see note below)

No of experimental units - 280

Block factors

No	Name	No of levels
1	ROOM	4
2	REPLICATE	4
3	GRID_ROW	5

Treatment factors

No	Name	No of levels	Level No	Name
1	ADDITIVE	2	1	CONTROL
			2	EPIZYM

'ariables recorded or to be recorded

No	Description
1	SLURRY_DEPTH_(mm)
2	SLUDGE_DEPTH_(mm)
3	SLUDGE_AS_PROPORTION_OF_SLURRY

nalyses required

No	Description
1	ANOVAR

UNIT LABEL	B 1	B 2	B 3	T 1	VAR 1	VAR 2	VAR 3
1	1	1	1	2	225	70	0.3111
2	1	1	1	2	240	45	0.1875
3	1	1	1	2	250	60	0.24
4	1	1	1	2	250	65	0.26
5	1	1	1	2	250	70	0.28
6	1	1	1	2	250	60	0.24
7	1	1	1	2	225	55	0.2444
8	1	1	2	2	230	65	0.2826
9	1	1	2	2	240	60	0.25
10	1	1	2	2	245	55	0.2245
11	1	1	2	2	250	60	0.24
12	1	1	2	2	250	60	0.24
13	1	1	2	2	245	50	0.2041
14	1	1	2	2	230	50	0.2174
15	1	1	3	2	230	70	0.3043
16	1	1	3	2	245	70	0.2857
17	1	1	3	2	245	55	0.2245
18	1	1	3	2	240	45	0.1875
19	1	1	3	2	245	55	0.2245
20	1	1	3	2	240	70	0.2917
21	1	1	3	2	230	85	0.3696
22	1	1	4	2	225	70	0.3111
23	1	1	4	2	230	60	0.2609
24	1	1	4	2	225	45	0.2
25	1	1	4	2	240	45	0.1875
26	1	1	4	2	235	50	0.2128
27	1	1	4	2	240	75	0.3125
28	1	1	4	2	225	90	0.4
29	1	1	5	2	225	65	0.2889
30	1	1	5	2	220	55	0.25
31	1	1	5	2	220	40	0.1818
32	1	1	5	2	230	40	0.1739
33	1	1	5	2	225	50	0.2222
34	1	1	5	2	225	80	0.3556
35	1	1	5	2	220	90	0.4091
36	2	2	1	1	180	110	0.6111
37	2	2	1	1	195	125	0.641
38	2	2	1	1	200	120	0.6
39	2	2	1	1	210	130	0.619
40	2	2	1	1	205	130	0.6341
41	2	2	1	1	195	125	0.641
42	2	2	1	1	175	115	0.6571
43	2	2	2	1	190	100	0.5263
44	2	2	2	1	195	110	0.5641
45	2	2	2	1	200	115	0.575
46	2	2	2	1	200	120	0.6
47	2	2	2	1	200	130	0.65
48	2	2	2	1	195	125	0.641
49	2	2	2	1	185	130	0.7027
50	2	2	3	1	190	115	0.6053
51	2	2	3	1	190	120	0.6316
52	2	2	3	1	200	120	0.6
53	2	2	3	1	195	115	0.5897
54	2	2	3	1	195	120	0.6154
55	2	2	3	1	190	125	0.6579
56	2	2	3	1	180	120	0.6667
57	2	2	4	1	180	110	0.6111

UNIT LABEL	B 1	B 2	B 3	T 1	VAR 1	VAR 2	VAR 3
58	2	2	4	1	185	110	0.5946
59	2	2	4	1	190	105	0.5526
60	2	2	4	1	195	110	0.5641
61	2	2	4	1	190	115	0.6053
62	2	2	4	1	190	120	0.6316
63	2	2	4	1	180	125	0.6944
64	2	2	5	1	180	100	0.5556
65	2	2	5	1	185	100	0.5405
66	2	2	5	1	180	100	0.5556
67	2	2	5	1	180	100	0.5556
68	2	2	5	1	180	100	0.5556
69	2	2	5	1	175	110	0.6286
70	2	2	5	1	180	120	0.6667
71	3	2	1	2	200	100	0.5
72	3	2	1	2	210	85	0.4048
73	3	2	1	2	225	80	0.3556
74	3	2	1	2	225	90	0.4
75	3	2	1	2	220	75	0.3409
76	3	2	1	2	210	70	0.3333
77	3	2	1	2	210	100	0.4762
78	3	2	2	2	205	75	0.3659
79	3	2	2	2	210	70	0.3333
80	3	2	2	2	210	80	0.381
81	3	2	2	2	215	80	0.3721
82	3	2	2	2	215	70	0.3256
83	3	2	2	2	215	70	0.3256
84	3	2	2	2	210	90	0.4286
85	3	2	3	2	205	95	0.4634
86	3	2	3	2	205	95	0.4634
87	3	2	3	2	200	95	0.475
88	3	2	3	2	205	95	0.4634
89	3	2	3	2	205	95	0.4634
90	3	2	3	2	205	95	0.4634
91	3	2	3	2	205	90	0.439
92	3	2	4	2	200	110	0.55
93	3	2	4	2	200	100	0.5
94	3	2	4	2	195	95	0.4872
95	3	2	4	2	200	80	0.4
96	3	2	4	2	200	85	0.425
97	3	2	4	2	205	90	0.439
98	3	2	4	2	205	85	0.4146
99	3	2	5	2	195	95	0.4872
100	3	2	5	2	195	90	0.4615
101	3	2	5	2	195	75	0.3846
102	3	2	5	2	195	70	0.359
103	3	2	5	2	195	80	0.4103
104	3	2	5	2	200	80	0.4
105	3	2	5	2	200	80	0.4
106	4	1	1	1	175	100	0.5714
107	4	1	1	1	190	90	0.4737
108	4	1	1	1	200	85	0.425
109	4	1	1	1	205	100	0.4878
110	4	1	1	1	205	95	0.4634
111	4	1	1	1	205	100	0.4878
112	4	1	1	1	190	95	0.5
113	4	1	2	1	175	90	0.5143
114	4	1	2	1	185	75	0.4054

