# PROSPECTS FOR RE-FEEDING AEROBICALLY TREATED LIQUID PIG MANURE

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## 1. INTRODUCTION

Pigs convert 30% of the nitrogen contained in the feed protein into meat protein and 50% is excreted as urea with the urine. The other 20% is excreted with the faeces as - mainly - microbial protein. As part of an environmentally acceptable solution of the problem of regional manure surpluses, we investigated some possibilities of recycling. An attempt at direct winning of the protein from the liquid manure (LM), by sieving and centrifugation has not been very successful, mainly because of a poor coagulation of the protein-rich particles. Next we tried the following treatments:

1. Aeration in a low loaded activated sludge system.
2. Aeration in a high loaded activated sludge system.
3. Composting together with straw.

Treatment 1 is directed towards the use of aerated liquid manure (ALM). With a retention time of 40 days or more, as 'drinking water' for pigs. Earlier experiments indicated that the protein and energy value of this ALM is negligible. Savings on copper and phosphate additions to the feed, however, might be possible. The odourless storage during long periods and a smaller volume that ultimately has to be spread on the land are the principal advantages. Treatment 1 is schematically shown in Figure 1.

Treatment 2 tries to keep as much as possible of the protein and energy value of the LM. Depending on the retention time in this system we will find a small increase, no change or a small decrease of the protein content of LM by aeration. To remove the excess of ammonium nitrogen with retention times of less than 7 days, nitrification and denitrification are separated in space. Treatment 2 is schematically shown in Figure 2.

Treatment 3 tries to use the ammonium nitrogen of the LM as a nitrogen source for biomass production with the carbohydrates of straw as the principal carbon source. The straw also serves as water absorbing and structuring material that enables satisfactory aeration of the mixture with LM. The compost produced could possibly serve as a roughage for ruminants or be used for mushroom cultivation or for soil improvement.

## 2. STARTING-POINTS OF THE ACTIVATED SLUDGE SYSTEMS

### 2.1. General comparison and materials balance sheet

The principal advantages and disadvantages of treatments 1 and 2 are given in Table 1. By calculating, as far as possible, the cost of these treatments a comparison can be made with a system in which the LM, after flushing from the piggery and sieving, is stored aerobically before spreading it on the land.

Starting point of all cost calculations is a materials balance sheet for pig fattening from 20 to 100 kg in 125 days.

| | per 125 days per pig |
|---|---|
| **Input** | |
| Feed (88% DM) | 250 kg = 220 kg DM = 207 kg OM + 13 kg Ash |
| Water | 500 kg |
| | 750 kg |
| **Output** | |
| Growth | 80 kg |
| Faeces and urine | 460 kg = 56.1 kg DM = 45.5 kg OM + 10.6 kg Ash |
| Transpiration and gases | 210 kg |
| | 750 kg |

During growth from 20 to 45 kg about 60 kg of feed are consumed and about 130 kg faeces and urine excreted, which after sieving leaves about 100 litre LM. In the USA no ALM is supplied to the pigs during this period for safety reasons (Harmon and Day, 1975). Therefore we assumed in our calculations that only pigs heavier than 45 kg get ALM. We also assumed that a treatment system can contain the LM produced during the whole fattening period. The coarse solids separated by sieving can be stored in a pile and spread on the land separately. According to Dutch experiences we have after sieving:

| Output | Per 125 days per pig |
|---|---|
| Coarse solids | 106 kg = 25.6 kg DM |
| Sieved LM | 354 kg = 30.9 kg DM = 20.1 kg OM |
| | + 10.8 kg Ash |

TABLE 1

ADVANTAGES (+) AND DISADVANTAGES (-) OF RECYCLING AEROBICALLY TREATED PIG LIQUID MANURE AS 'DRINKING WATER' TO PIGS

| | Treatment 1 low loaded activated sludge | Treatment 2 high loaded activated sludge | Remarks |
|---|---|---|---|
| Odourless storage and landspreading | + | + | the manure stays aerobic |
| Lower transportation cost (less volume) | + | + | evaporation and saving of water |
| Feed value (biomass protein) | negligible | +? | feed value has not yet been proven |
| Saving on phosphate addition to feed | + | + | P in ALM is mostly inorganic/available |
| Saving on copper addition to the feed | +? | +? | activity of Cu unknown |
| Better climate in the accommodation | + | + | flushing with ALM |
| Better mechanical separation after treatment | + | + | supernatant can be spread through irrigation; sludge dried and/or spread |
| Hygienic risk to the animals | - | - | difficult to estimate; no predominant problem in the USA |
| Failures in the system; more supervision necessary | - | - | service-contract? extra man hours or automatic process-control |
| Higher investment | - | - | see cost calculations |
| Temperature sensitivity | - | - | problems at very low T |
| Larger loss of nitrogen than with aerobic storage | - | - | loss of N-fertiliser value: no $NH_3$-emission |

