Research Stimulus Fund

Final Report

Assessment of a solid-liquid separation system for pig manure and the influence of pig diet on composition of solid and liquid fractions

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Please tick below the appropriate area on the research continuum where you feel this project fits

BASIC/FUNDAMENTAL ————————————————————> APPLIED/PRE COMMERCIAL

Key words: Pig manure composition, solid-liquid separation, pig diet, manure management
1. **Rationale for Undertaking the Research**

The Nitrates Action plan imposes restrictions on the use of pig manure on intensive grassland. Separation of manure into solid and liquid fractions gives the possibility of utilising the two fractions in different situations (e.g. the solid fraction which is rich in phosphorus (P) might be used on tillage land and the liquid which is relatively rich in nitrogen (N) might be used for grassland or even on growing cereal crops). In addition, it would allow the liquid fraction to be applied at a higher rate to land in the vicinity of the pig unit and the solid fraction could be transported more economically to land further away where nutrient requirements are higher. However, not much is known about the practical and economic benefits of solid-liquid separation for both pig and tillage farmers.

In addition, the variable composition of pig manure and the generally low nutrient content, limits the attractiveness of pig manure as a crop fertilizer. Reducing the manure volume by reducing water wastage and/or by optimising the water to meal ratio on pig units, would increase the dry matter content of pig manure. Manure of high dry matter (DM) has many advantages. It will occupy less storage space, cost less to transport and spread and has more nutrients per unit weight/volume, thereby increasing its value as a fertilizer.

The amount of nutrients excreted in manure (total per pig produced) can be minimised by feeding diets which are formulated to more closely match the nutrient requirements of the pig at each stage of growth. Reduced surpluses of N and P in the diet will result in an overall reduction in manure nutrients and also a redistribution of nutrients between the faeces and urine. Low nutrient diets of higher digestibility will result in lower urinary excretion of N and P (water soluble urea and soluble P) and proportionately less water-soluble nutrients in the total excreta. This will also have implications for the distribution of N and P in the solid and liquid phases of separated manure. Other dietary factors include high fibre levels in diets which result in increased N excretion in faeces and reduced N excretion in the urine. The aim here was to determine how such dietary adaptations could be combined to minimize nutrient excretion and manure volume, and to determine their influence on solid-liquid separation.

2. **Research Approach**

**Task 2) Evaluation of farm scale manure separator(s):**

The performance of a fixed decanter centrifuge for solid-liquid separation of pig manure was monitored and compared to other mechanical separators. In addition, tests were conducted to determine the effect of dietary levels of crude protein (CP; 170-231 g/kg), digestible (d)P (1.44 -3.40 g/kg) and crude fibre (35-7 g/kg vs. 65-7 g/kg), manure DM
(1.6-7.7%) and chemical pre-treatment of manure (dose of coagulant: a liquid mixture of Polydadmac and Poly Aluminium Chloride; dose of a flocculant: a high molecular weight/highly cross linked Cationic Polyacrylamide) on separation efficiency. To determine separation performance, DM, N and P were analysed in the raw manure as well as the separated solid and separated liquid fractions. The costs of manure separation were modelled.

Field studies conducted over two-year were carried out where separated liquid (Task 3) and solid fractions (Task 4) were applied to crops in addition to chemical fertiliser. Crop nutrient uptake and crop and grain yields were measured. The application rates for the respective tasks were:

**Task 3) Response of growing cereals to application of liquid fraction from separated pig manure:**
15,000, 30,000 and 45,000l/ha of separated liquid fraction (4.04g/kg N and 0.18g/kg P) were applied to winter wheat fields in the spring.

**Task 4) Response of growing cereals to application of solid fraction from separated pig manure:**
0, 4, 8 and 12t/ha of separated solid fraction (7.99g/kg N and 6g/kg P) were applied to spring barley and maize fields in autumn.

Several experiments were conducted to determine the effect of pig diet composition on manure output. Nutrient digestibility, N excretion and manure output were analysed. Metabolism crates were used for nutrient balance studies. Urine and faeces collections were pooled in original excretion ratios. Manure samples were separated into liquid and solid fractions using a separating-cloth. The following experiments were conducted:

**Task 5) Effect of manure separation on ammonia emissions from pigs:**
Diets varying in dietary CP concentration (150/200g/kg) and sugar beet pulp (SBP; 0/200g/kg) inclusion (to increases dietary fibre) were fed to male finisher pigs.

**Task 6) To assess the effect of diet on the partitioning of N and P into the solid and liquid fractions & 7) Effect of diet on manure output from pigs:**
Diets varying in dietary CP concentration (150/200g/kg), cereal type (barley vs. wheat) and P level (0.35/0.55g/kg) were fed to male finisher pigs.

**Task 8) Survey of dry matter and nutrient content of pig manure:**
A manure survey was carried out on a sample of 11 farms to give an indication of current pig manure composition on Irish pig farms. Samples were taken from under-slat storage tanks and analyzed for pH, DM, N, P and potassium (K).