UNIT LABEL	B 1	B 2	B 3	T 1	VAR 1	VAR 2	VAR 3
115	4	1	2	1	195	90	0.4615
116	4	1	2	1	200	90	0.45
117	4	1	2	1	200	95	0.475
118	4	1	2	1	200	100	0.5
119	4	1	2	1	195	100	0.5128
120	4	1	3	1	175	85	0.4857
121	4	1	3	1	185	80	0.4324
122	4	1	3	1	185	80	0.4324
123	4	1	3	1	200	90	0.45
124	4	1	3	1	195	95	0.4872
125	4	1	3	1	195	95	0.4872
126	4	1	3	1	200	95	0.475
127	4	1	4	1	175	70	0.4
128	4	1	4	1	175	70	0.4
129	4	1	4	1	175	65	0.3714
130	4	1	4	1	190	75	0.3947
131	4	1	4	1	190	75	0.3947
132	4	1	4	1	190	80	0.4211
133	4	1	4	1	195	80	0.4103
134	4	1	5	1	170	65	0.3824
135	4	1	5	1	175	65	0.3714
136	4	1	5	1	175	60	0.3429
137	4	1	5	1	185	70	0.3784
138	4	1	5	1	190	75	0.3947
139	4	1	5	1	190	75	0.3947
140	4	1	5	1	190	75	0.3947
141	1	3	1	1	165	50	0.303
142	1	3	1	1	185	60	0.3243
143	1	3	1	1	200	60	0.3
144	1	3	1	1	205	70	0.3415
145	1	3	1	1	205	50	0.2439
146	1	3	1	1	190	50	0.2632
147	1	3	1	1	175	50	0.2857
148	1	3	2	1	170	80	0.4706
149	1	3	2	1	190	80	0.4211
150	1	3	2	1	195	70	0.359
151	1	3	2	1	200	50	0.25
152	1	3	2	1	200	70	0.35
153	1	3	2	1	195	60	0.3077
154	1	3	2	1	175	50	0.2857
155	1	3	3	1	175	100	0.5714
156	1	3	3	1	185	110	0.5946
157	1	3	3	1	180	80	0.4444
158	1	3	3	1	190	40	0.2105
159	1	3	3	1	195	100	0.5128
160	1	3	3	1	190	90	0.4737
161	1	3	3	1	175	80	0.4571
162	1	3	4	1	170	110	0.6471
163	1	3	4	1	170	90	0.5294
164	1	3	4	1	170	50	0.2941
165	1	3	4	1	180	60	0.3333
166	1	3	4	1	175	70	0.4
167	1	3	4	1	180	100	0.5556
168	1	3	4	1	180	90	0.5
169	1	3	5	1	170	100	0.5882
170	1	3	5	1	165	60	0.3636
171	1	3	5	1	165	40	0.2424