## 2.2. Required size of aeration basin for one period when recycling ALM

If 50% of the organic matter in sieved LM is decomposed during aeration or metabolised by the pig that consumes ALM, then after 125 days we have about 10 kg organic matter per pig in the treatment system. If the amount of ash in the system is not influenced by the recycling then we have 10.8 kg ash per pig after 125 days. Assuming that the DM content of the mixed liquor in the aeration basin can be no more than 10% to permit good aeration and mixing, the result is a necessary volume of at least 208 litres per pig. By recycling and repeated passage through the sieve probably more organic matter and ash are removed with the coarse solids; in that case a somewhat smaller volume per pig will do.

Besides the DM content in the treatment system, the content of mineral salts in it might become a limiting factor for recycling. We calculated that by supplying ALM as drinking water to pigs with a ration that is rather rich in minerals, the limit to their kidney function will be reached at the end of the fattening period. By decreasing the minerals content of the ration, the salt content of the ALM will be a limiting factor only after 1.5 to 3 periods. This calculation does not take into account that a considerable part of the salts in ALM are present as insoluble salts (eg $CaHPO_4$, $CaCO_3$ and $MgCO_3$) that do not contribute to the osmotic value of the ALM. Also, partial removal of the salts with the coarse solids has not been taken into account in the calculation. Thus it may be expected that the salt content of ALM will pose no problem for recycling during one fattening period. The principal ions that determine the osmotic value of ALM are the cations K+ and Na+, with $HCO_3^-$, $Cl^-$ and $SO_4^{2-}$ as the principal anions.

# 3. TREATMENT 1: RECYCLING OF ALM FROM A LOW LOADED ACTIVATED SLUDGE

## 3.1. Introduction

Treatment 1 is rather similar to the system of Harmon in Illinois that is shown in the upper corner of Figure 1.

