

EFFECTIVENESS OF MANURE ADDITIVES

by

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SUMMARY

A study was conducted at Agriculture Canada's Centre for Food and Animal Research in Ottawa to determine the effectiveness of a few manure additives to control the production of known odorous chemicals, to retain nitrogen and organic matter, and to improve the ease of flow of stored swine manure slurry. Fresh slurry from a grower finishing barn was stored for a ten week period in sixty 45-gallon capacity grey plastic barrels which were filled to a depth of thirty inches with 40 gallons of average 5.2% dry matter slurry. Seven additives were tested along with untreated slurry in four replications in two mixing systems. In one system slurry was mixed and sampled every week for ten weeks (weekly-mix system), and in the other, at the end of the ten week treatment period (final-mix only system). A total of sixty slurry-filled barrels were used in the study. Additive addition rate was determined assuming that the test system represented a storage pit without any settled sludge or floating solids.

Slurry treated with additives AGRI-SCENTS, BIOSURGE, HYDROGEN CYANAMIDE, NATURAL ODOR CATALYST, PEAT and ROEBIC was compared with the untreated slurry or CONTROL over the ten-week treatment period. The additive MICRO-AID (for use with slurry) was tested for a one-week treatment period only. To ensure a more than adequate supply of additive in the slurry, about one-third more additive was generally used than that recommended in the product literature.

To determine the effect of additives on production of odorous chemicals, hydrogen sulphide and ammonia gases were measured in the air space above the slurry, and volatile fatty acids were determined in the slurry. To determine the effect on nitrogen retention, total and ammonia nitrogen were determined in the slurry and its liquid fraction (centrifuged supernatant). Slurry dry matter and ash were analyzed to determine the effect on organic matter retention. Slurry dry matter and apparent viscosity measurements were used to determine the effect on ease of flow of slurry. Slurry electrical conductivity was measured to determine the effect on slurry mineralization.

Except for HYDROGEN CYANAMIDE and PEAT treatments, there was generally little difference between the behaviour of treated and untreated slurry. HYDROGEN CYANAMIDE completely eliminated the release of odorous and hazardous hydrogen sulphide gas (rotten egg odor), but increased slightly the proportion of odorous butyric acid (rancid butter odor) in the slurry. An eight-inch thick cover of PEAT significantly reduced the release of ammonia gas from the slurry compared to untreated slurry. It also increased the slurry organic matter content but significantly reduced the ease of flow of slurry. Some of the other additives appeared to increase ammonia release from the slurry. The nitrogen content of the slurry did not change during storage presumably because of the loose-fitting cover that was used on the storage barrels. Consequently, there was no significant difference between treated and untreated slurry. Therefore, no conclusions could be made on the

effectiveness of additives in retaining nitrogen in the slurry. The effect of additives on slurry organic matter retention and mineralization, and on ease of flow, was not significant.

Under the test conditions used in this study, significant beneficial effects of commercial additives to control odor, retain organic matter, and improve mineralization and ease of flow of slurry, were not clearly evident. The use of the chemical HYDROGEN CYANAMIDE to control slurry odor characteristics, flies and insects, and the hazard from hydrogen sulphide gas during slurry mixing needs further investigation. There is some evidence that PEAT may help control odor and conserve nitrogen. Further research is required in this regard. Some such research is already in progress at Macdonald College of McGill University. The results in this study for the effectiveness of MICRO-AID as a slurry additive are valid for one week of use only. Possible effectiveness over a longer period was not determined. The currently recommended rate for use of BIOSURGE additive is about ten times more than the rate that was recommended by the supplier at the time of the tests of this study. Whether this additive would be effective at the newly recommended higher dosage was not determined in this study.

In general, the results from this study are consistent with those of previous studies which have shown that slurry additives are usually not effective in controlling slurry odor.

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INTRODUCTION

The study was conducted under the Collaborative Research Agreement of May, 1991, between the Animal Research Centre, now the Centre for Food and Animal Research (CFAR) of the Research Branch of Agriculture Canada and the Ontario Pork Producers' Marketing Board (OPPMB). The objective of the study was to determine the effectiveness, under controlled conditions, of a few selected manure additives for the control of odor-producing chemicals, nitrogen, organic matter, solids and other properties of stored swine manure slurry. The actual study was preceded by a survey of hog producers on their experiences with the use of additives. This report describes the results of this survey, the procedures used in this study to test the effectiveness of additives, and the results obtained. Conclusions and recommendations are given at the end of this report.

It is worth noting here that the number of additives tested, and the number of tests done per additive, were more than the number originally planned under the above-mentioned Collaborative Research Agreement. This was possible because of additional resource input from CFAR, and was done to increase and improve the information output. This report includes the results from this additional work.

SURVEY OF PRODUCERS

During the summer of 1991, a request was made through the OPPMB to hog producers to contact Dr. N.K. Patni of Agriculture Canada if they had experience with the use of additives for control of manure odor, solids, flow characteristics, or other properties. A total of twenty-six (26) producers responded by letter and/or phone. About ten additive-product suppliers also responded by letter, phone or personal visits. The producers were subsequently interviewed by phone to obtain information on their experiences and observations with respect to the effectiveness of the product(s) they used. The information given by the producers indicated that additive products were being used for addition to the slurry and also to the water or feed given to the animals. Producers' experiences with the use of additives were rated as good, fair or poor with respect to effectiveness of the additive in terms of criteria such as control of odor, scum and crust formation, ease of flow, cost effectiveness, and in a few cases, fly control. Tables 1 and 2 summarize producer experience with additives used with slurry and with water or feed, respectively.

Results in Tables 1 and 2 show that the effectiveness of the same product in some cases was reported as good, fair or poor. This suggests that a product may perform well or poorly under different sets of circumstances. The composition of slurry in storage is usually under constant change due to bacterial action, and this could possibly have caused the observed differences in the effectiveness of the additives in Tables 1 and 2. Another reason for the variation in ratings for the same product could be the subjective nature of judgement. The same performance could be judged as being good by one producer and only fair by another producer. Also, in a few cases, the producers reported their experiences based on memory, because the product had been used some time ago. Changes in product formulation since the time of original use would not therefore be taken into account in their reported experience.

In Tables 1 and 2, the additive products have been listed in terms of decreasing order of reported effectiveness. These ratings should be considered as guidelines only as they are subject to considerable variation because of the reasons noted above. This is particularly true for additives for which only one producer-report was received. The products MICRO AID, NATURE AID, SWINE AID B and ROOTS were reportedly used as both slurry and feed or water additive. The reports suggest that the first three products were more effective when added to the feed or water rather than to the slurry whereas the opposite appeared to apply to ROOTS. One producer reported using feed grade lime with solid swine and cattle manures with good to fair results. Additives used with slurry systems only are listed in Table 1.

In our survey, only twenty-six producers reported their experiences with additive products. It would be useful if more producers could be persuaded to report their experiences for the benefit of those who might, in the future, consider using additives in their production system. It should be noted that

only two feed additives are reportedly registered with Agriculture Canada for effect on manure characteristics. DEODORASE is registered for control of manure odor, and MICRO-AID is registered for control of ammonia gas release from manure. PRIMALAC is also a registered feed additive, but without claims for control of manure odor or other characteristics.

Table 1. Effectiveness of additive products for use with slurry, based on producer experience.

No.	Product Name	Number of Producers Reporting	Reported Effectiveness of Product		
			good	fair	poor
1)	NATAGRI	3	2	0	1
2)	SEAKELP/MOLASSES	1	1	0	0
3)	ROOTS	3	0	2	1
4)	MOLASSES/YEAST	1	0	1	0
5)	ROEBIC	1	0	1	0
6)	NUHN BIOTECH	3	0	1	2
7)	LS-600	1	0	0	1
8)	NATURE AID	1	0	0	1
9)	SWINE AID B	1	0	0	1
10)	MICRO AID	2	0	0	2

Table 2. Effectiveness of additive products for use with drinking water or feed, based on producer experience.

No.	Product Name	Number of Producers Reporting	Reported Effectiveness of Product		
			good	fair	poor
1)	SWINE AID B	5	1	3	1
2)	PRIMALAC	3	1	2	0
3)	SWINE SCENCE	1	1	0	0
4)	NATURE AID	3	0	3	0
5)	MICRO AID	1	0	1	0
6)	AGRO-OXY	1	0	0	1
7)	NUHN BIOTECH	1	0	0	1
8)	ROOTS	3	0	0	3

STUDY PROCEDURE

This section describes the treatment system used, the additives used, and the tests and measurements conducted to determine the effectiveness of additives.

Treatment System

Treated manure was compared with untreated manure ("control" treatment) for effectiveness of additives during a ten-week treatment period. Each treatment was replicated four times. Seven treatments were tested instead of five that were originally planned in order to make more effective use of resource input. The treatment effect was tested in two systems. In the first system, slurry was mixed and tested every week. In the second system, the slurry was mixed initially when the treatments started and then once again after ten weeks of undisturbed storage. The rationale for using the first system was that different treatments may be effective for different periods of time. This system would allow us to establish how long the given treatment was effective. The rationale for using the second system was that manure is usually not mixed on a weekly basis at operating farms. This system would allow us to determine if the treatment was effective without periodic mixing.

The test system consisted of grey plastic barrels of 45-gallon nominal capacity. The full capacity of the barrels was nearly 51 gallons. The barrels were 39 inches high. They were filled to a depth of 30 inches with forty (40) gallons of slurry. The barrels were equipped with a threaded cover which was kept loosely closed except when mixing and sampling slurry. An adjustable-height, long-shaft propeller mixer was constructed to mix the manure slurry in the barrels. A total of sixty (60) test barrels were kept indoors in a heated barn during the test period. Twenty-eight (28) barrels were used for the weekly-mix treatment (7 treatments including control x 4 replications) and thirty-two (32) for the initial-and-final-mix treatment (8 treatments including control x 4 replicates; this group included peat-cover-on-slurry as a treatment, which was not included in the first group). The barrels were first filled outdoors with well-mixed manure using a slurry tanker equipped with a mixer, and then transferred indoors. The swine manure slurry was obtained fresh from a four-foot deep gutter in a partially-slatted floor, grower -finishing barn at a commercial farm about 50 km from the study site in Ottawa.

At operating farms, fresh manure is usually added continuously or periodically to manure already in the storage pits or tanks. Simulation of such a system was not considered necessary in this study because of the following two reasons. First, if a product is ineffective for stored manure slurry, it is likely to be also ineffective for stored slurry to which fresh manure is added regularly. Second, it would have considerably increased resource input requirement without providing much additional useful information on effectiveness of additives.

