Characterisation of most relevant feedstock for biogas and bioethanol production in organic farming

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Abstract

Bioenergy production from local bioresources has a great potential. It is important to reduce dependency on fossil fuels and decrease green house gas emission in organic agriculture (OA). Both biogas and bioethanol can be produced in OA and significantly contribute to the sustainability of organic farms.

Soil fertility is the basis for OA: it has been of concern that the fertility might decline if most of the organic residues were converted into energy and only effluent from anaerobic digestion process was recycled. However, by intelligent management of organic residues and crop rotation it is possible to avoid decrease of soil fertility and at the same time produce renewable energy.

The presented study is part of the BioConcens project (http://www.bioconcens.elr.dk/uk/). This study is focused on characterisation of relevant feedstock for co-production of biogas and bioethanol within organic farming.

Clover grass silage, dry clover grass and dried grass from meadows were selected. Theoretical biogas and bioethanol yields were calculated. Biogas potential batch tests were performed for each substrate individually and the obtained yield in the lab was compared to the theoretical one. It is expected that the on-farm production of the bioenergy would improve not only sustainability of such a farm but as well economics. Further investigations will be carried out. add some results

INTRODUCTION

The production of biofuels in organic agriculture (OA) can reduce its dependency of fossil fuels and decrease greenhouse-gas emission; consequently it might increase the sustainability of organic farming. Biorefinery concept based on co-production of biogas, bioethanol and protein fodder in organic farming is developed within BioConcens project (Biomass and bioenergy production in organic farming – consequences for soil fertility, environment, spread of animal parasites and socio-economy; http://www.bioconcens.elr.dk). The project is part of research programme called: "International research cooperation and organic integrity", which was commenced for a period 2006-2010. It is coordinated by DARCOF (The Danish Research Centre for Organic Farming). The whole programme, with acronym DARCOF III, consists of 15 projects (http://www.darcof.dk/research/darcofiii/index.html).
Anaerobic digestion based on animal manure and energy crops is well known technology. Due to utilisation of manure, the methane emission from livestock production is diminished. Production of heat and electricity from biogas will reduce fossil fules usage; consequently GHG emission will be decreased. Furthermore, anaerobic digestion process improves nutrients utilisation and diminishes odour problem (Braun and Wellinger). Even though biogas technology is known as low land use and relatively low cultivation and soil-related emission, large storage facilities are required for biogas, moreover, compression of biogas is required for use as fuel (Frederiksson et al., 2006).
Biogas can be produced from any organic-carbon rich by-product. Commonly, grown in OA clover grass has a great potential as a raw material for anaerobic digestion (Jørgensen et al., 2005). Co-fermentation of clover grass with animal manure or whey permeate can be one of the examples for efficient biogas production in OA.

Bioethanol from starch can be a substitute for diesel or gasoline (Fredriksson et al., 2006), and protein rich effluents from whey-based fermentations will be valuable product for organic pig production.

Biogas can be further utilized to produce heat electricity for organic farms (Persson et al., 2006). Bioenergy from organic sources should not negatively influence the carbon and nutrients cycle, therefore intelligent management of organic residues and crop rotation is necessary. BioConcens project aims of design and evaluating a combined concept for biomass and bioenergy production in OA, while considering soil fertility. It is expected that the on-farm production of the bioenergy would improve not only sustainability of such a farm but as well economics.
The aim of the study was to investigate which kind of the feedstock would be favourable either to produce biogas or bioethanol to supply organic farm with necessary heat and power.

METHODS

Raw materials

Three different biomasses were selected:

- dry grass from meadows – the grass was harvested in 27-06-2007 from a meadow, in which in 2004 the hudegræs and Timotek was sown, no further changes were done in the meadow since that time
- dry clover grass (mixture of white clover grass, red clover grass separated on the field – Ø-45, **www.dlf.dk**),
- clover grass silage - mixture of white and red clover grass and rye grass, cut in November 2007 and ensilaged in bales – Ø-45, **www.dlf.dk**)

The total solids and volatile solids of the selected raw materials are shown in Table 1.

Table 1 Total solids (TS) and volatile solids (VS) of the selected organic raw materials

	TS [g/100g raw material]	VS [g/100g raw material]
Dry grass from meadows	89.1	83.0
Dry clover grass	91.3	83.3
Clover grass silage	71.3	64.0

Strong acid hydrolysis

The strong acid hydrolysis is an analytical method to determine full content of main sugars in the biomass. The biomasses (0.16 g DM) were treated with 1.5mL of H_2SO_4 (72%) at 30^oC for one hour, and then 42 mL of water was added and the samples were autoclaved (121^oC) for one hour. The acid hydrolyzate was filtered and the glucose, xylose, and arabinose were quantified by HPLC (Biorad HPX-87H). Klason lignin was calculated as the ash free residue after hydrolysis. The ash content was determined by heating for 3 h in an oven at 550°C.