**Task 9) Investigation of water use on pig farms:**
Water meters were installed on the Moorepark pig unit and read monthly for two consecutive years. A model was developed to determine water usage and manure volume
for a 100-sow integrated unit. Guidelines to reduce water usage and manure volume were developed.

Task 10) Study of factors affecting the economics of manure handling and processing: The costs of manure separation, manure haulage and spreading on land were modelled and compared. The economic implications of water management were also modelled.

3. Research Achievements

Task 2) Evaluation of farm scale manure separator(s):

The fixed decanter centrifuge was found to produce solid fractions of up to 35% DM outperforming other mechanical separators tested. The centrifuge proved to have a good performance regarding P removal, but its effect on N removal was poorer. The annual costs of separation with a fixed decanter centrifuge were estimated at €123,067 (€11.7 per m³ of manure) for a 500 sow integrated pig unit. Decreasing dietary crude protein and phosphorus (from 216-31g/kg CP and 3.4g/kg dP to 170-3g/kg CP and 1.44-74g/kg dP) reduced N and P excretion and increased DM and N separation efficiency. Increasing fibre (from 35-7g/kg to 65-67g/kg) increased N and P manure separation efficiency. Increasing doses of a coagulant (from 0 to 2.5ml per 500ml of manure) and a flocculant (from 0.1 to 0.4% flocculation solution added) during the separation process increased the separation efficiency of P and DM.

Task 3) Response of growing cereals to application of liquid fraction from separated pig manure:

Spring application of the separated liquid fraction of pig manure in addition to a chemical fertiliser resulted in an additional crop uptake of 58 kg N/ha by winter wheat. Nitrogen use efficiencies for separated liquid ranged from 23 to 56% while inorganic N use efficiency levels were higher ranging from 58 to 73%.

Task 4) Response of growing cereals to application of solid fraction from separated pig manure:

Autumn application of the separated solid fraction of pig manure in addition to a chemical fertiliser increased grain yield and crop nitrogen uptake. However, separated solid application also significantly increased crop lodging resulting in reduced yields.

Task 5) Effect of manure separation on ammonia emissions from pigs:

Reducing dietary CP (from 200 to 150g/kg) decreased N excretion and ammonia emissions. Increasing dietary fiber by including SBP (200g/kg) in the diet reduced ammonia emissions and increased the dry matter of raw manure. However, SBP inclusion had no effect on the dry matter of the separated manure fractions.

Task 6) To assess the effect of diet on the partitioning of N and P into the solid and liquid fractions:

Substituting barley for wheat in the diet and reducing CP (from 200 to 150g/kg) reduced total N excretion and thereby the N concentration in the separated manure fractions.
Barley-based diets increased faecal N excretion (compared to wheat based diets), however there was no effect in partitioning organic-N to the separated solid fraction.

7) Effect of diet on manure output from pigs:
Feeding reduced CP (150g/kg) barley-based diets reduced pH in the ileum, caecum and in unseparated manure, which would be expected to reduce ammonia emissions from pig manure.

Task 8) Survey of dry matter and nutrient content of pig manure:
Based on the units surveyed, mean manure composition values were estimated at: dry matter: 48.0kg/m³ (SD ± 3.8), N: 2.4kg/m³ (SD ± 1.3), P: 1.3kg/m³ (SD ± 1.4), K: 2.3kg/m³ (SD ± 1.5), and pH: 7.55 (SD ± 0.58).

Task 9) Investigation of water use on pig farms:
At Moorepark water use was approximately 17.34 m³/sow and progeny/year. An interactive model in Excel was developed to predict water usage and manure volume for pig farms. This tool can be used to model management practices aimed at reducing manure output per sow.

Task 10) Study of factors affecting the economics of manure handling and processing:
The most economic manure management options were found to be haulage and spreading on land. Haulage by tractor is more economical if spreadlands are close to the unit (up to 14 km for manure of 4.8% DM), whereas haulage by truck is more economical if spreadlands are more distant. Manure separation is currently not cost-effective. With regard to water management as a means of reducing manure volume and haulage costs, reducing the water:meal ratio of feed presented to pigs (without affecting animal welfare) was calculated to be the management strategy that delivered the most cost effective immediate benefit.

4. Impact of the Research

The fixed decanter centrifuge was found to be the most effective separator tested, producing solid fractions of the highest DM content. It proved especially effective at removing P from the liquid fraction, but was less effective at removing N. The separation efficiency could be enhanced by reducing dietary crude protein and phosphorus and by increasing the fibre level of the pigs’ diet. Increasing the dosage of coagulant and flocculant also improves separation efficiency. However, increasing the DM% of pig manure leads to a reduction in P separation efficiency. Nonetheless, manure separation using a decanter centrifuge is currently not cost effective. Therefore, solid-liquid separation of pig manure is not expected to be widely used by Irish pig farmers in the immediate future.