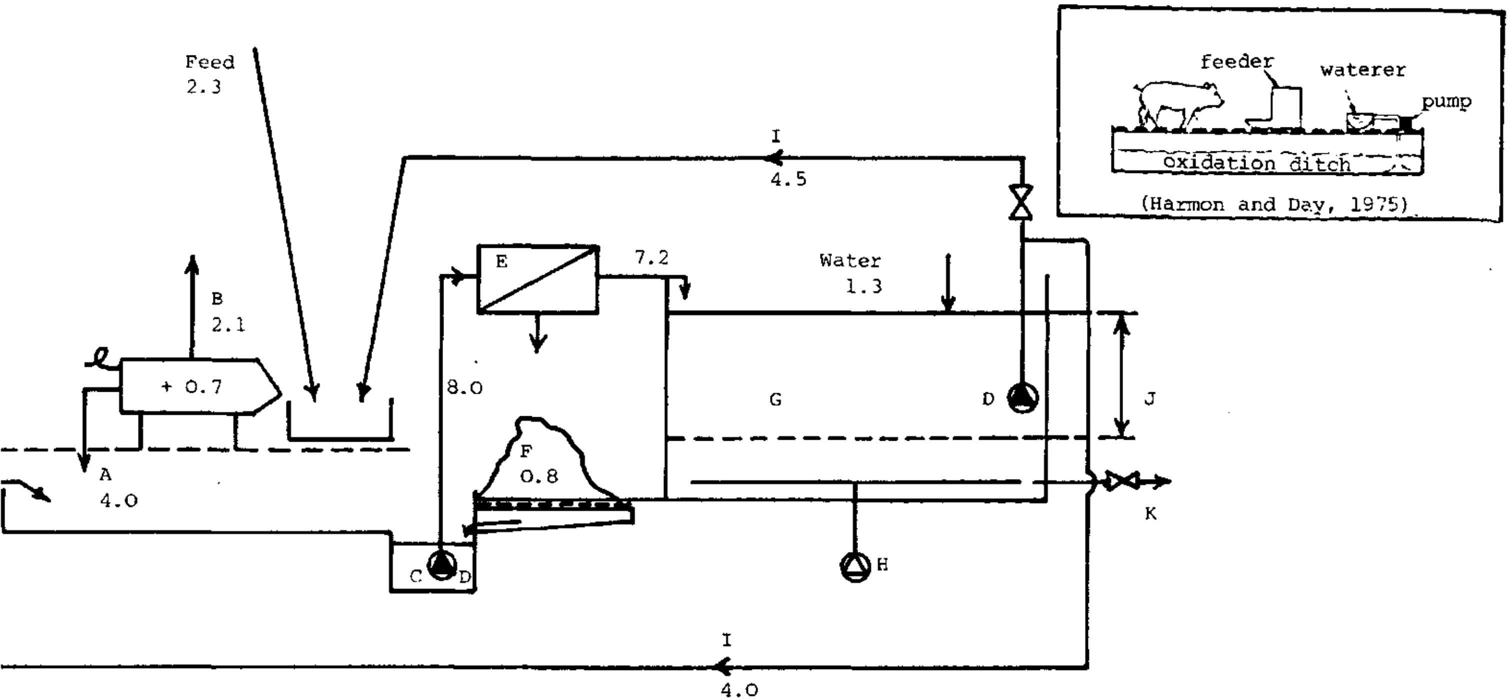


Fig. 1. Recycling activated sludge mixed liquor (low loading rate). Materials balance sheet over the period 45 to 100 kg (averages in kg per pig per day)

A = faeces and urine; B = transpiration and gases; C = collection pit; D = pumps;
E = sieve; F = coarse solids; G (210 litre/pig) = aeration basin; H = aeration system;
I = mixed liquor used as drinking water and for flushing manure into the pit;
J = volume built up before recycling starts; K = transport to the land.

Differences from Harmon are that we remove the coarse solids and suggest limiting recycling to one period. With a maize soya ration, Harmon could recycle for two years before the contents of his oxidation ditch had to be spread on the land because of DM accumulation. The ration that Harmon supplies contains relatively little potassium and other minerals and has a low content of crude fibre; the ration also contains less protein than Dutch rations. The improved feed conversion that Harmon found by supplying ALM to pigs is thus not simply applicable to other cases. On some farms in the USA the system 'Harmon' has been successfully applied. A warning should be given that recycling of over-aerated LM may lead to nitrite poisoning, while under-aerated LM may reduce the growth rate and feed conversion. In contrast to The Netherlands, no copper is added to the feed in the USA.

## 3.2. Continuous or semi-continuous mode of operation

When we operate this system with the aeration basin continuously filled with 210 litre per pig and about 10% DM, we need a storage tank after it of the same size. This storage will need some aeration to keep it odour free; its contents may be used for flushing or for recycling (in case of temporary unsuitability of the contents of the aeration basin) or for fertilising whenever it is convenient during the 125 days. With this continuous mode of operation temporary accumulations of nitrite and/or nitrate during start-up of the activated sludge will be avoided. Also maximum use can be made of the phosphate and copper in it. A drawback is the extra investment needed for the storage tank. The chance of transferring infection from one group of pigs to the next is decreased by the fact that from 20 to 45 kg of weight the pigs get no ALM.

We can also start each fattening period with a clean basin with eg 100 litre water per pig. During the growth period of 20 to 45 kg the activated sludge is built up until the volume per pig reaches 210 litre. In this case, after 125 days we have to empty the aeration basin completely. Although no extra investment for a storage tank is needed, this semi-continuous operation may give start-up problems and permit less saving on minerals added to the feed; also the composition of the ALM will be more variable with time than with continuous operation.

A compromise might be to use a somewhat larger tank (310 litre per pig) and start every period with 100 litre per pig ALM from the previous period.

### 3.3. Feed value of the organic matter in ALM

Some feeding trials with rats and chickens receiving 'biomass' obtained by centrifugation of ALM (system with a mean retention time of 40 days) indicated low digestibilities of the organic matter in it. However, the digestibility of the crude protein was higher than could be expected from the digestibility of the organic matter in general.