Treatment Additives

Based on the producer survey, information and literature received from additive suppliers, additive material availability, and our current knowledge in the subject matter, the following seven materials were selected for use in the study : AGRI-SCENTS, BIOSURGE, HYDROGEN CYANAMIDE, MICRO-AID, NATURAL ODOR CATALYST, PEAT and ROEBIC. The names and addresses of the suppliers for these materials are listed in Appendix 1. Two products that we wanted to include in the study but were unable to obtain from suppliers at the time of the study were DEODORASE for addition to slurry (not feed) and NATAGRI.

The additive addition rates were selected assuming that the test system in barrels represented a manure storage pit without any settled sludge at the bottom, or scum at the top, at the time of the start of the treatment. The individual product literature was used to determine the additive addition rates. In the tests, about one-third more additive was generally used than that suggested in the product literature to ensure that there was more than sufficient additive in the slurry. The frequency of addition and rates used were as follows:

AGRI-SCENTS: 2.6 oz. per 1000 gallon slurry, added once

BIOSURGE: 8.7 oz. per 1000 gallon slurry, added once

HYDROGEN CYANAMIDE: 305 oz. of 50% solution per 1000 gallon slurry, added once

MICRO-AID: 30.5 oz. per 1000 gallon slurry, added once

NATURAL ODOR CATALYST: 62 oz. per 1000 sq. ft. slurry surface, added weekly

PEAT: 8-in floating cover, used at the start, in final-mix system only

ROEBIC: 21.8 oz. per 1000 gallon slurry, added once.

The product literature for MICRO-AID for use with slurry suggests weekly addition of the additive to the slurry. Inadvertently, this product was added only once at the beginning at about four times the recommended rate. Consequently, the comparison of MICRO-AID to the untreated control should be considered valid for the initial week only in the results section to follow. For this reason, MICRO-AID is called PRODUCT X in the discussion of results on additive performance over the ten week treatment period.

Subsequent to the completion of the tests, the supplier of BIOSURGE informed us that the product addition rate they had suggested in the initial literature had been revised to a higher value. The rate used in this study was estimated to be about one-tenth of the revised suggested rate. The results to be discussed below are for the originally suggested lower rate.

Tests and Measurements

The tests were conducted from mid-September to early December. The barn temperature was continuously monitored. Slurry samples were collected every week (eleven times) in the weekly-mix system (28 barrels), and at the beginning and end of the treatment period (two times) in the final-mix-only system (32 barrels). The latter system had PEAT as an additional treatment.

The slurry samples were tested for temperature, pH, electrical conductivity, dry matter, ash, total and ammonia nitrogen, and apparent viscosity. A subsample of the slurry was centrifuged to obtain a supernatant or "liquid" fraction. The volume percent of this liquid fraction was determined. The supernatant samples were analyzed for volatile fatty acids, and total and ammonia nitrogen. Ammonia gas concentration was determined in the free space above the slurry. Concentration of hydrogen sulphide gas above the slurry surface was determined during slurry mixing. Standard methods of analysis were used for the above determinations. The rationale for the use of the above tests and measurements is given below.

The pH value is an indication of slurry acidity. Lower the pH, higher is the acidity. Release of free ammonia from solution increases as the solution pH increases. Electrical conductivity is an indication of the concentration of mineralized material in solution. Slurry dry matter gives an indication of dilution of manure. Lower dry matter content slurry is easier to pump but also requires more labour to haul than high dry matter content slurry. The difference between slurry dry matter and its ash content is indicative of organic matter which improves soil quality when slurry is applied to the soil. Low organic matter is indicated by a high ash content in slurry dry matter. Slurry viscosity indicates the ease with which slurry would flow. Lower viscosity slurry is easier to pump than higher viscosity slurry. Since the flow behaviour of manure slurry is different from that of water, absolute viscosity is difficult to determine. In this report, the measured viscosity is referred to as apparent viscosity because of the determination was made at one specific shear rate only. Both total and ammonia nitrogen determinations were made in the slurry and its supernatant. Generally, ammonia nitrogen is considered to be the nitrogen form immediately available to plants. Volatile acids are generally associated with malodours. Thus volatile acid concentration changes can be indicative of odour potential of slurries.

RESULTS

The results are discussed below in terms of effects on physical properties, manure gases released, and effects on chemical properties. The week-by-week effect of treatments is given in the **figures** to be described below. The properties and composition at the beginning and end of the two mixing systems is given in the **tables** to be described below. Photos of the test system used are shown on plates 1 to 17.

The variation of the mean daily temperature in the barn and in the ambient air outside is shown in Fig. 1. The barn temperature was maintained at about 20°C. The ambient air temperature was between 10 to 20°C, and 0 to -10° at the beginning and end of the test period, respectively. Slurry temperature variation in all treatments was similar (Fig. 2). The treatment symbols used in Figs. 2 to 15, and the treatment numbers used in Tables 4 to 7 are identified in Table 3. Each point in Figs. 2 to 15, and each value in Tables 4 to 7, for each treatment indicates the average value for four replications. For the reasons noted in the section on Treatment Additives above, the MICRO-AID treatment is identified as PRODUCT X in Table 3.

Table 3. Treatments and their corresponding symbols in figures 2 to 15 for weekly-mixed manure. (Note: PEAT treatment was not used in the weekly-mix system).

Treatment Number	Treatment	Symbol in Plots Number
1	CONTROL	*
2	HYDROGEN CYANAMIDE	+
3	ROEBIC	"
4	AGRI-SCENTS	9
5	NATURAL ODOR CATALYST	L
6	BIOSURGE	#
7	PRODUCT X	Z
8	PEAT	

Biochemical reaction rates are temperature dependant. Results in Fig. 2 indicate that slurry temperature variation was similar amongst treatments. Thus the effect of temperature variation would be the same in all treatments including the control.

Effects on Physical Properties

The results for slurry electrical conductivity dry matter, ash content, supernatant volume percent and apparent viscosity in the weekly-mixed slurry are shown in Figs. 3 to 7. The initial and final values for these properties under the two mixing systems are shown in Table 4.

Statistically significant differences between treatments and the control (Treatment No. 1) at the end of the treatment period are also shown in Table 4 (and also in the subsequent tables). Results in Figs. 3 to 7 and in Table 4 indicate that there was no substantial difference in the treated slurry and the untreated slurry except in treatments with HYDROGEN CYANAMIDE and PEAT. The dry matter tended to be consistently higher and the ash lower in the HYDROGEN CYANAMIDE treatment than in the control. Loss of dry matter usually occurs in stored slurry due to loss of organic carbon by microbial action. It appears that the hydrogen cyanamide treatment inhibited microbial activity in the slurry which would explain the observed results.

The PEAT treatment was given in the final-mix system only. Results in Table 4 show that the slurry conductivity increase was significantly less in the peat treatment than in the control. This suggests that a peat cover on the slurry inhibited mineralization of the organic matter in the slurry. As would be expected, addition of peat to the slurry resulted in a significant increase in dry matter and viscosity, and decrease in ash and supernatant volume at the end of the treatment period.

Manure Gases in Free Space

Results for hydrogen sulfide and ammonia gases in Figs. 8 and 9, and in Table 5, show large variations in gas concentrations in all treatments. HYDROGEN CYANAMIDE treatment completely eliminated hydrogen sulfide gas production whereas near lethal concentrations of the gas were observed in all other treatments. Ammonia gas concentrations were higher at the end of the treatment period than at the beginning in all treatments except PEAT. In the weekly-mixed slurry, (Table 5), significantly higher ammonia concentrations were observed in treatments with HYDROGEN CYANAMIDE (#2), AGRI-SCENTS (#4), NATURAL ODOR CATALYST (#5), and PRODUCT X (#7) compared to the control. In the final-mix system, the same was true for HYDROGEN CYANAMIDE treatment but the opposite for PRODUCT X and PEAT.

Table 4. Change in physical properties of slurry in different treatments.

PROPERTY	TREAT- MENT NUMBER	WEEKLY-MIX SLURRY			FINAL-MIX ONLY SLURRY		
		Initial Value	Final Value	Signi- ficance	Initial Value	Final Value	Signi- ficance
CONDUCTIVITY ms/cm	1	31000	32100		29400	32800	
	2	31800	32200		29500	32100	
	3	31800	32200		29300	32200	
	4	30900	32300		29500	32300	
	5	30800	32500		29500	32600	
	6	30800	32400		29600	32600	
	7	31000	32300		29500	32400	
	8				29300	30200	S
DRY MATTER (DM) %	1	5.4	4.7		5.1	4.8	
	2	5.2	5.0	S	5.3	5.0	
	3	5.1	4.5		5.3	4.8	
	4	5.3	4.6		5.4	4.8	
	5	5.8	4.7		5.4	4.7	
	6	5.2	4.6		5.3	4.8	
	7	5.2	4.6		5.1	4.7	
	8				5.2	6.1	S
ASH % DM	1	31.4	33.9		31.5	33.8	
	2	31.1	33.5		31.6	33.0	
	3	33.6	34.7		33.3	35.3	
	4	32.5	34.6		31.2	34.7	
	5	30.8	33.7		31.2	34.8	
	6	34.7	33.5		31.1	33.8	
	7	32.7	34.9		32.5	35.2	
	8				32.2	27.0	S
SUPERNATANT volume %	1	80	79		77	81	
	2	81	80		76	79	
	3	80	81		80	80	
	4	80	80		78	80	
	5	79	81		79	80	
	6	80	79		78	81	
	7	78	81		78	81	
	8				76	71	S
APPARENT VISCOSITY centipoise	1	99	30		83	48	
	2	108	30		90	44	
	3	104	36		96	34	
	4	100	31		83	53	
	5	95	34		100	49	
	6	100	43		90	44	
	7	95	34		83	53	
	8				85	99	S

Table 5 Concentration of manure gases in the free space above slurry in different treatments.

GAS	TREATMENT NUMBER	WEEKLY-MIX SLURRY			FINAL-MIX ONLY SLURRY		
		Initial Value	Final Value	Significance	Initial Value	Final Value	Significance
HYDROGEN SULFIDE ppm	1	1600	900		820	2000	
	2	930	0	S	920	0	S
	3	1100	880		1100	2200	
	4	2000	980		640	3500	
	5	870	820		1600	2800	
	6	850	820		1100	3800	
	7	980	550		680	2400	
	8				870	3800	
AMMONIA ppm	1	16	56		9	56	
	2	10	175	S	6	138	S
	3	10	88		5	47	
	4	23	94	S	18	34	
	5	13	100	S	7	73	
	6	10	69		13	28	
	7	21	144	S	7	15	S
	8				15	6	S

ppm = parts per million by volume

S indicates significant difference from "control" or untreated slurry (Treatment 1) at end of treatment period.