UNIT LABEL	B 1	B 2	B 3	T 1	VAR 1	VAR 2	VAR 3
172	1	3	5	1	175	50	0.2857
173	1	3	5	1	165	60	0.3636
174	1	3	5	1	160	70	0.4375
175	1	3	5	1	160	80	0.5
176	2	4	1	2	170	75	0.4412
177	2	4	1	2	190	75	0.3947
178	2	4	1	2	200	75	0.375
179	2	4	1	2	205	65	0.3171
180	2	4	1	2	200	60	0.3
181	2	4	1	2	185	60	0.3243
182	2	4	1	2	170	65	0.3824
183	2	4	2	2	170	75	0.4412
184	2	4	2	2	190	75	0.3947
185	2	4	2	2	200	60	0.3
186	2	4	2	2	200	50	0.25
187	2	4	2	2	195	60	0.3077
188	2	4	2	2	190	65	0.3421
189	2	4	2	2	170	65	0.3824
190	2	4	3	2	180	100	0.5556
191	2	4	3	2	185	80	0.4324
192	2	4	3	2	195	95	0.4872
193	2	4	3	2	195	55	0.2821
194	2	4	3	2	190	75	0.3947
195	2	4	3	2	185	80	0.4324
196	2	4	3	2	175	95	0.5429
197	2	4	4	2	175	90	0.5143
198	2	4	4	2	180	85	0.4722
199	2	4	4	2	185	60	0.3243
200	2	4	4	2	185	45	0.2432
201	2	4	4	2	185	50	0.2703
202	2	4	4	2	180	80	0.4444
203	2	4	4	2	175	80	0.4571
204	2	4	5	2	175	85	0.4857
205	2	4	5	2	175	85	0.4857
206	2	4	5	2	175	70	0.4
207	2	4	5	2	175	40	0.2286
208	2	4	5	2	175	50	0.2857
209	2	4	5	2	175	65	0.3714
210	2	4	5	2	175	75	0.4286
211	3	4	1	1	230	80	0.3478
212	3	4	1	1	240	75	0.3125
213	3	4	1	1	245	75	0.3061
214	3	4	1	1	250	90	0.36
215	3	4	1	1	250	80	0.32
216	3	4	1	1	240	80	0.3333
217	3	4	1	1	230	110	0.4783
218	3	4	2	1	230	110	0.4783
219	3	4	2	1	235	75	0.3191
220	3	4	2	1	240	75	0.3125
221	3	4	2	1	245	80	0.3265
222	3	4	2	1	245	80	0.3265
223	3	4	2	1	240	80	0.3333
224	3	4	2	1	235	90	0.383
225	3	4	3	1	230	110	0.4783
226	3	4	3	1	230	120	0.5217
227	3	4	3	1	230	90	0.3913
228	3	4	3	1	235	80	0.3404

UNIT LABEL	B 1	B 2	B 3	T 1	VAR 1	VAR 2	VAR 3
229	3	4	3	1	240	85	0.3542
230	3	4	3	1	235	90	0.383
231	3	4	3	1	230	100	0.4348
232	3	4	4	1	225	100	0.4444
233	3	4	4	1	225	95	0.4222
234	3	4	4	1	225	90	0.4
235	3	4	4	1	225	70	0.3111
236	3	4	4	1	225	80	0.3556
237	3	4	4	1	230	80	0.3478
238	3	4	4	1	235	100	0.4255
239	3	4	5	1	220	90	0.4091
240	3	4	5	1	220	85	0.3864
241	3	4	5	1	220	70	0.3182
242	3	4	5	1	220	70	0.3182
243	3	4	5	1	220	75	0.3409
244	3	4	5	1	220	90	0.4091
245	3	4	5	1	220	95	0.4318
246	4	3	1	2	275	125	0.4545
247	4	3	1	2	280	130	0.4643
248	4	3	1	2	295	125	0.4237
249	4	3	1	2	300	90	0.3
250	4	3	1	2	300	120	0.4
251	4	3	1	2	295	130	0.4407
252	4	3	1	2	285	150	0.5263
253	4	3	2	2	270	130	0.4815
254	4	3	2	2	275	145	0.5273
255	4	3	2	2	290	140	0.4828
256	4	3	2	2	295	80	0.2712
257	4	3	2	2	295	125	0.4237
258	4	3	2	2	295	140	0.4746
259	4	3	2	2	295	170	0.5763
260	4	3	3	2	270	130	0.4815
261	4	3	3	2	280	145	0.5179
262	4	3	3	2	280	130	0.4643
263	4	3	3	2	295	80	0.2712
264	4	3	3	2	285	140	0.4912
265	4	3	3	2	290	160	0.5517
266	4	3	3	2	290	170	0.5862
267	4	3	4	2	270	125	0.463
268	4	3	4	2	275	125	0.4545
269	4	3	4	2	270	130	0.4815
270	4	3	4	2	280	90	0.3214
271	4	3	4	2	280	125	0.4464
272	4	3	4	2	285	120	0.4211
273	4	3	4	2	285	120	0.4211
274	4	3	5	2	265	100	0.3774
275	4	3	5	2	265	80	0.3019
276	4	3	5	2	265	75	0.283
277	4	3	5	2	275	60	0.2182
278	4	3	5	2	280	80	0.2857
279	4	3	5	2	280	100	0.3571
280	4	3	5	2	280	110	0.3929