The composition of this tested 'biomass' was as follows: ash 35%, crude protein 30%, true protein (amino acids) 18%, crude fat 4%, crude fibre 11%, Ca 4.1%, P 5.6%, Na 0.75%, Cl 0.55%, and Cu about 1 000 mg/kg. No feeding trials with pigs were carried out. An acceptability test with 'biomass', contributing 20% to the DM of the ration supplied to pigs, was positive.

As can be seen from Figure 1, the retention time in the aeration basin will be about 210/4.5 = 47 days. This will lead to a rather low protein and energy value of the organic matter in the mixed liquor; in our calculation this value will be neglected.

### 3.4. Saving on phosphate and copper addition to the feed

About 2 g of P is excreted per kg faeces plus urine. It is assumed that copper added to the feed is totally excreted. This will give the following balance sheet for one fattening period:

| | | P | Cu |
|---|---|---|---|
| in liquid manure | (g per pig) | 460 x 2 = 920 | 250 x .2 = 50 |
| in sieved LM | (g per pig) | 0.7 x 920= 640 | 0.8 x 50 = 40 |
| in ALM | (g per litre) | 640/210 = 3 | |

These data apply to the continuous system.

When we supply 2 litre of ALM per kg of feed, we add with the former 6 g of P and 0.38 g of Cu. Normally 2 g of P and 200 mg of Cu are added per kg of feed. If we stop the addition of this phosphate to the feed then we will find less P in the LM too, at most 250 x 2 = 500 g less, leaving still 420 g of P per pig or 1.4 g P per litre ALM; this means that with ALM we still add 2.8 g of P per kg of feed, somewhat more than the normal addition without recycling. Perhaps for good growth we should still add 0.2% P to the feed during the period of 20 to 45 kg when the pigs get no ALM.

When we stop the addition of copper when half of the feed (125 kg) has been supplied we save 25 g of Cu per pig and in the ALM we will find only 20 g of Cu or about 0.1 g per litre. With 2 litre of ALM then about 0.2 g of Cu is supplied per kg of feed or the same amount as normally added without recycling.

Phosphate in ALM is largely present in an inorganic form ($CaHPO_4$); the availability of this phosphate to the pig is therefore expected to be about equal to that of added inorganic phosphate. About the availability and activity of copper in ALM much less is known.

## 3.5. Cost calculations

When we compare treatment 1 with a system where the LM, after being flushed out of the piggery and sieved, is stored aerobically for odour control, then treatment 1 has the following advantages and disadvantages:

a) a smaller volume of LM has to be spread on the land;

b) if phosphate and copper are fully available in ALM then 75% and 50% respectively of the P and Cu addition to the feed can be saved;

c) in case of semi-continous operation of treatment 1, the aeration basin can be smaller than a storage basin for odour control;

d) increased risk for the health of the pigs?

e) a higher loss of nitrogen;

f) the management is more complicated, demanding more supervision.

It is assumed that the electricity costs for aeration are more or less equal in both cases.

a) Volume of LM to be transported to the land, per pig per period:

| | Aerobic storage | Treatment 1 |
|---|---|---|
| total volume | 0.45 $m^3$ | 0.31 $m^3$ |
| coarse solids | 0.10 $m^3$ | 0.10 $m^3$ |
| ALM | 0.35 $m^3$ | 0.21 $m^3$ |

With transport over large distances (70 - 80 km) the cost for transport, intermediate storage and landspreading will be together about D.fl 10 per $m^3$, if not subsidised by the government. With treatment 1 this means per pig 0.14 $m^3$ less than with aerobic storage, or D.fl 1.40 per pig.

b) <u>Copper</u>: Copper sulphate ($CuSO_4 . 5H_2O$) costs D.fl 1.50 per kg, or D.fl 6.00 per kg Cu, saving 25 g of Cu which represents D.fl 0.15 per pig.

<u>Phosphate</u>: Price at the moment is about D.fl 3.00 per kg P. If only in the period 20 to 45 kg, extra phosphate is added to the feed, the saving will be 190 (kg feed) x 2 (g P per kg feed) = 380 g P per pig, or D.fl 1.14.

c) The net storage capacity for LM has to be 400 litre per pig per period. For the continuous operation of treatment 1 about the same net volume per pig is needed, in the semi-continuous mode one basin of about 200 litre per pig will do. Only in the latter case will the smaller volume of the basin lead to lower investment that partially compensates for the extra investment mentioned under f).

d) It is difficult to express the increase of health risk in money.

e) Loss of nitrogen fertiliser value: During aerobic storage for odour control about 40% of the nitrogen in the LM is lost into the air in the form of ammonia. In the case of treatment 1 the nitrogen lost via nitrification and denitrification, in the form of nitrogen gas, amounts to 80% of the nitrogen in the LM.