The results indicate a good control on release of hydrogen sulfide gas by HYDROGEN CYANAMIDE and ammonia gas by PEAT cover.

Effects on Chemical Properties

The results for slurry pH, and for total and ammonia nitrogen in the slurry and its supernatant are shown in Figs. 10 to 14, and in Table 6. Slurry pH increased from about 6.6 to 7.3 in all treatments. The pH changes in the treated slurry were not different from that in the untreated slurry except that the pH tended to be slightly lower in the HYDROGEN CYANAMIDE treatment than in the other treatments.

Total and ammonia nitrogen changes were also not much different in the treated and untreated slurry or its supernatant (Figs. 11 to 14 and Table 6). Total nitrogen in the HYDROGEN CYANAMIDE treated slurry was higher than that in other treatments (Figs. 11, 12, Table 6) because of the addition of nitrogen contained in the chemical itself. The ammonia nitrogen increased in the slurry in all treatments due to mineralization of organic nitrogen in the slurry (Fig. 13). As expected, most of the slurry ammonia nitrogen was contained in its liquid fraction (Fig. 14).

Table 6 Change in chemical composition of slurry in different treatments.

PROPERTY	TREATMENT NUMBER	WEEKLY-MIX SLURRY			FINAL-MIX ONLY SLURRY		
		Initial Value	Final Value	Significance	Initial Value	Final Value	Significance
pH	1	6.7	7.3		6.6	7	
	2	6.7	7.2		6.6	7	
	3	6.7	7.3		6.6	7	
	4	6.7	7.3		6.7	7	
	5	6.7	7.3		6.6	7	
	6	6.7	7.3		6.7	7	
	7	6.7	7.3		6.6	7	
	8				6.7	7	
TOTAL NITROGEN IN SLURRY %	1	0.65	0.66		0.66	0.66	
	2	0.65	0.74	S	0.65	0.73	S
	3	0.65	0.66		0.66	0.66	
	4	0.65	0.66		0.66	0.66	
	5	0.66	0.66		0.66	0.66	
	6	0.65	0.66		0.66	0.66	
	7	0.66	0.66		0.66	0.66	
	8				0.66	0.64	
TOTAL NITROGEN IN SUPERNAT. %	1	0.49	0.5		0.46	0.5	
	2	0.49	0.58	S	0.47	0.57	S
	3	0.47	0.5		0.48	0.51	
	4	0.49	0.5		0.48	0.52	
	5	0.49	0.51		0.48	0.51	
	6	0.48	0.51		0.47	0.5	
	7	0.49	0.49		0.47	0.5	
	8				0.48	0.48	
AMMONIA NITROGEN IN SLURRY %	1	0.48	0.53		0.48	0.53	
	2	0.48	0.54		0.49	0.53	
	3	0.48	0.52		0.48	0.53	
	4	0.48	0.53		0.49	0.53	
	5	0.48	0.53		0.48	0.53	
	6	0.48	0.53		0.49	0.52	
	7	0.48	0.53		0.49	0.52	
	8				0.48	0.51	
AMMONIA NITROGEN IN SUPERNAT. %	1	0.45	0.47		0.43	0.45	
	2	0.45	0.47		0.44	0.48	
	3	0.44	0.47		0.44	0.48	
	4	0.45	0.48		0.44	0.48	
	5	0.44	0.48		0.44	0.48	
	6	0.42	0.48		0.43	0.48	
	7	0.45	0.46		0.44	0.47	
	8				0.45	0.44	

S indicates significant difference from "control" or untreated slurry (Treatment 1) at en. o treatment period.

In the treatment system studied here, loss of nitrogen from the slurry, if any, was within the range of analytical variation (i.e., small). Consequently, increased nitrogen retention in slurry due to any specific treatment could not be established in this study.

The results for total volatile fatty acids (VFAs), and the proportion or distribution of these acids as a percentage of the total, are shown in Fig 15 and Table 7. In the weekly-mixed slurry, there was a tendency for the VFA concentration to decrease slightly (Fig. 15), whereas in the final-mix only slurry treatment, the VFAs appeared to increase slightly (Table 7). Significant effect of treatments on volatile acid production was, however, not evident. The distribution of VFAs was not affected by the treatments either except for the HYDROGEN CYANAMIDE treatment in which the proportion of acetic and propionic acids decreased and that of butyric acid increased significantly over the control. Acetic and propionic acids are pungent smelling, and butyric acid is associated with the odor of rancid butter. Results in Fig. 15 and Table 7 suggest that the odor causing potential of volatile acids was not much different in the treated and untreated slurry.

CONCLUSIONS

Odor Control

Effectiveness of additives in controlling the production of known odor-producing chemicals (hydrogen sulfide, ammonia and volatile fatty acids) was tested. HYDROGEN CYANAMIDE treatment completely eliminated the release of hydrogen sulfide gas which is not only odorous (rotten egg odor) but can also be hazardous at concentrations in excess of 500 ppm. An 8 inch thick PEAT cover significantly reduced ammonia gas released from slurry compared to slurry without such cover. Concentrations of odor producing volatile fatty acids was not significantly affected by any of the treatments. However, HYDROGEN CYANAMIDE altered the distribution of the relative proportions of the different acids. The commercial additives had no significant effect on concentrations of the specific odor-producing chemicals tested in this study

Nitrogen Retention

Ability of additives to retain nitrogen in the slurry could not be determined in this study because no significant loss of nitrogen occurred in any of the treatments, including the control. This may be due to a lack of a continuously moving air mass above the slurry surface, which would remove nitrogen from the slurry in the form of ammonia gas. Consequently, no conclusion can be drawn regarding the ability of additives to increase nitrogen retention in the slurry.

Table 7. Change in volatile acid distribution in slurry in different treatments.

VOLATILE ACID	TREATMENT NUMBER	WEEKLY-MIX SLURRY			FINAL-MIX ONLY SLURRY		
		Initial Value	Final Value	Significance	Initial Value	Final Value	Significance
TOTAL VOLATILE FATTY ACIDS (mmole/L)	1	321	296		280	314	
	2	304	307		293	299	
	3	309	292		297	318	
	4	306	288		284	311	
	5	297	290		295	317	
	6	314	292		292	315	
	7	303	288		298	315	
	8				296	295	
ACETIC ACID AS PERCENT OF TOTAL VFA	1	63	66		63	64	
	2	62	62	S	63	63	S
	3	63	66		62	64	
	4	63	66		63	64	
	5	63	66		63	64	
	6	63	66		63	65	
	7	63	65		63	64	
	8				63	64	
PROPIONIC ACID AS PERCENT OF TOTAL VFA	1	14	14		14	14	
	2	14	13	S	14	16	S
	3	14	14		14	14	
	4	14	14		14	14	
	5	14	14		14	14	
	6	14	14		14	14	
	7	14	14		14	14	
	8				14	14	
ISOBUTYRIC ACID AS PERCENT OF TOTAL VFA	1	4	4		4	4	
	2	4	4		4	4	
	3	4	4		4	4	
	4	4	4		4	4	
	5	4	4		4	4	
	6	4	4		4	4	
	7	4	4		4	4	
	8				4	4	
BUTYRIC ACID AS PERCENT OF TOTAL VFA	1	14	10		14	11	
	2	14	14	S	14	14	S
	3	14	10		14	12	
	4	14	10		14	12	
	5	14	10		14	11	
	6	14	10		14	11	
	7	14	10		14	11	
	8				14	11	

Table 7. contd. Change in volatile acid distribution in slurry in different treatments.

VOLATILE ACID	TREAT-	WEEKLY-MIX SLURRY			FINAL-MIX ONLY SLURRY		
	MENT NUMBER	Initial Value	Final Value	Significance	Initial Value	Final Value	Significance
ISOVALERIC ACID AS PERCENT OF TOTAL VFA	1	4	4		4	4	
	2	4	4		4	4	
	3	4	4		4	4	
	4	4	4		4	4	
	5	4	4		4	4	
	6	4	4		4	4	
	7	4	4		4	4	
	8				4	4	
VALERIC ACID AS PERCENT OF TOTAL VFA	1	2	2		2	2	
	2	2	2		2	2	
	3	2	2		2	2	
	4	2	2		2	2	
	5	2	2		2	2	
	6	2	2		2	2	
	7	2	2		2	2	
	8				2	2	

S indicates significant difference from "control" or untreated slurry (Treatment 1) at end of treatment period.

Solids Content and Flow Properties

Low values of dry matter and viscosity as opposed to high values indicate better flow characteristics of slurry. Addition of PEAT to the slurry significantly increased both the dry matter and the viscosity, thus making the slurry worse than before in terms of ease of flow. There was a tendency for the slurry to lose less dry matter solids during storage in the HYDROGEN CYANAMIDE treatment than in the other treatments. From the results it is reasonable to conclude that none of the treatments significantly improved flow characteristics in the slurry. Effectiveness of additives in reducing crust formation was not tested in this study.

Increased ash content in slurry indicates an increased loss of organic matter in the slurry due to microbial degradation. High organic matter in the slurry is preferable if the slurry is to be used for land application because it helps improve soil quality. Based on the results for ash content, it may be concluded that none of the additives improved organic matter retention in the slurry.

Other Benefits

Although it was not a part of the study, other observations indicated that a lower fly and larvae population, and less scum and odor-offensiveness was associated with the HYDROGEN CYANAMIDE treated slurry than with other treatments. This is consistent with other reports on the use of this chemical for slurry treatment.

RECOMMENDATIONS

Based on the results of this study, none of the commercial additives that were tested can be recommended for addition to slurry to obtain significant beneficial effects. Further investigations on the use of the chemical HYDROGEN CYANAMIDE and PEAT are recommended. These investigations could be focused on optimization of the dosage and the method of use, and on cost-effectiveness.

Since this study was completed, the supplier of the additive BIOSURGE has informed us that the recommended dosage for this additive has now been increased, based on tests reportedly done at the National Research Council. The additive MICRO-AID was found to be ineffective in the initial week of treatment although more than the recommended dosage was used. The effectiveness of these two additives for addition to slurry could be further tested before making definite conclusions about their effectiveness.