Theoretical ethanol yield

The theoretical bioethanol potential was calculated based on the total amount of glucan in biomass from the formula:

$$Y^T_{EtOH} = 0.51 \cdot m_{Glucose} \text{ [g/100gTS]}$$

$$m_{Glucose} = 1.11 \cdot m_{Glucan},$$

Anaerobic digestion batch trials

A procedure for measuring the biogas potential for organic raw materials was developed. In order to optimize the process, two different concentration of the energy crops were prepared: 2.0; and

4.0 organic matter per 100g of the solution [gVS/100g] (where VS – volatile solids). Inoculum used in the experiment was effluent (digestate) from one of the Snertinge biogas plant (Denmark). 100g of the mixture of energy crop and inoculum was placed in into 500mL flasks; the bottles were flushed with nitrogen to remove the oxygen from the headspace and closed tightly in order to keep anaerobic conditions. Batch fermentation trials were performed in triplicates. The anaerobic digestion had been running in thermophilic conditions (53^{o}C) for around 40 days. The methane concentration in the headspace of the bottles was weekly measured with a gas chromatography (GC).

RESULTS AND DISCUSSION

Theoretical ethanol yield of selected lignocellulosic raw materials

The theoretical ethanol yield was calculated based on the total glucose content. The strong acid hydrolysis was performed to determine the total content of sugars in lignocellulosic biomass. The three main sugars (glucan, xylan and arabinan) were measured by HPLC (high pressure liquid chromatography). The most important is the polymer of glucose – glucan. Results are shown on the figure 1, similar were obtained by Neureiter et al., (2004). In typical yeast based ethanol fermentation only glucose is converted into ethanol. The rest of the sugars remain in the process effluent, which can be either used as a animal feed or further fermented to methane through anaerobic digestion process.

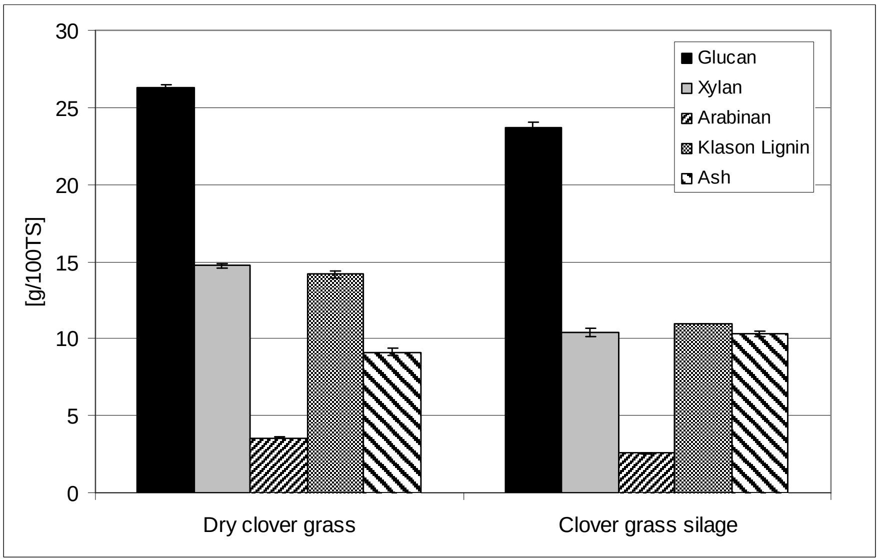

Figure 1 Sugars, Klason lignin and ash concentration in clover grass (dry and silage).

The theoretical ethanol yield based on glucose content was calculated and it is presented in table below.

The theoretical ethanol yield was calculated and it was found to be 14.9 and 13.4 [g/100TS] for dry and silage clover grass, respectively.

The dry clover grass contains more glucan compared to the silage form, which consequently gives higher theoretical ethanol yield. During the ensilaging process of the clover grass, the lactic acid bacteria are utilizing glucose to lactic acid, which cannot be further fermented into ethanol by yeast strains, therefore the lower ethanol yield. Future work will include measurements of the sugars and calculation of the theoretical ethanol yield for following organic raw materials: maize (fresh and silage), vetch and rye, and whey permeate.
Enzymatic hydrolysis of the investigated raw materials including both, cellulase and amylase enzymes (to reveal glucose monomers from cellulose and starch, respectively) would be necessary to investigate the practical ethanol yield.

Biogas potential of selected raw materials

Practical biogas potential was measured for dry grass from meadows, dry clover grass and clover grass silage. Similar range of biogas yield was achieved by Amon et al., (2007), where potential of energy crops was investigated. The biogas potential of energy crops depends on time and place of harvest, ensilage method, etc., therefore it can differ even between the same species but harvested in different years.