Spring top-dressing of the separated liquid fraction of pig manure to a winter wheat crop proved to be a useful, cheaper alternative to chemical N application. The liquid fraction of separated pig manure can be used as a partial replacement for chemical fertilisers. Solids may be used a N source or possibly as a soil conditioner for long standing cereal rotations.
where additional organic matter is necessary. However due to its high P content, this will limit application rates.

Diets high in sugar beet pulp were found to reduce ammonia emissions from pig manure. However, dietary manipulation was ineffectual in improving the separation efficiency of either P or N.

Results from a manure survey of pig units suggests that N concentrations in pig manure have decreased (to 2.4kg/m$^3$ in this limited survey) in the last decade and are lower than the estimated (4.2kg/m$^3$) in S.I. no 610 (2010) on which current N application rates are based. In addition, rapid on-farm tests (Argos Nitrogen Meter, Quantofix N-Volumeter and Hydrometer) gave accurate estimates for DM and N values of pig manure.

The water use model, developed in task 9, provides Advisors and pig farmers with a useful tool to predict manure volumes produced on pig units and simulate changes in management practices that might help in this regard.

Studies on the cost of manure handling and transport show that direct spreading on land is, at the moment, the most cost-effective treatment for pig manure. In order to reduce manure volume and handling costs, our investment appraisal suggests that the most immediate cost effective method is to reduce the water: meal ratio (without compromising pig welfare) where pigs are liquid fed. Installing wet/dry feeders is an attractive option which can reduce manure volumes further with the payback taking longer.

5. Exploitation of the Research

Four students were trained. Two were trained up to PhD level and two up to Masters level. Information regarding crude protein and P levels in pig diets will be used in formulating commercial pig diets with reduced environmental impact. Separation, although not currently economically viable, may be important in the future.

6. Summary of Research Outputs

(a) Intellectual Property applications/licences/patents
None

(b) Innovations adopted by industry
Reduced P and crude protein diets

(c) Number of companies in receipt of information
The information from this project was disseminated to 320 pig farms during the project via pig manure workshops, the annual pig conference, information on the Teagasc website
and newsletters. Likewise information to other companies was disseminated freely via newsletters, publications and the Teagasc website.

(d) Outcomes with economic potential
1. Four students were trained. Two were trained up to PhD level and two up to masters level
2. Knowledge generated by this project will enable pig producers and tillage farmers make informed decisions regarding dietary manipulation, water usage and manure separation so that their costs of production can be reduced.

(e) Outcomes with national/ policy/social/environmental potential
Information on solid-liquid manure separation and on optimum crude protein and P levels in pig diets was generated, which can help to underpin initiatives at all levels above.

(f) Peer-reviewed publications, International Journal/Book chapters.


(g) Scientific abstracts or articles including those presented at conferences


(h) National Report
None

(i) Popular non-scientific publications


http://www.teagasc.ie/pigs/articles/farming_independent/2007/Pig_Manure_as_a_Low_Cost_Fertiliser07.pdf


12. Teagasc pig newsletter (2006), 9(1). This entire issue was dedicated to manure management.


(j) Workshops/seminars/open days at which results were presented (excluding those in (g))


7. Permanent Researchers

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<th>Institution Name</th>
<th>Number of Permanent staff contributing to project</th>
<th>Total Time contribution (months)</th>
<th>Average time contribution per permanent staff member</th>
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8. Researchers Funded by RSF

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<td>Contract Researchers</td>
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<td>Other</td>
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9. Postgraduate Research

Total Number of PhD theses: 2

Please include authors, institutions and titles of theses and submission dates. If not submitted please give the anticipated submission date


Total Number of Masters theses: 2

Please include authors, institutions and titles of theses and submission dates. If not submitted please give the anticipated submission date


10. Project Expenditure

Total expenditure of the project: €442,506

Total Award by RSF €394,250

Other sources of funding (Teagasc Grant In Aid) €48,256

Breakdown of Total Expenditure

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<td><strong>442,505.97</strong></td>
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11. Future Strategies

The results of this study led to further investigation of alternative manure treatment options, such as anaerobic digestion. Also further treatment of the separated solid and liquid fractions was studied. The liquid fraction was denitrified by means of Integrated Constructed Wetlands and Woodchip filters. The solid fraction was composted. Based on the findings of the present project pig advisers are currently advising pig farmers not to use solid-liquid separation. Pig producers are advised on how to minimize water use in order to reduce manure volume and on dietary modifications to reduce N and P excretion.

12. Industry Collaboration

An intensive collaboration with Glanbia was established at the start of the project. Glanbia took part in the preparation of the project and shared their expertise during the
implementation of the project. They also allowed the use of their farms for the collection of data. However, as the project progressed Glanbia decided to withdraw from the project. R.J. Mooney supplied a Geotube separator for experiments.