Inferences on the effectiveness of other slurry additives, which were not tested in this study, should not be drawn on the basis of the results reported here. However, it may be noted that none of the other reported studies have identified slurry additives that were found to control odor, or impart other significant beneficial effects under controlled testing. Further research is required on the effectiveness of **feed** additives to control manure odor and its offensiveness.

APPENDIX 1

Additive Products Used and Suppliers

AGRI-SCENTS: Liquid, Yucca Plant Extract

Supplier: Pine Isle Inc. (Patricia Ostrander)
595 Northgate Avenue
Waterloo, Ontario

BIO-SURGE: Nutrient combination

Supplier: SciCorp Systems Inc. (Ronald Roth)
320 Yonge Street, Unit 5, Suite 325
Barrie, Ontario L4N 4C8

HYDROGEN CYANAMIDE: Chemical H_2NCN

Supplier: Cyanamid Canada Inc.
88 McNabb Street
Markham, Ontario L3R 6E6

MICRO-AID: Liquid, Saponin Surfactant, Urease Inhibitor

Supplier: Papillon Canada Inc. (Jeff Currah)
R.R. #1, Innerkip Ontario

NATURAL ODOR CATALYST (N.O.C.): Solution of amino acids,
vitamins, trace minerals & enzymes

Supplier: NonScents Inc.
Deborah Rowen (Independent Distributor)
744 Balaton Avenue
Pickering, Ontario L1W 1W5

PEAT: Sphagnum peat from Shippagan, New Brunswick

ROEBIC: Mixture of aerobic, anaerobic and facultative bacteria

Supplier: Wood Lynn Farm Equipment (Gerry Long)
R.R. #1, Delaware, Ontario

DAILY AIR TEMPERATURE VARIATION WITH TIME

— AMBIENT MAX AMBIENT MIN — MEAN BARN TEMP

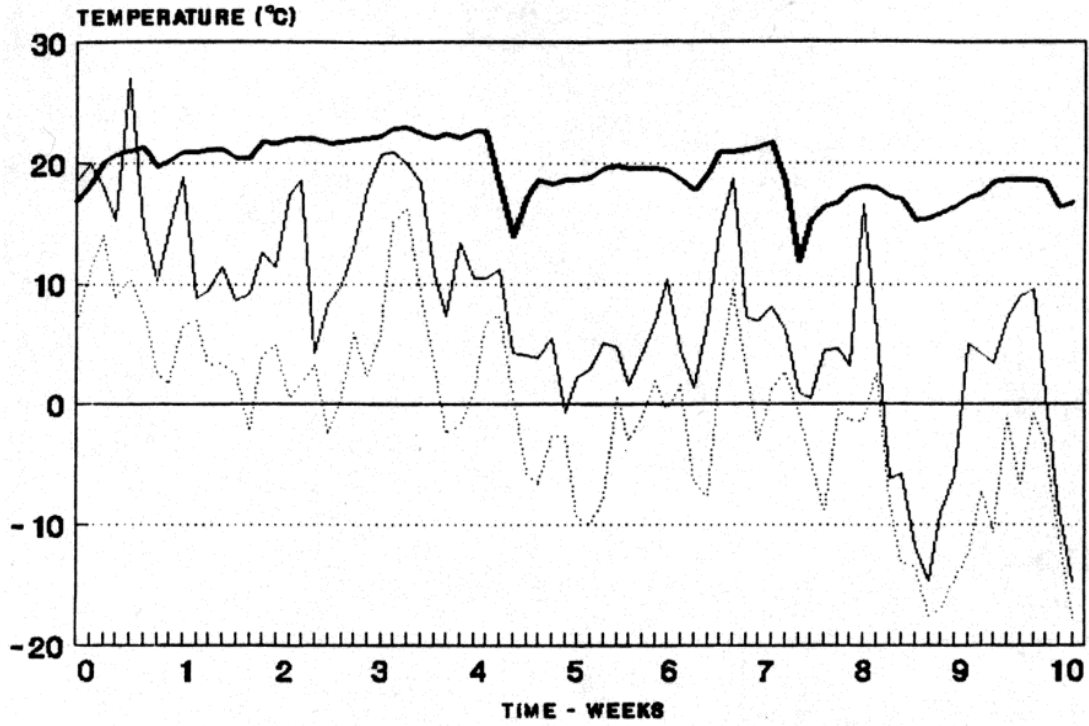


Fig. 1. Variation of daily temperature in the barn and in the ambient air outside the barn during the study period

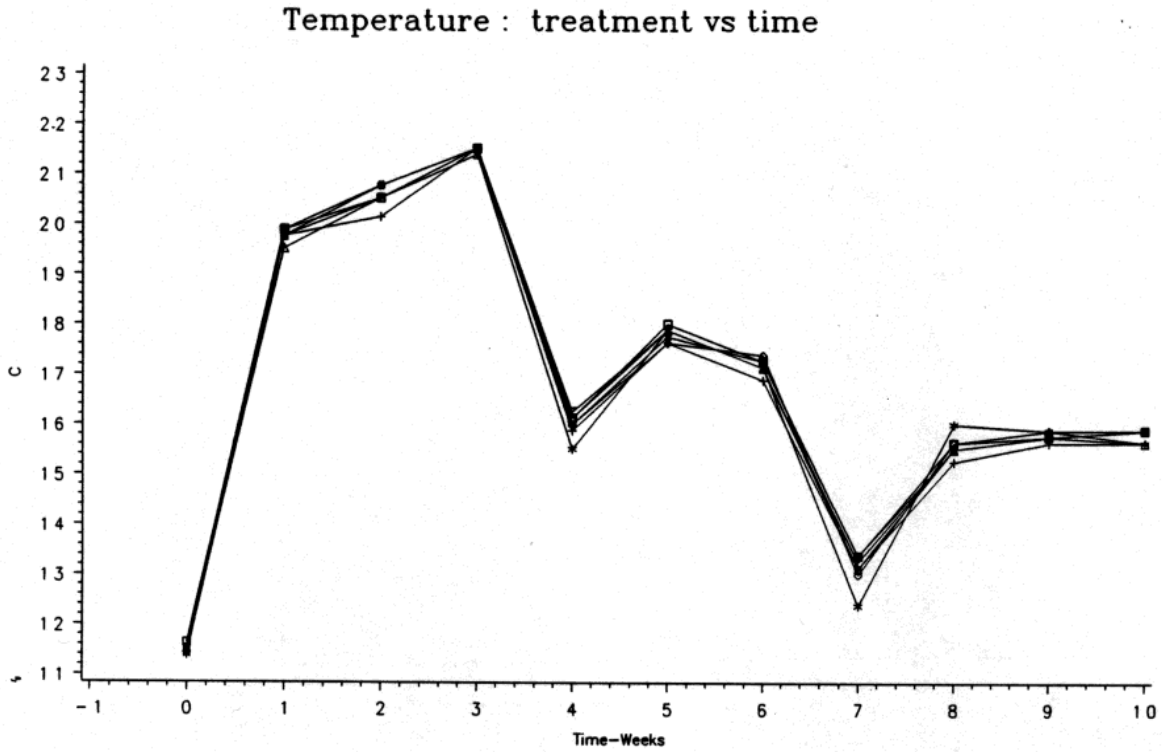


Fig. 2. Slurry temperature variation in different treatments. Each point in this and subsequent figures represents a mean of four replications for each of seven treatments including the control. The low initial temperature was due to outdoor storage of slurry in barrels (at low outside temperature, prior to transfer indoors). The temperature drop during week 7 occurred when the barn door inadvertently flung open during a weekend when the outside temperature was low. (Fig. 1).

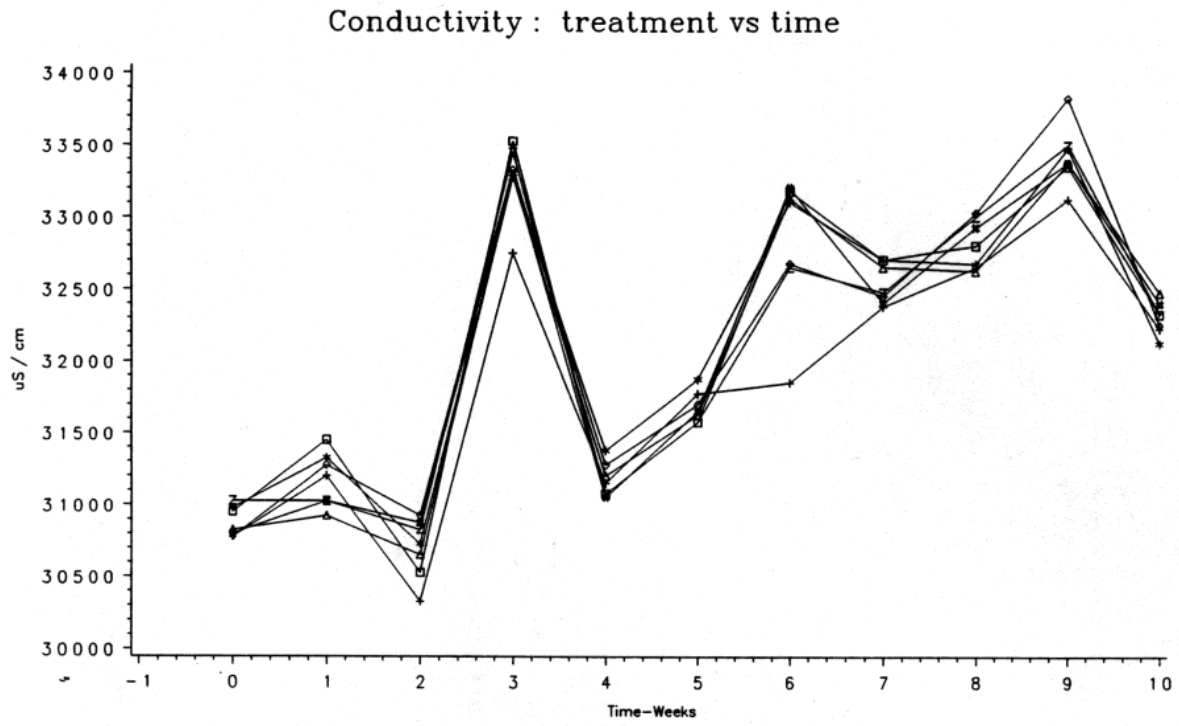


Fig. 3. Slurry conductivity variation in different treatments.

