Energy generation from mechanically separated pig slurry –Incineration and anaerobic digestion

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Abstract
The main objective of this study was to determine the potential for energy generation from the dry matter rich(DMR) fractions currently produced by mechanical separation at Danish pig farms. One of the reasons for the study is the farmers demand for alternative outlet for their DMR fractions currently(2010) 86 % of the DMR are anaerobically digested and 1 % is incinerated. The samples were collected at farms 17 farms using four different types of separation technology. The Biochemical methane potentials (BMPs) were recorded after a 300 days long batch experiment. The study showed that methane production from DMR fractions obtained from screw presses were significantly($p<0.05$) lower than the BMPs from the shaking filters and the decanter centrifuges. The mean maximum energy yield was 2.32 and 5.26 MJ/kg from anaerobic digestion and incineration, respectively. No significant correlation between lignin, hemicellulose and cellulose content in the volatile solids (VS)were found.

Introduction
Currently 90,000 t of manure fibre is produced annually from separation technology which corresponds approximately to 3% of the annual Danish animal slurry production. Dry-matter-rich (DMR) fractions obtained from animal slurry separation are great potentials as co-substrate to enhance biogas production by concentrating organic material contents, as prime feedstock such as fresh animal slurries and industrial organic waste have high contents of water caused by cleaning water, high amount of urine in pig slurry and blood etc. in industrial organic waste (Møller et al., 2007) [1]. However, manure fibres from separation may have lower digestibility and methane potentials, as larger fractions of relatively easily digestible organic pools are separated into liquid rich fractions, whereas refractory carbon pools such as lignocellulosic fibres i.e., lignin, cellulose and hemicellulose are moved to DMR fractions. Thus, incineration would be a more suitable energy conversion method and therefore Danish power plants have shown interest in incinerating DMR. It has been estimated that within a few years incineration of manure fibre could replace 3.6 PJ of coal energy. Nevertheless, direct incineration of DMR has been an on-going issue due to high moisture in DMR which may result in low net energy value or pre-treatment of DMP prior to incineration. It has been shown that lignin concentration in volatile solids (VS) can be used to predict the BMP in animal manure and energy crops[2].
The aim of the study was to determine the amount of energy that can be obtained from the DMR fraction from separated pig slurry based on currently produced manure fibres at commercial plants in Denmark. This study focuses on the use of DMR fraction obtained from pig slurry separation as either fuel or as feed in a biogas plant. Analyses were carried out on the wet DMR fraction. Assessment of refractory carbon pools of DMR applying Van Soest characterisation was performed focusing on lignocellulosic fibre concentration. BMP were determined by batch fermentation experiments.

Materials and Methods
The DMR fractions from animal slurry separation used in the study were collected in April-June 2010 from 17 of 33 commercial separation plants operating at Danish pig farms. The samples are representative for the samples currently produced in Denmark and show the variability of the DMRs currently available to biogas and incineration plants in Denmark. Four different types of separators were used; the pig farms were divided into two groups, one group mainly having sows and the other group having sows as well as pigs from piglets to finishing pig.

Table 1 − Origin and treatment of the samples of manure fibre from livestock farms

Sample ID	Type of separation[a]	Origin of the slurry treated
1,2,4,6	SI, SP, PO	Sows, piglets and finishing pigs
3	SI, SP, PO	Sows
5	SI, SP, PO	Sows and piglets
7,8,11	SP	Sows, piglets and finishing pigs
9	SP	Finishing pigs
10	SP	Sows
12	SF	Sows, piglets and finishing pigs
13	SF	Piglets and finishing pigs
14	SF	Sows
15,16,17	DC	Sows

[a] DC= decanter centrifuge, SF= shaking filter, SI=sieve, SP= screw press, PO= polymers added

The DMR fractions were sampled at the outlet of the separator by collecting five subsamples, giving a total volume of 8-10 l. The samples were homogenised upon arriving to the laboratory and one subsample was taken for test of the calorific value, the rest of the samples were stored at -18 ˚C thawed at room temperature prior to analysis.

The dry matter (DM) concentration and ash content were determined according to DS/EN 14346[5] and DS/EN 12879[6], respectively. Measurements were carried out in triplicate.

Gross calorific value (GCV) was determined using a Parr 6300 calorimeter (Parr instrument company, IL, USA) in accordance with DIN 51900 [3]. Single measurements were carried out.