During a fattening period a pig excretes about 3 kg N with faeces and urine; about 15% of this nitrogen will be removed with the coarse solids and 85% goes into the aeration basin. Thus the extra loss of nitrogen with treatment 1 amounts to 0.85 x 0.4 x 3 = 1 kg N. The fertiliser value of this nitrogen will be about D.fl 1.25. This drawback only fully applies if, of the nitrogen in the LM stored for odour control, nothing is lost during landspreading; this is only the case if the LM is injected into the soil, a more costly operation than mere sprinkling.

After treatment 1 the ALM contains almost exclusively organic nitrogen compounds, giving no further loss during landspreading.

A negative value of D.fl 0.70 is accounted for by the above reasons.

f) More attention has to be given to process control. For nitrification and denitrification intermittent aeration or oxygen gradients may be necessary at low DM contents during start-up. The construction of the installation should be more sound than with aeration for odour control only.

Summarising: Cost comparison of treatment 1 with aerobic storage. Investment: extra investment estimated to be D.fl 10 000.00 for 2 000 pig places. The costs per pig compare as follows:

| | | | |
|---|---|---|---|
| Advantages: | less transport | D.fl | 1.40 |
| | copper saving | D.fl | 0.15 |
| | phosphate saving | D.fl | 1.15 |
| | total | D.fl | 2.70 |
| Disadvantages: | extra yearly cost | D.fl | 0.40 |
| | extra N-loss | D.fl | 0.70 |
| | net profit | D.fl | 1.60 per pig delivered |
| | or | D.fl | 3.50 per $m^3$ liquid manure |

## 4. TREATMENT 2: RECYCLING ALM FROM A HIGH LOADED ACTIVATED SLUDGE

Treatment 2 is schematically shown in Figure 2. The retention time in the high loaded activated sludge system is limited by the time needed for removal of excess ammonium nitrogen by nitrification and denitrification. To speed up the nitrogen removal the nitrification ($G_2$) is separated from the denitrification ($G_1$), with a large recirculation from $G_2$ to $G_1$. The LM is added continuously to $G_1$ to promote denitrification and to prevent inhibition of the nitrification. Thus both nitrification and denitrification can proceed with maximum speed under almost constant environmental conditions. In tank $G_3$ a secondary denitrification removes nitrite and/or nitrate before recycling to the pigs. The total mean retention time in the tanks $G_1$, $G_2$ and $G_3$ is about 10 days (2.5 + 5 + 2). Part of the mixed liquor goes from $G_2$ directly into a storage tank L, from which regularly a certain volume is used to flush the piggery.

It is expected that with this retention time of about 10 days, the ALM will have a certain protein and energy value for the pig, in contrast to treatment 1. Concerning the value of the organic matter in ALM the following approximate calculation can be made:

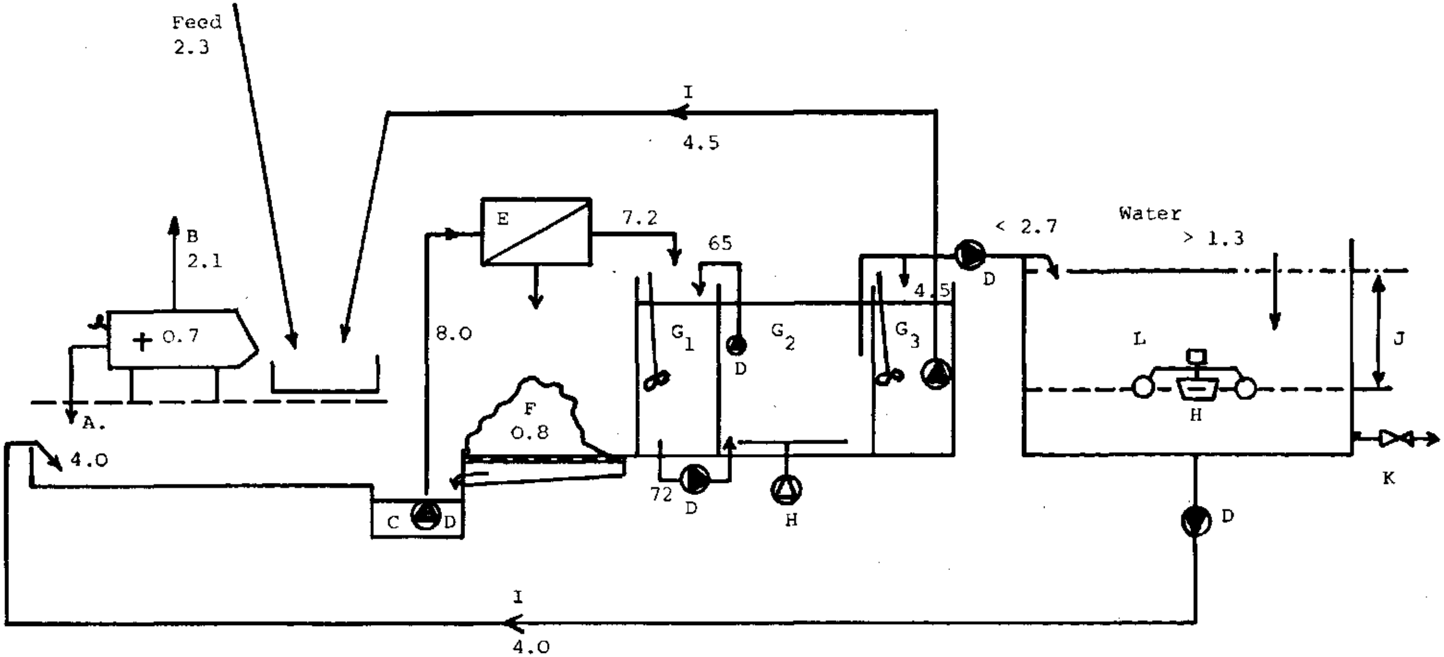


Fig. 2. Recycling activated sludge mixed liquor (high loading rate). Materials balance sheet over the period 45 to 100 kg (averages in kg per pig per day)

A = faeces and urine; B = transpiration and gases; C = collection pit; D = pumps; E = sieve
F = coarse solids; $G_1$ (18 litre/pig) and $G_3$ (10 litre/pig) = denitrification basins;
$G_2$ (36 litre/pig) = aeration basin; H = aeration systems; I = mixed liquor used as drinking water and for flushing manure into the pit; J = volume built up before recycling starts;
K = transport to the land; L (210 litre/pig) = storage basin.

| | Organic Matter (% of feed OM) | |
|---|---|---|
| Feed | 100 | |
| Faeces and urine | 22 | |
| Sieved LM | 10 | (more than 50% removed with coarse solids) |
| ALM | 7.6 | (25% decomposition during treatment) |
| Recycled ALM | 4.8 | (4.5/7.2 x 100% = 62.5% recycled) |

If the digestibility of the organic matter in recycled ALM is assumed to be 40% of that of feed organic matter then about 2% can be saved on feed. In the period 45 to 100 kg the pigs get 190 kg feed. Thus 3.8 kg feed may be saved, or 3.8 x D.fl 0.50 = D.fl 1.90 per pig.

Against this possible saving on feed there is an extra investment of about D.fl 25 000 for 2 000 pig places, with annual capital and repair costs of D.fl 5 000. The extra cost for electricity is estimated at D.fl 400 per year. The extra annual cost means D.fl 3.20 per place, or D.fl 1.40 per delivered pig.

A clear drawback of treatment 2 is its complexity. Because of much higher rates in the processes, the possibility of temporary accumulations of ammonium, nitrite and nitrate because of failures in the system is more important than with treatment 1. Therefore the composition of the ALM should be controlled before recycling to the pigs. Just as with treatment 1 we can recycle mixed liquor from the storage tank to the pigs in case the mixed liquor in tank $G_3$ is temporarily unsuitable for recycling. To be sure of the quality of the mixed liquor in the storage tank L, this tank should be aerated intermittently eg controlled by a redox monitor.