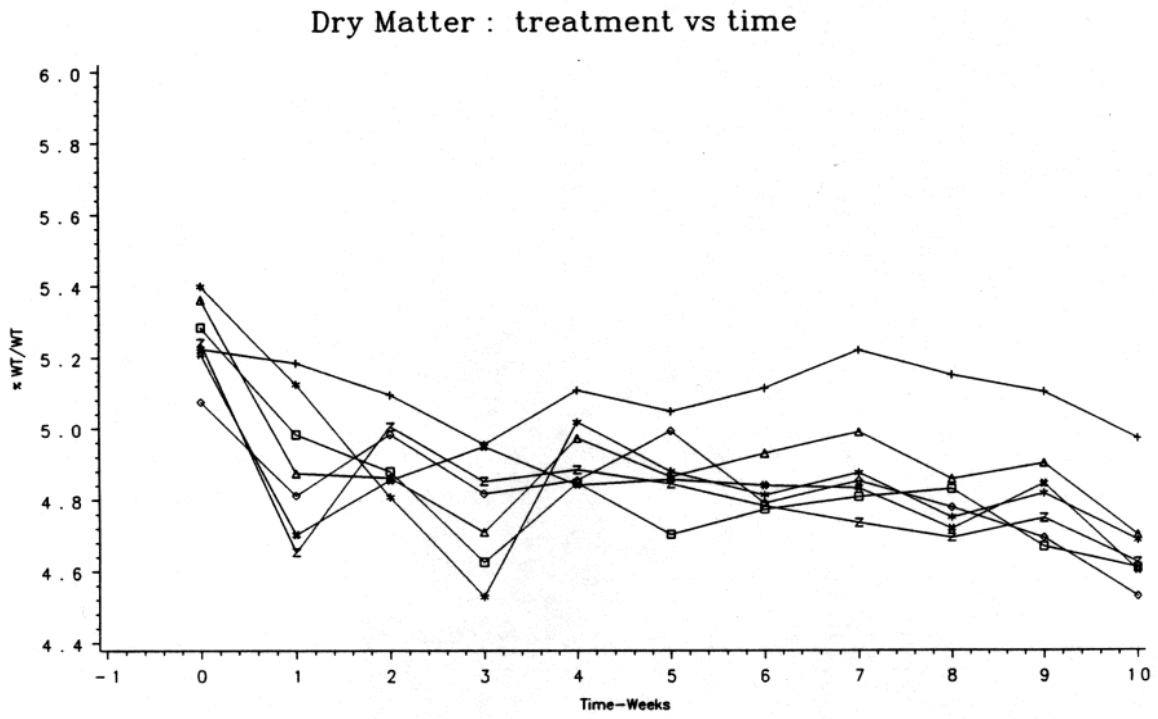


Fig. 4. Slurry dry matter variation in different treatments.

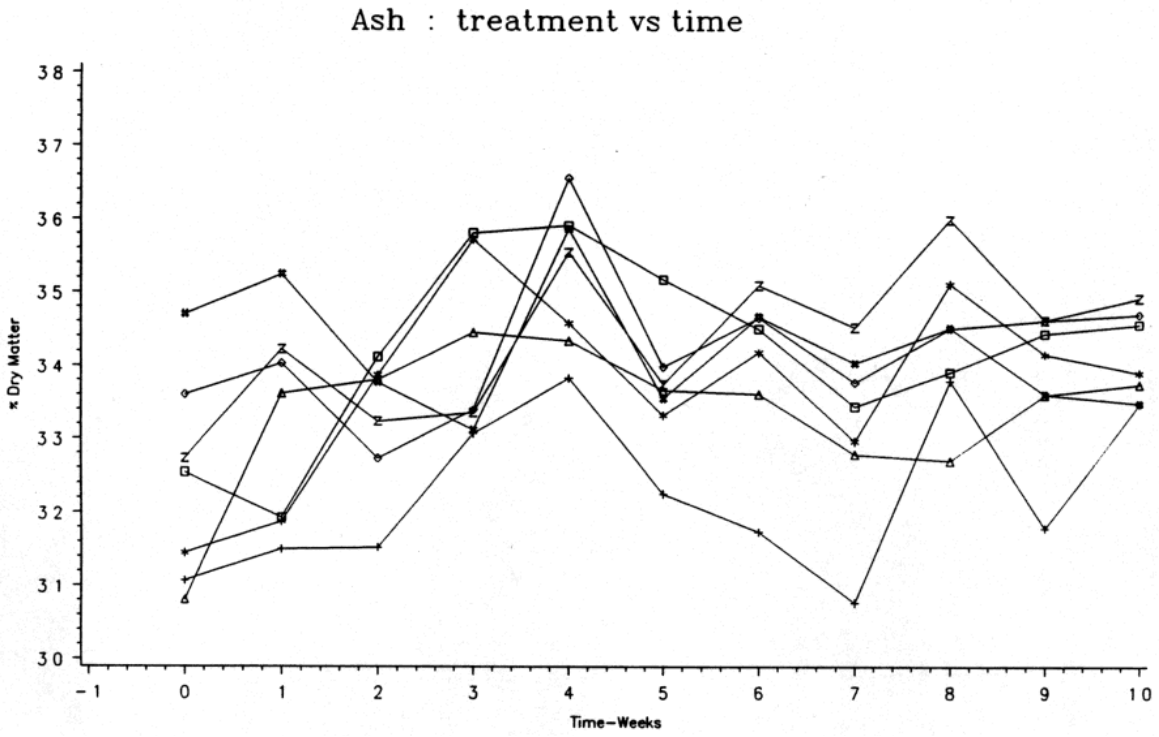


Fig. 5. Slurry ash variation, as per cent of dry matter, in different treatments. Dry matter = ash + organic matter. Lower ash content indicates higher organic matter content.

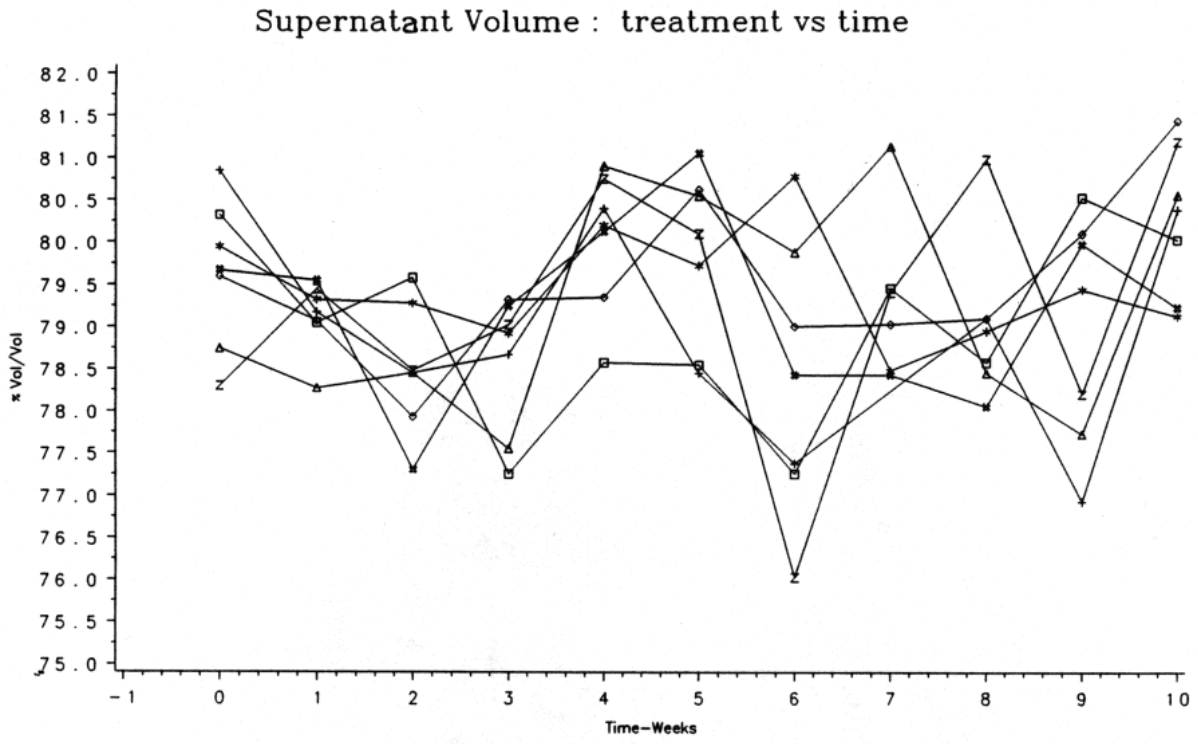


Fig. 6. Centrifuged supernatant volume variation, as percent of volume of slurry, in different treatments