BMPs were determined according to VDI 4630[2] using 1.0 L batch digesters for 300 days. Inoculum was obtained from Fangel Biogas plant, which operates at 37 ˚C and is fed a mixture of 20 % organic waste and 80 % animal slurry.

The energy yield for the anaerobic digestion is calculated as the amount of methane produced multiplied with the GCV of methane. The energy yield from incineration is given as GCVs of the DMR fractions.

Neutral detergent fibre (NDF) was determined according to Mertens et al. [7]. Acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to ISO standards [8]. Hemicelluloses, cellulose and lignin were assessed in accordance with Van Soest characterisation [9, 10] using the results of NDF, ADF and ADL analyses. Hemicellulose was determined as the difference between NDF and ADF and cellulose by subtracting ADL from ADF.

Statistical analysis was carried out using Graphpad Prism®, Graphpad software inc. ANOVA analysis were applied to test if the mean values are equal.

Results and discussion

The mean content of lignocellulosic fibers in the volatile solids fraction was 78.9 % with a standard deviation of 6.9 %. The ratio between lignin, hemicellulose and cellulose is in the same range as previously reported by Triolo et al. (2011) [2].

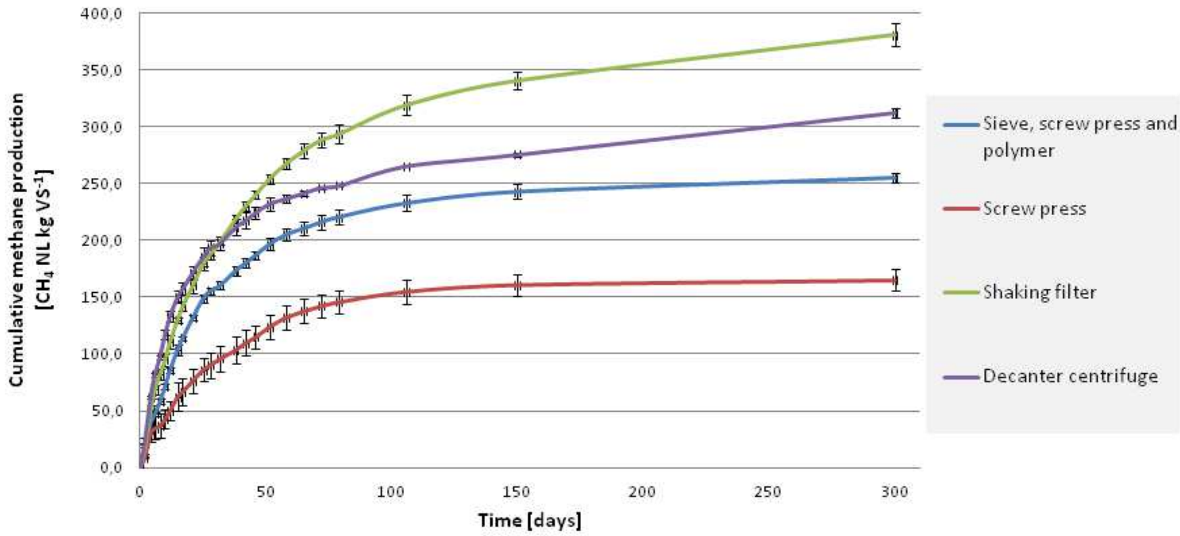
Table 2 -Standard error given in brackets. Min–max = the lowest and highest measured value

	Unit	Lignocellulose	Lignin	Hemicellulose	Cellulose
Fiber content	[% of VS]	78.9(6.9)	16.9(4.3)	32.6(5.5)	29.3(5.2)
Min-max	[% of VS]	68.5-93.7	11.9-26.8	24.4-41.3	18.4-37.3

The study shows that there is a large variation in BMPs for the DMR fractions from 89 CH_4 NL kg VS^{-1} in sample No. 9 to 401 CH_4 NL kg VS^{-1} in sample No. 15. The BMPs from DMR fractions obtained from screw presses were significantly($p<0.05$) lower than the BMPs from the shaking filters and the decanter centrifuges, this result would be due to the larger content of small particles in DMR fractions. BMPs from the shaking filters and the decanter centrifuges [11] yields higher biogas production[12,13]. There is a non-significant($p=0.07$) trend that adding the sieving and polymer addition steps to the screw press increases the BMP.

Around 10 % of the DMR fraction (m/m) was converted to biogas and the methane concentrations were 56 - 65 % in the biogas. The maximum energy yield from the anaerobic digestion was 2.32 MJ/kg DMR fraction on average from the batch experiment, but due to shorter operation time currently used at Danish biogas plants(≈ 25 days)only about 50 % of this energy would be produced.