Summarising: Cost comparison of treatment 2 with aerobic storage. Investment: extra investment D.fl 25 000 for 2 000 pig places. The costs per pig compare as follows:

| | | |
|---|---|---|
| Advantages: | less transport | D.fl 1.40 |
| | P and Cu saving | D.fl 1.30 |
| | feed saving | D.fl 1.90 |
| | total | D.fl 4.60 |
| Disadvantages: | extra N-loss | D.fl 0.70 |
| | extra yearly cost | D.fl 1.40 |
| | net profit | D.fl 2.50 per pig delivered |
| | or | D.fl 5.50 per $m^3$ liquid manure |

The greater net profit of treatment 2 compared with treatment 1 depends on realising the assumed feed value. We have done no feeding trials with mixed liquor or 'biomass' from a system like treatment 2.

In our opinion, feeding trials by Drepper et al. (1977) give no conclusive answer. These workers supplied LM aerated with a 10 days retention time but their mixed liquor still contained much ammonium nitrogen as they did not remove this by treatment. Addition of easily available carbon sources gave them only small increases of protein in the mixed liquor.

A further difficulty of interpreting their results is that the rations used did not have the same composition.

It is still advisable therefore to investigate, in a recycling trial with pigs, the feed value of ALM from a high loaded activated sludge system as described in treatment 2. That trial may also give information on the possibility of saving on the phosphate and copper addition to the feed.

## 5. TREATMENT 3: COMPOSTING OF LIQUID MANURE TOGETHER WITH STRAW

The development of a manure treatment system with no drawbacks to the environment has been the major aim of this system too.

Trials performed at the Experimental Station for Mushroom Cultivation have shown that mixtures of straw and liquid manure compost rapidly with temperatures up to 70°C. Only very limited amounts of ammonium nitrogen were transformed into biomass organic nitrogen compounds. A considerable loss of ammonia was noted which, especially when the piles were turned, gave rise to nuisance complaints. The typical pig manure odour however had disappeared after a short time. A considerable volume reduction has not been attained.

Before evaluation of the compost as a roughage for ruminants becomes interesting, the biomass production during composting should be improved, perhaps by working at a temperature of 50 to 55°C where the role of fungi is more important.

Theoretical considerations show that straw is a far from ideal carbon source for production of a biomass that may be used as a roughage. After composting the easily degradable carbohydrates are gone and only a small amount of biomass is formed instead. Besides, a large part of the compost, eg lignin will be indigestible to ruminants. Trials where the compost was used for mushroom cultivation gave lower or even no yields of mushrooms. Analysis showed however, that the compost still contained too much ammonium nitrogen for mushroom growth. We do not expect that in The Netherlands composting liquid manure together with straw will contribute substantially in solving the regional problems of manure surpluses.

## 6. NITROGEN, PHOSPHATE AND COPPER FROM PIG LIQUID MANURE ADDED TO AGRICULTURAL SOILS

When treatments 1 or 2 are used, then the amounts of N, P and Cu that have to be spread on agricultural land are decreased. The chance of air pollution and pollution of ground and surface water with N and P or damage to the soil because of copper accumulation will also be smaller. These advantages of treatments 1 and 2 are difficult to express in money and therefore were not included in the cost comparison. The following data may show their importance. Calculated are the amounts of N, P and Cu that are spread on the land with pig liquid manure when we have 25 pig places to the hectare:

| Treatment of LM before landspreading | N | P ($kg.ha^{-1}.year^{-1}$) as P | / as $P_2O_5$ | Cu |
|---|---|---|---|---|
| anaerobic storage | 70 - 200 | 73 | 167 | 3.2 |
| aerobic storage | 70 - 130 | 73 | 167 | 3.2 |
| treatment 1 or 2 | about 65 | 48 | 110 | 1.6 |

These data show that the amount of nitrogen that actually reaches the soil can differ widely. This is a consequence of differences in the nitrogen losses during storage and/or landspreading. For instance, injecting the liquid manure into the soil gives only very small losses, compared to sprinkling (volatilisation of ammonia).

With the treatments 1 and 2 the nitrogen loss,in the form of nitrogen gas, is completely harmless to the environment (loss by nitrification, denitrification). The nitrogen in ALM of treatments 1 and 2 is almost fully organic nitrogen, that will work more or less as a slow release fertiliser. As shown in the above data, about 1/3 less phosphate and half as much copper reach the soil in the case of treatments 1 and 2. As long as the addition of copper to the pig feed is indispensable for economic reasons, halving this addition will also halve the rate of copper accumulation in the soil.