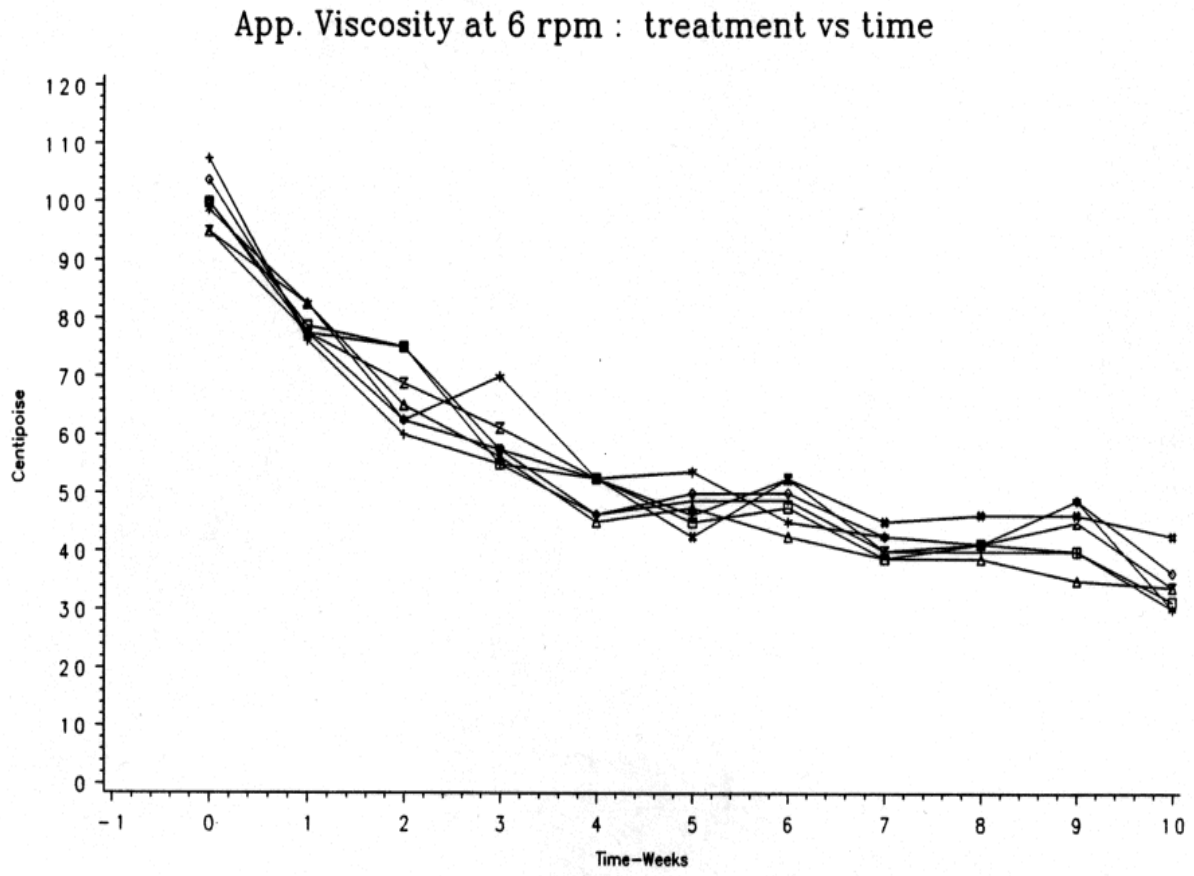


Fig. 7. Slurry apparent viscosity variation in different treatments.

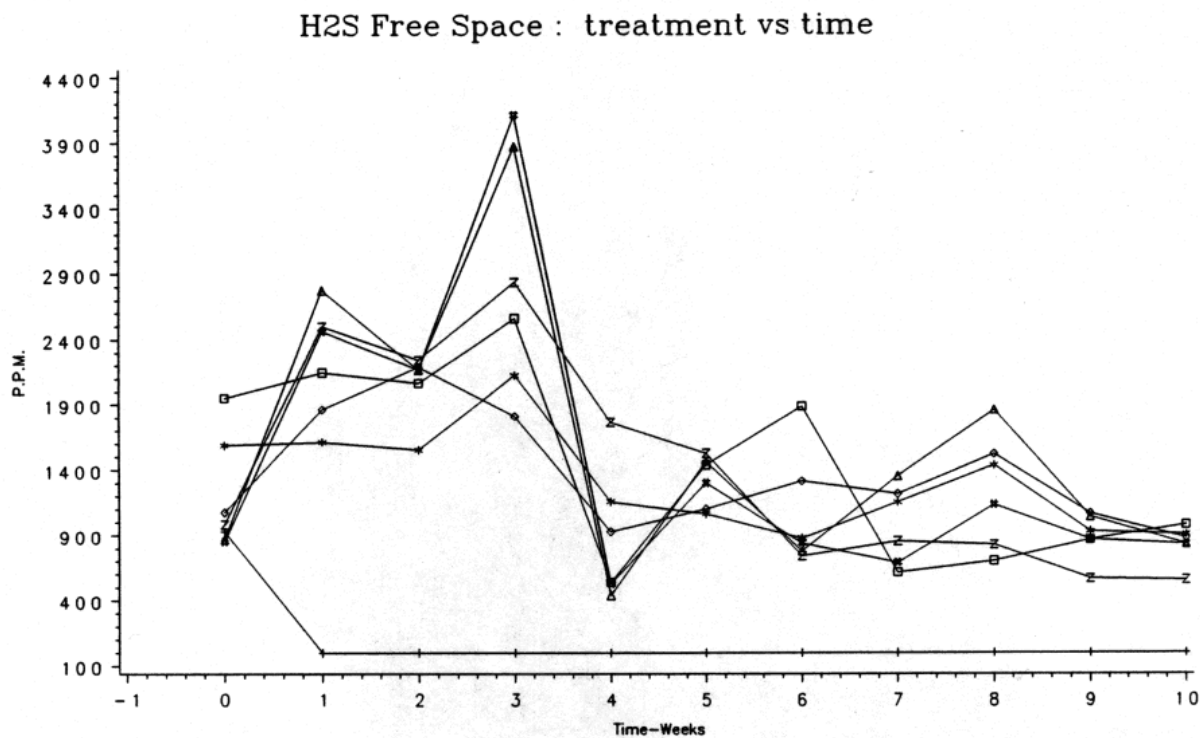


Fig. 8. Hydrogen sulfide gas release from slurry during mixing, in different treatments. Concentrations of 500 to 600 parts per million (ppm) of the gas can cause unconsciousness in 30 minutes; 700 to 2000 ppm can be rapidly fatal. (Source: Canada Animal Manure Management Guide, 1980; Publication 1534, Agriculture Canada, Ottawa).

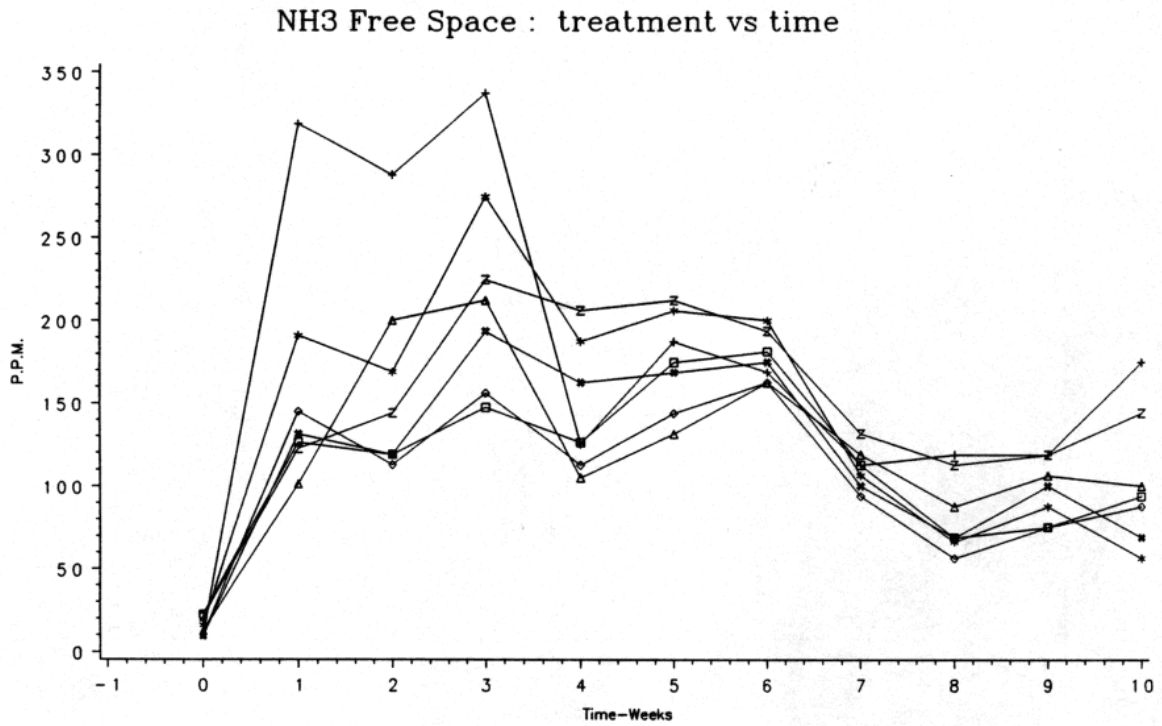


Fig. 9. Ammonia gas in the free space above slurry in different treatments. Note that concentration of 100 to 500 ppm of the gas causes irritation to mucous surfaces in one hour; 400 to 700 ppm causes immediate irritation of eyes, nose and throat. (Source: Canada Animal Manure Management Guide).

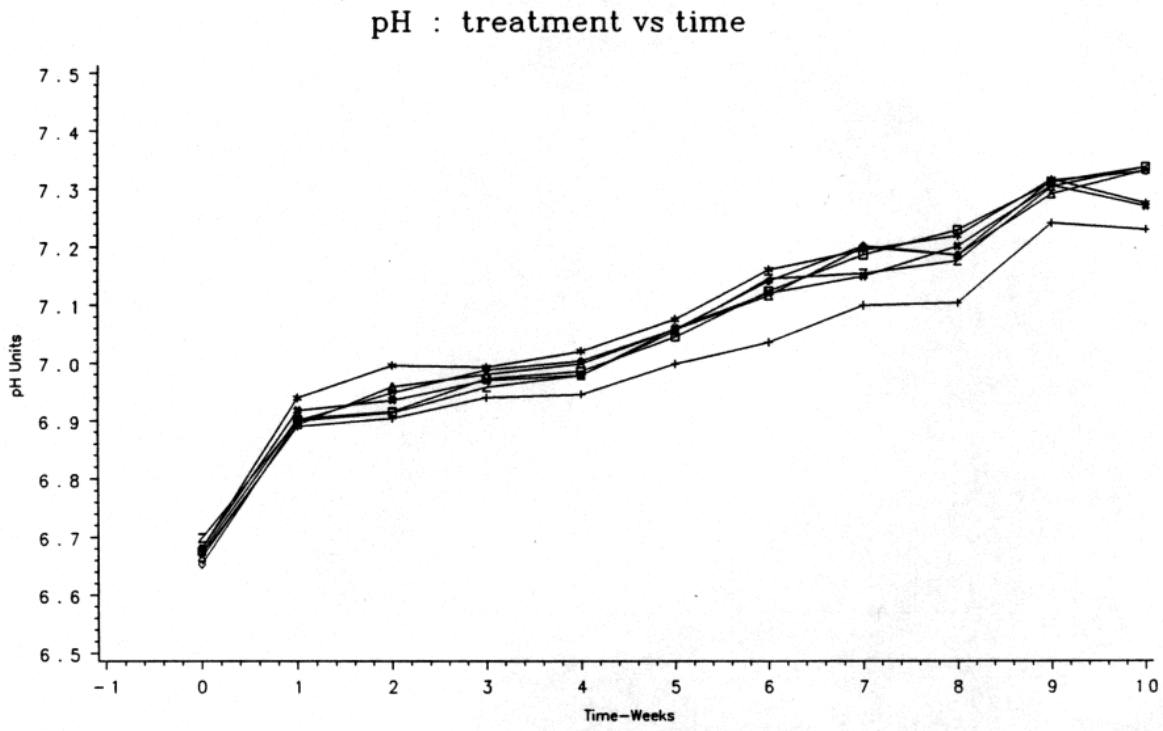


Fig. 10. Slurry pH variation in different treatments.