Figure 1- Cumulative methane production of representative samples(sample 3, 7, 13 and 16)



There are no significant difference between the BMP for DMR fractions from farms with only sows and farms that have sows as well as piglets and finishing pigs. No significant correlation between fiber composition(relative content of hemicelluloses, cellulose and lignin in VS) and energy yield was found using linear and multilinear regression.

Table 3 –**Biochemical Methane Potentials(BMP,) from the different seperataion methods**. **Standard error given in brackets. Min–max = the lowest and highest measured value. Means followed by the same letter indicate the means are not significantly different from each other (p<0.05)**

	Units	SI, SP, PO	SP	SF	DC
Average BMP	**[CH_4 NL kg VS^{-1}]**	258a,b (48)	187a (86)	325b,c(68)	344c(50)
Min-max	**[CH_4 NL kg VS^{-1}]**	193-323	89-264	250-381	313-401

The energy yields from combustion show a large variability from 3.74 to 7.20 MJ kg^{-1} fiber. There are no significant(p>0.05) difference between the means of the energy yields between the different separator types. No significant correlation between fiber composition and energy yield was found using linear and multilinear regression.

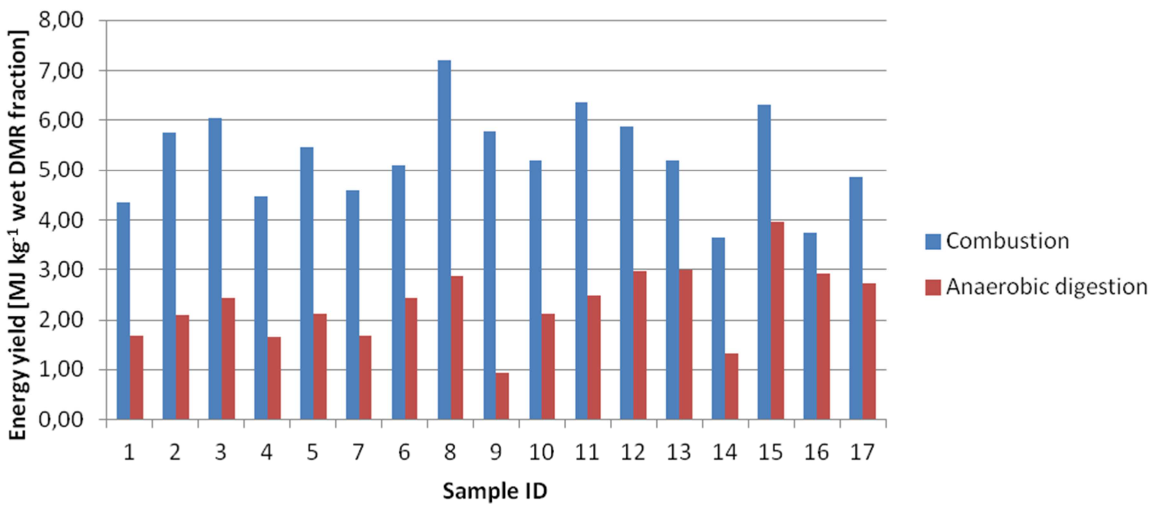


Figure 2- Energy yield of the 17 samples from incineration and anaerobic digestion

The average energy yield from the incineration was 5.26 MJ/kg DMR fraction. The ash content in the DMR fractions was between 1.8 and 10.0 %.

The advantages of incinerating the DMR fractions are a higher energy yield than anaerobic digestion and the ash produced is easy transportable which can be used as an ingredient in phosphorus fertilizers. Due to the high water contents of the DMR fractions a co-substrate has to be used to be able to incinerate most of the DMR fractions, and the flue gas has to be monitored and possibly cleaned to meet the demands set in regulation. Furthermore, the loss of plant nutrients during incineration also has to be taken into account, when deciding whether to use anaerobic digestion or incineration.

Conclusion

The study shows that methane production from DMR fractions obtained from screw presses were significantly lower than the BMPs from the shaking filters and the decanter centrifuges. When incinerating the DMR fractions, the type of separator did not have a significant impact on the energy yield obtained. The mean maximum energy yield was 2.32 and 5.26 MJ/kg wet DMR fraction from anaerobic digestion and incineration, respectively. No significant correlation between energy yield and lignin, hemicellulose and cellulose content in the VS were found.

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