## 7. CONCLUSIONS

1. The advantages of recycling aerated liquid pig manure (ALM) as 'drinking water' to pigs are mainly volume reduction and therefore lower transportation cost of liquid manure and the possible saving on the addition of phosphate and copper to the pig feed. A possible feed value of the organic matter in ALM may add to this. How far saving of phosphate and copper in the feed are possible in practice must be proven in further investigations.

2. If the supposed saving on phosphate and copper in the feed can be attained, then the loading of agricultural soils with P and Cu from pig liquid manure will decrease by 33% and 50% respectively.

3. Treatment 1, with a low loaded activated sludge system, offers more practical prospects than treatment 2, with a high loaded activated sludge system, because of greater simplicity and smaller risks. Besides, the supposed feed value of the organic matter in ALM of treatment 2 has still to be proven. The question remains whether the calculated net profit of the treatments offsets the risks of these methods of recycling.

4. Composting of pig liquid manure together with straw will at most offer a small contribution to solving the problem of regional surpluses of manure. It is likely that the compost will be of only moderate quality as a roughage for ruminants.

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DISCUSSION

M.R. Evans *(UK)*

In aeration system No. 1, what is the operating temperature or what is the dissolved oxygen level in the aeration tank? In our experiments in the laboratory at the West of Scotland Agricultural College, we find that if we are operating at ambient temperatures of say 15 to 20°C and 3% saturation, then we can achieve simultaneous nitrification/denitrification. We also get complete nitrification and denitrification so there is no ammonia and no nitrate left at the end of the system. This would be considerably cheaper than having to denitrify after treatment.

J.H. Voorburg *(The Netherlands)*

We are attempting to work at the temperature of the building - 18 to 21°C - and also at slightly lower temperatures. If you have sufficient retention time, you have simultaneous, and almost complete nitrification/denitrification in system No. 1. However, with this long retention time, the feeding value of the surplus sludge is very low. Therefore, our idea is that, if we want sludge with a higher feeding value, we should work with a high loading rate and a short retention time. We have not tried it, but we think that with this sort retention time the risk of insufficient nitrification or denitrification is increased and so we made the system more complicated - scheme No. 2. Here the aeration basin has a retention time of 5 days. We hope that during, this time, all the ammonia will be nitrified to $NO_2$ and $NO_3$. The ALM is mixed with the fresh manure for denitrification. For the sake of safety we have a second denitrification basin because nitrate is poisonous to the pig, so one needs to be careful.

J.S.V. McAllister *(UK)*

You say that little is known about the availability of copper in ALM, so would you, or anybody else, like to express an opinion?

J.H. Voorburg

We are optimistic about the value of the phosphate: we think it is available. I have no idea about the availability of copper. To find this out, it would be necessary to run an experiment.

L. Berthelsen *(Denmark)*

Do you prefer a temperature of 15 - 21°C in your aeration tank, or would you prefer it to be lower?

J.H. Voorburg

It depends where the aeration system is. If it is in a building, we have no problems. If it is outside, we have problems in winter and our experience is that it is better there to have bubble aeration than surface aeration.

L. Berthelsen

What do you consider to be the best temperature to get a good feedingstuff on average?

J.H. Voorburg

I think 20°C is sufficient. Do you agree Mr. Meijboom?

F.W. Meijboom *(The Netherlands)*

Yes - you do not need very high temperatures.

J.L. Woods *(UK)*

As you decreased the retention time the economics seemed to improve - you are getting more protein into the feed. You have not included energy in your calculations, but you would also have more energy left in the material. Have you considered further reducing the retention time? This might introduce pathogen and parasite problems; but, if you were to go to the liquid system, increasing the temperature as well as shortening the retention time, do you not think that the economics might improve?

There are many constraints on the pig diet such as fibre and energy density. In our work on the subject, we have had to use a least-cost-ration programme in order to check that we were not breaking any of these constraints and to allow for the full range of alternatives in the feed mix. For example, if you have too high a fibre level in what you are putting in, you can possibly compensate for this by using maize instead of barley. How do you deal with that problem?

J.H. Voorburg

I have one answer to both questions. Because it was our aim to develop a practical system that could be used on the farm, the system could not be too complicated. In practice, you cannot work on the farm with different rations - there is one type of concentrate which is available for fattening pigs. In experiments, you can make variations but in practice it is very difficult. So the system has to be simple and must work with the ration that the farmer can buy.