ADMIXTURE OF CEREAL ASH INTO LIQUID BIOGAS DIGESTATE

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1 INTRODUCTION

The increased use of biomaterials for combustion is generating large amounts of ash. In most cases, e.g. incineration of straw and grain, bottom ash contains small amounts of heavy metals, but significant amounts of phosphorus (P) and potassium (K). This gives the bottom ash from combustion of straw and grain good qualities as a fertiliser. The use of the bottom ash as a fertiliser also faces some difficulties, including problems in spreading the ash with high accuracy (Marmolin et al., 2008).

Biogas plants are becoming increasingly common in Sweden. They produce considerable amounts of digestate, a liquid fertiliser with a high content of nitrogen (N) but lower contents of P and K. High quality digestate can be spread on farmland today. The spreading equipment for liquid fertilisers gives the same accuracy as current spreaders for mineral fertilisers (JTI et al., 1994).

This study investigated techniques and systems for blending and spreading liquid digestate with ash. The amounts of N, P, K and heavy metals applied with different digestate-ash mixtures were calculated. Different types of ash, liquid digestate and mixtures of ash and digestate were analysed at laboratory scale with regard to important properties, including the influence of ash admixture on ammonia emissions and mixture pH. Different properties of ash/digestate mixtures were also tested at pilot scale in order to identify a homogeneous admixture rate with no sedimentation. A cell wheel for liquid manure was tested for adding the ash to a flow.

2 MATERIALS AND METHODS

2.1 Laboratory scale

Three different types of ash (from combustion of oats, straw and wood pellets) and liquid digestate from two biogas plants were included in the study. The ash samples were analysed for physical and chemical qualities including bulk density, fractionation, water content, volatile solids, and CaO, K, Na and P content (Table 1). The digestate samples were analysed for nutrient content, heavy metal content and pH (Table 2). The feeding effluent for the two biogas plants consisted of offal, food waste, organic household waste, sludge from fat separation in large-scale kitchens and clover/grass silage.

TABLE 1 **Results of analyses on ash samples**

Parameter	**Oat ash (% dm)**	**Straw ash (% dm)**	**Wood pellet ash (% dm)**
Dry matter	99.5	99.3	92.0
Calcium oxide, CaO	3.8	7.3	26.3
Potassium, K	9.7	4.7	6.1
Sodium, Na	0.1	0.2	0.4
Phosphorus, P	7.0	1.0	1.0

TABLE 2 **Results of analyses on digestate samples**

Parameter	Content	Units
Dry matter	2.5	%
Total nitrogen, N	3.0	kg/tonnes
Ammonium N, NH_4-N	2.0	kg/tonnes
Phosphorus, P	0.3	kg/tonnes
Potassium, K	0.6	kg/tonnes
pH	8.3	

The solubility of the ash samples in water and digestate was analysed. The pH was also measured at different times after ash admixture into digestate.

The potential for increased ammonia emissions was determined by measuring the equilibrium concentration for different admixtures of ash (0, 1, 3 and 5 %-vol/vol) into digestate. The micrometeorological method used (Svensson, 1993) involved exposing four passive diffusion samplers to the ammonia emissions (Figure 1).

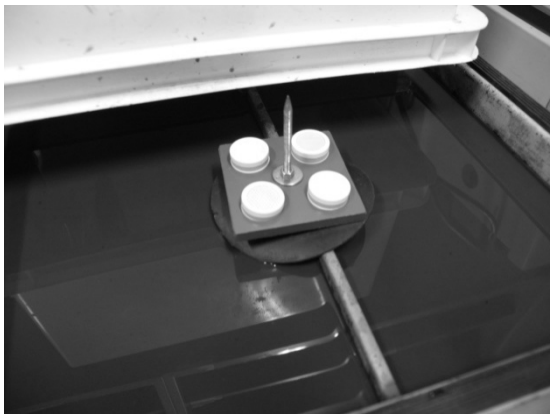

FIGURE 1 **Four passive diffusion samplers placed above the ash-digestate mixture.**

2.2 Pilot scale

Batch-wise admixture of oat ash (0, 1, 3 and 5%-w/w) to digestate was conducted using a tank (1500 litres) and an unattached stirring pump. The admixtures were stirred for two minutes and then the tank was emptied at a flow rate of 0.5 m^3/minute to imitate spreading of slurry. Avoiding separation was the main aim of the procedure. A cell wheel was tested to investigate the possibility of adding the ash into a flow of digestate.