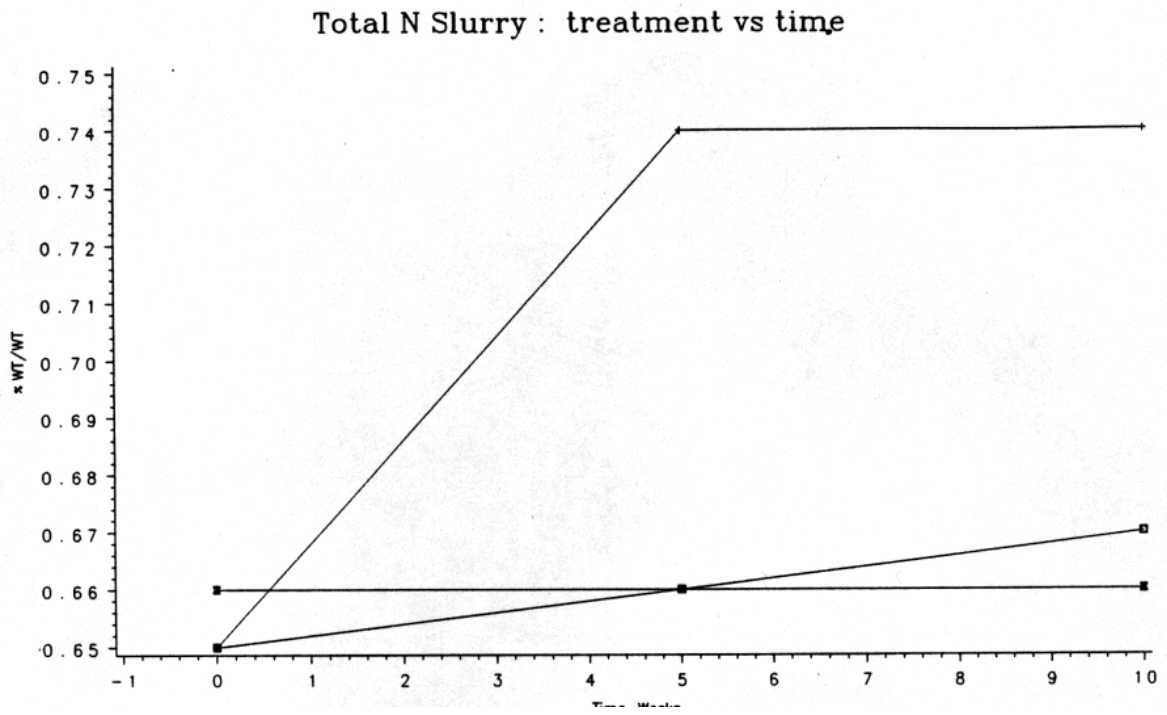


Fig. 11. Slurry total nitrogen variation in different treatments (seven treatments including the control).

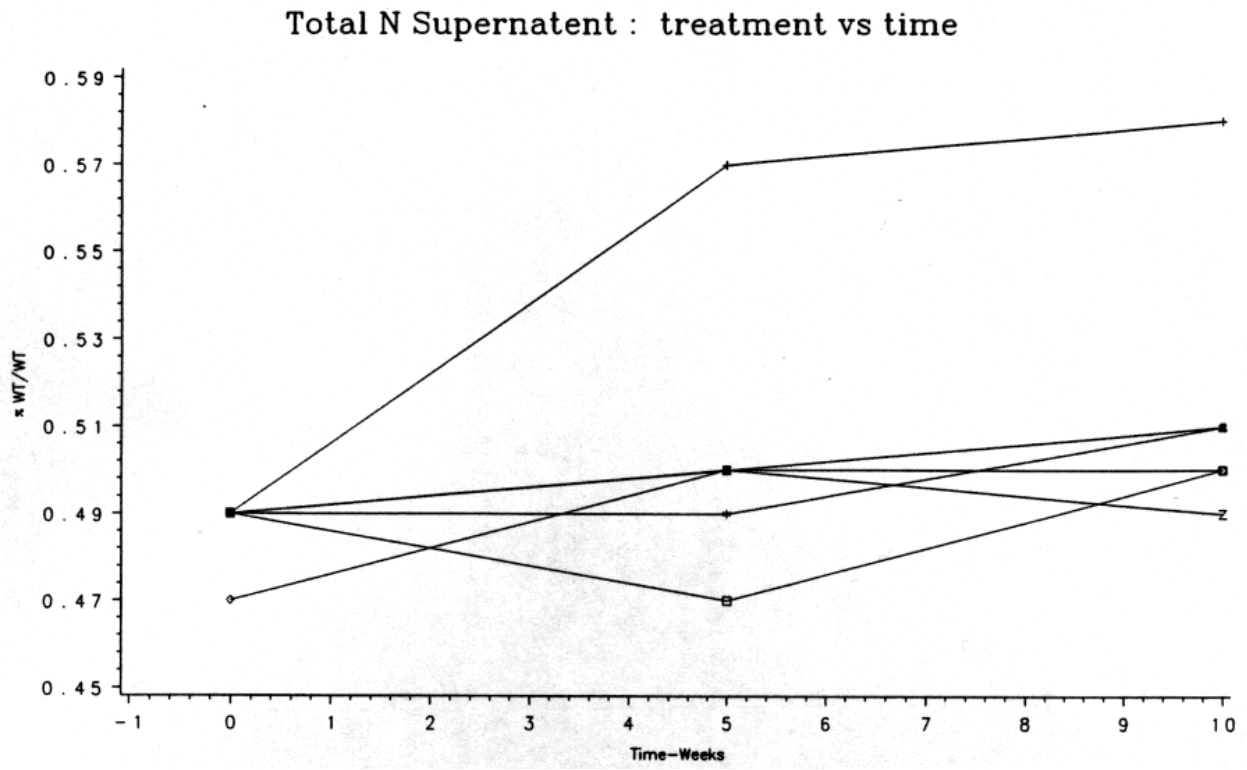


Fig. 12. Centrifuged supernatant total nitrogen variation in different treatments.

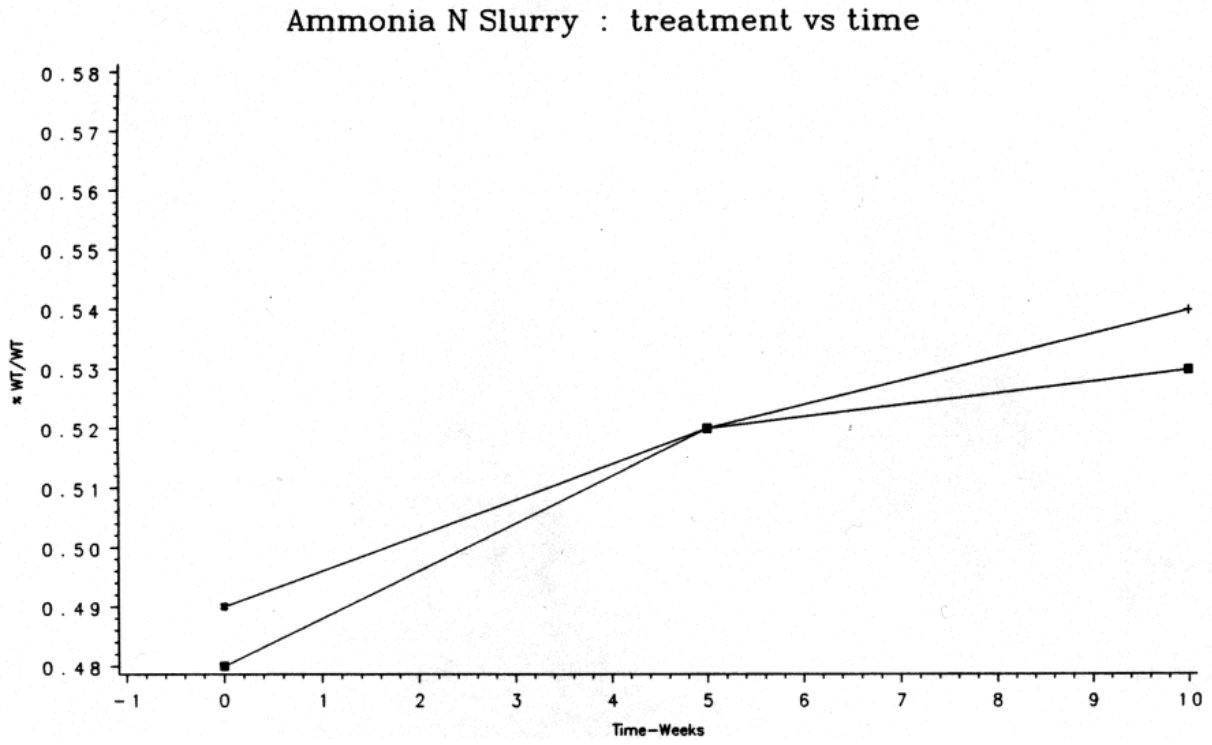


Fig. 13. Slurry ammonia nitrogen variation in different treatments (seven treatments including the control)