It was concluded that the most optimal concentration to estimate the biogas potential of the energy crop was 2.0 gVS/100g solution. With the content of 4gVS/100g, the organic overloading was observed. This process inhibition occurs when more substrate is fed to the bioreactor than microorganisms can degrade (Angelidaki, 2002). The biogas production was significantly inhibited during the first 4 days of the process and after 38 days reached only around 200mLCH_4/gTS for all three substrates, therefore full biogas potentials could not be measured at that concentration. Further measurements of the biogas potentials of raw materials will be carried out only at 2.0 gVS/100g solution.

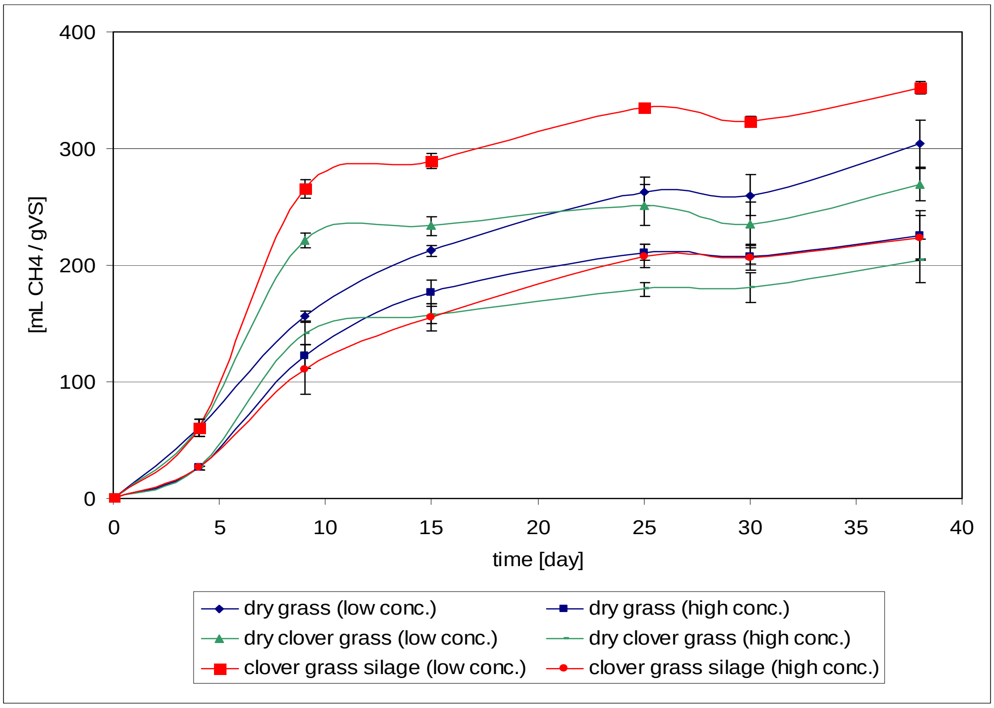

Figure 2 Biogas potential of dry grass from meadows, dry clover grass, and clover grass silage in two different concentrations: low (2gVS/100g) and high (4gVS/100g).

Table 2. Biogas potential of selected raw materials

	[mLCH_4/gTS]	[mLCH_4/gVS]
Dry grass from meadows	326 ± 21	304 ± 21
Dry clover grass	295 ± 14	269 ± 14
Clover grass silage	392 ± 5	352 ± 5

Table above summarizes the biogas potential of the investigated biomass. The biogas potential is expressed as mL of methane per 1g of total (dry matter) or volatile (organic matter) solids.

Most of the biogas was produced during the first 10-15 days of the incubation. Clover grass silage seems to be the most promising feedstock from the presented ones. Energy crop in form of silage might be more effective for the biogas production, due to easier access for microorganisms to the valuable organic compounds.
Further measurements of the biogas potential of other organic raw materials originating from organic farming (such as: maize (fresh and silage), vetch and rye, and whey permeate) is planned. Moreover, scale-up to 5L bioreactors for further optimization of the process will be performed for the most promising feedstock among selected ones.

CONCLUSIONS

From these initial results following conclusions can be drawn:

- The theoretical ethanol yield of the dry clover grass was slightly higher compared to clover grass silage (14.9 and 13.4 g/100TS, respectively). It was caused by converting part of the sugars into lactic acid during the ensilaging process which cannot be formed into ethanol;
- The highest biogas yield from the investigated raw materials was achieved from clover grass silage (394mL CH_4/gTS). The energy crop in form of silage can be easier degraded to the biogas during anaerobic digestion process than dry lignocellulosic material;

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