2.3 Calculations

The plant nutrient value and heavy metal content in the different ash-digestate admixtures were calculated in order to give recommendations on frequency of application to a particular field. These calculations used the Swedish limit values (g/hectare and year) for application of heavy metals and phosphorus (P) to arable land (SNFS, 1994) and the application rate was set to 30 tonnes/hectare. The content of heavy metals in the ash used in the calculations represented average values and were taken from Marmolin et al. (2008). The contents were 20 mg Ni/kg dm, < 0,5 mg Cd/kg dm and 345 mg Zn/kg dm.

3 RESULTS AND DISCUSSION

3.1 Laboratory scale

Only 7% of the oat ash dissolved in water, 3.5% of the straw ash and 12% of the wood pellet ash, indicating that the stirring is very important to achieve homogeneity if the admixture is to be spread in the field. Additions of 3-10% by weight of ash into the digestate gave a clear increase in pH, but there was no change in pH over time.

The equilibrium concentration of ammonia was on average 262 ppm for the digestate and 82 ppm (1%-v/v ash), 90 ppm (3%-v/v ash) and 83 ppm (5%-v/v ash) for the ash-digestate mixture. When oat ash was mixed into digestate, the equilibrium concentration of ammonia did not increase. In fact, ammonia concentrations were lower when ash was added, possibly because of ammonia binding to some metal ions.

3.2 Pilot scale

Batch admixture of ash into liquid digestate was unsuitable, because the majority of the ash settled and formed sediment in the bottom of the tank, despite efficient stirring (Table 3). For continuous dosage of finely pulverised ash into digestate, the cell wheel made for dosage of liquid manure worked as planned. However, for dosage into a flow under pressure a sluice is necessary to prevent digestate being pressed up into the ash container. Admixture of ash into solid digestate is another possible alternative, e.g. during augering of the solid fraction from a digestate separator to a store.

TABLE 3 **Results of analyses for the sedimentation study**

Mixture	**Sedimented ash (%)**	**Ash in drained admixture (%)**
Only digestate	0	0
1%-w/w ash in digestate	61	39
3%-w/w ash in digestate	38	62
5%-w/w ash in digestate	41	59

3.3 Calculations

Digestate and oat ash with the properties presented in Table 1 were used in the calculations. The oat ash contained 71 kg P and 98 kg K per ton. The content of Ni, Cd and Zn in the ash limited the admixture rate. With 5% admixture of ash into digestate and with an application rate of 30 tonnes per hectare and year, application should not be repeated on the same field more often than every fifth year in order to avoid exceeding the limits for application of trace elements and P. With less ash added or other types of ash, application could be more frequent.

4 CONCLUSIONS

Only a small proportion of the ash types tested dissolved in water, resulting in a high sedimentation rate in the liquid digestate. Therefore admixture of ash may be more suitable for solid digestate than for liquid.

The content of abrasive material in the ash was so high that the risk of wear to pumps, pipes and other parts of the spreading equipment was rather high. It is therefore best if the ash is added as late as possible to equipment for spreading on arable land.

There is no risk of increased ammonia emissions as long as the mixture does not contain more than 5% by volume of ash. Equilibration calculations indicate that ash types with different composition might give increased ammonia emissions. The proportion of ash added per m^3 digestate and the frequency of spreading to the same field must be restricted in order to avoid accumulation of trace elements and P in soil.

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REFERENCES

JTI, SLU, SMP 1994. Teknik och metodik för typprovning av konstgödsel- och stallgödselspridare: sammanfattande slutrapport av projekten i TYP93-programmet, som utförts på uppdrag av Statens jordbruksverk. Typ 93 programmet/Sveriges lantbruksuniversitet, Institutionen för lantbruksteknik, Jordbrukstekniska institutet, Statens maskinprovningar. Uppsala, Sweden. 143 p.

Marmolin C, Ugander J, Gruvaeus I, Lundin G 2008. Aska från halm och spannmål – kemisk sammansättning, fysikaliska egenskaper och spridningsteknik. JTI-rapport Lantbruk & Industri nr. 362 Hushållningssällskapet Skaraborg, Energigården och JTI – Institutet för jordbruks- och miljöteknik. Uppsala, Sweden.

SNFS 1994. Kungörelse med föreskrifter om skydd för miljön, särskilt marken, när avloppsslam används i jordbruket. SNFS 1994:2 MS:72, Miljöskydd, Statens naturvårdsverks författningssamling, Statens naturvårdsverk. Stockholm, Sweden.

Svensson L 1993. Ammonia Volatilization from Land-Spread Livestock manure. Effects of Factors Relating to Meterology, Soil/Manure and Application Technique. Dissertation. Department of Agricultural Engineering, Swedish University of Agricultural Sciences. Uppsala, Sweden.