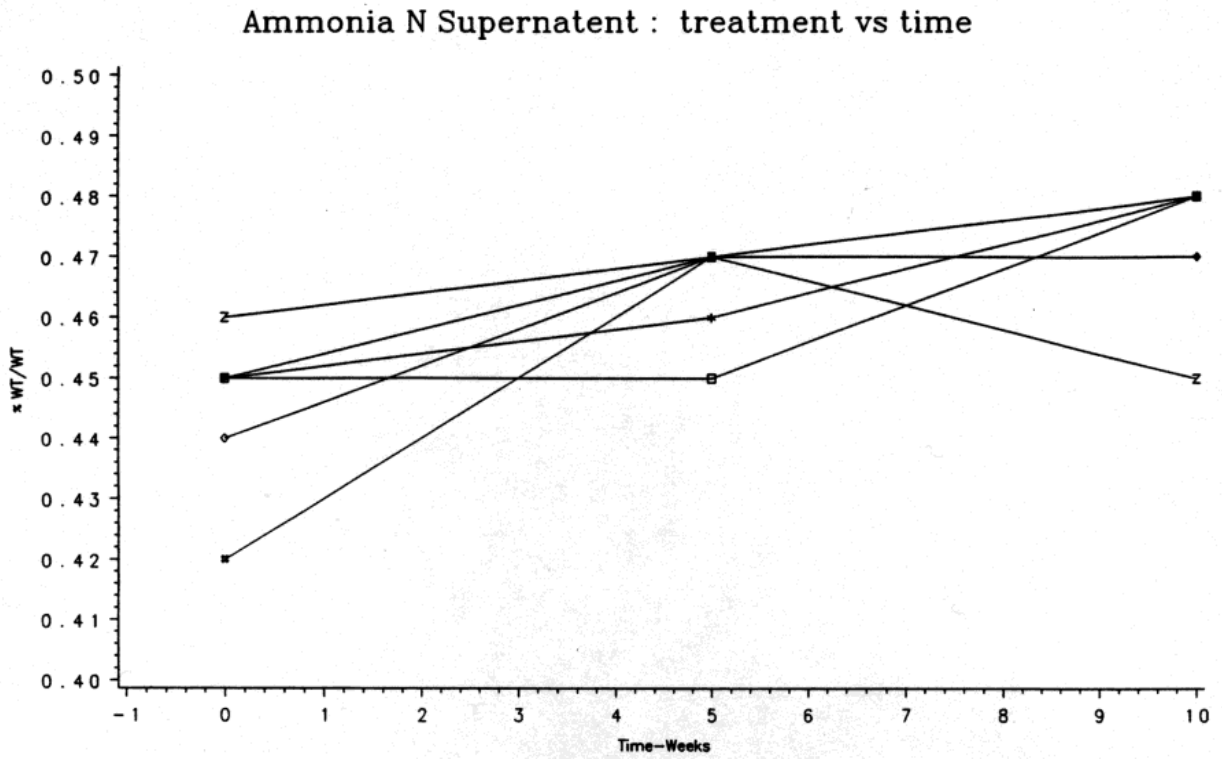


Fig. 14. Centrifuged supernatant ammonia nitrogen variation in different treatments.

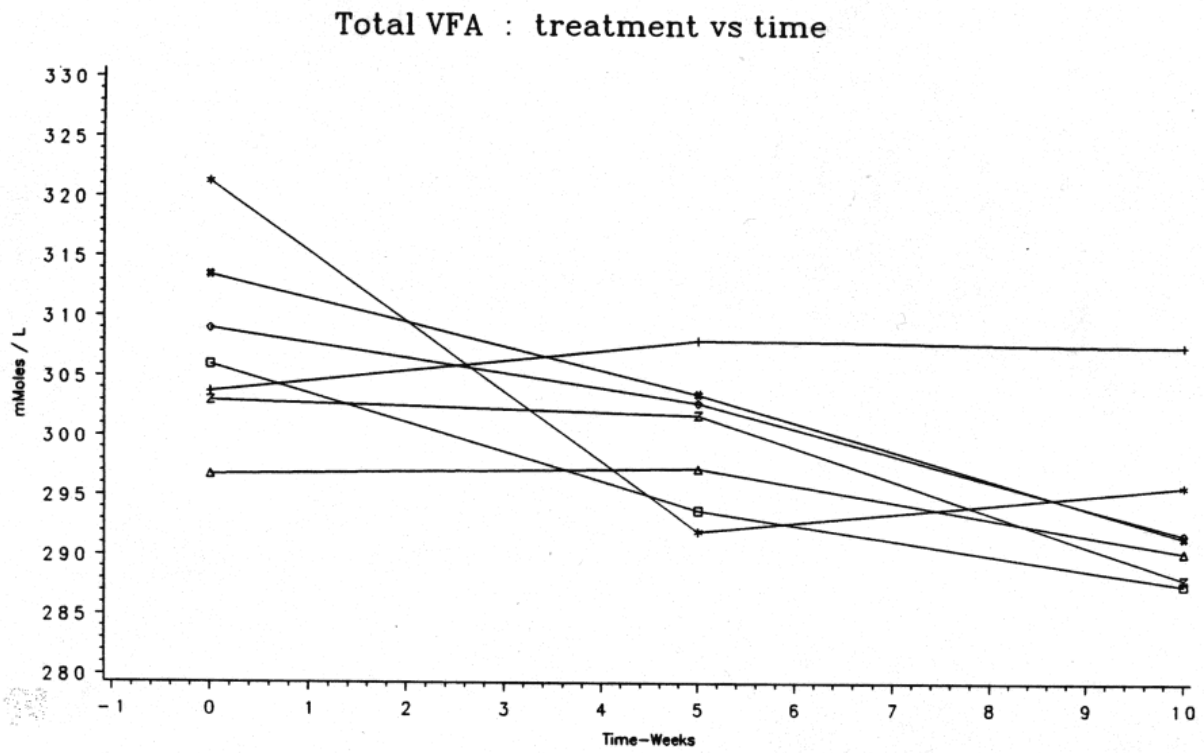


Fig. 15. Total volatile fatty acid variation in supernatant during different treatments.



Plate 1. Loading manure slurry from a sump pit of a partially slotted floor barn.



Plate 2. Sump pit at the swine farm.



Plate 3. Test barrels lined up outside the barn prior to filling.



Plate 4. Aligning tanker discharge pipe to barrel opening.



Plate 5. Filling test barrel with a fixed volume of slurry.



**Plate 6. Slurry surface inside the barrel after filling;
a nine-inch free space was left above the slurry.**



Plate 7. Slurry-filled barrels after transfer to inside of the barn.

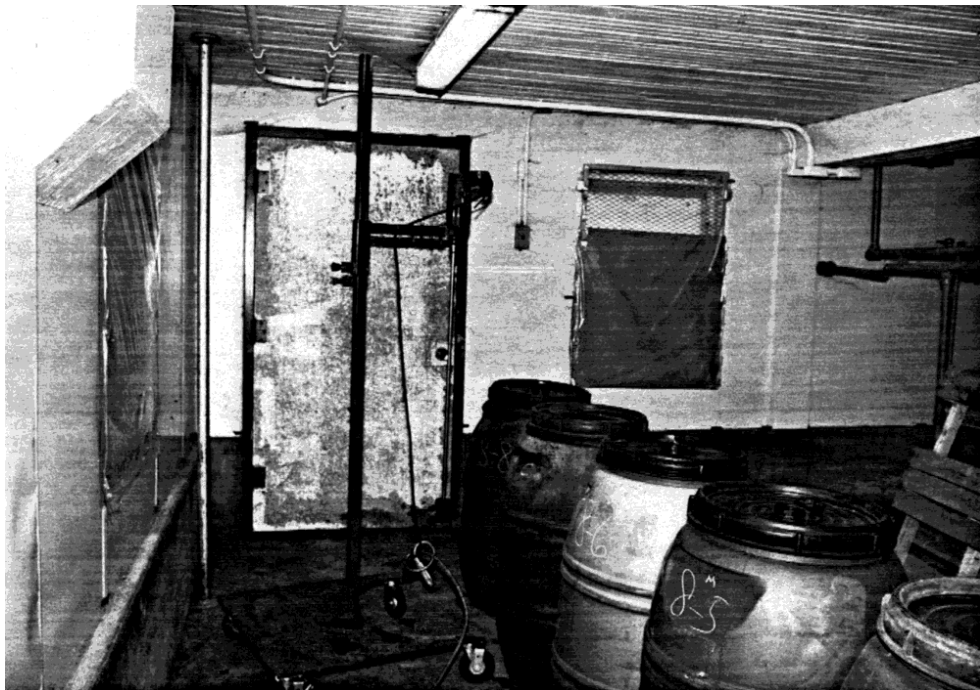


Plate 8. Custom built, adjustable height propeller-mixer for mixing slurry in the test barrels.



Plate 9. Mixing slurry in the barrels.



Plate 10. Testing for gas concentration in the free space inside the barrel.



Plate 11. Determining slurry temperature.



Plate 12. Drying oven used in the barn for slurry dry-matter determination.



Plate 13. Barn temperature recorder.



Plate 14. In-the-barn laboratory for slurry sample processing and analysis.



Plate 15. Typical surface appearance of unmixed slurry at the end of 10 week storage period in all treatments, including control, except peat and hydrogen cyanamide.



Plate 16. Appearance of peat on top of unmixed slurry at the end of 10-week storage period.

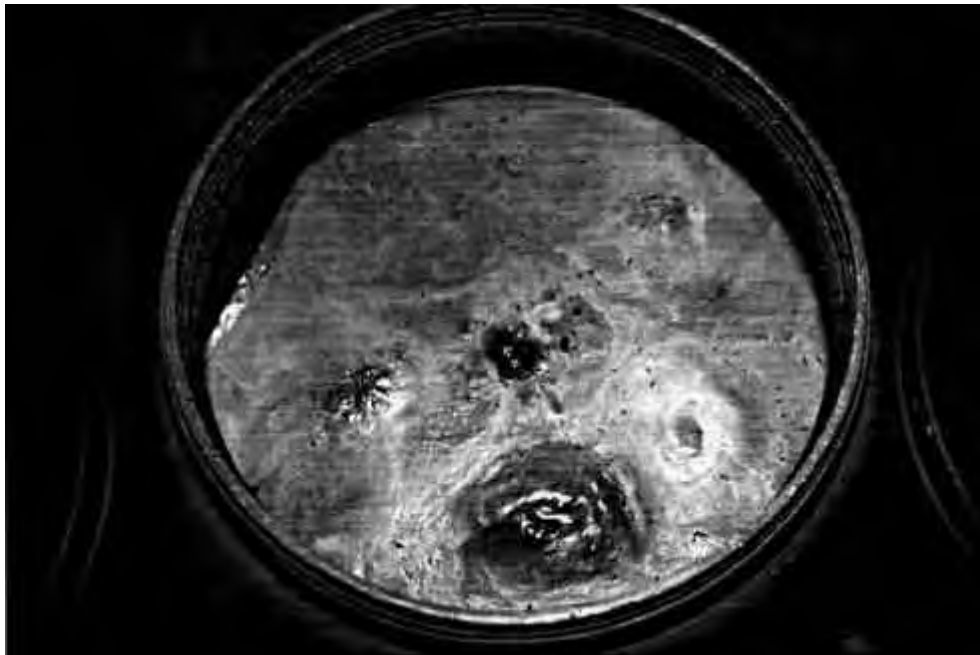


Plate 17. Appearance of hydrogen cyanamide-treated slurry at the end of 10-week storage period.