Methane production from reed canary grass

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1 Introduction

The increasing need to reduce greenhouse gas emissions in order to slow down the climate change requires more effective and versatile methods for producing energy. In anaerobic digestion (AD) a renewable fuel, methane, is produced, which can be used to replace fossil energy sources. AD is a globally widespread technology for treating organic materials such as biowaste, sewage sludge and manure. At the present time, there is increasing interest to produce methane from crops and crop residues. Methane production of a specific energy crop is affected by the chemical composition which changes as the plant matures (e.g. Gunaseelan 1997). Timing and frequency of harvest are thus important in optimising the biomass yield and feedstock quality as well as the total annual biomass yield per hectare.

Reed canary grass (*Phalaris arundinacea*) is a tall (150-300 cm) perennial grass, which grows well on many kinds of soils. It is native to the temperate regions of Europe, Asia and North America and it is used as a forage crop mainly in North America, but also in Europe and Japan. Reed canary grass is one of the most efficient producers of herbaceous biomass in boreal conditions (Lewandowski et al. 2003). In Finland, the cultivation area of reed canary grass used mainly for combustion has increased quite rapidly within the last few years, and it is estimated to reach 70 000 hectares in year 2010 (Pahkala et al. 2005). For combustion, reed canary grass is mostly harvested at spring when the dry matter content is high (about 85 – 90 %), but for methane production it should be harvested as fresh biomass, enabling harvesting usually at least twice a year in boreal growing conditions.

The objective of this study was to determine the effect of crop maturity stage on the methane production potential of reed canary grass.

2 Materials and Methods

2.1 Substrates and experimental set-up

Reed canary grass was cultivated in Central Finland, Saarijärvi during 2005-2006 on two plots established in 2004. Crops were harvested twice a year (1st and 2nd harvest) in 2005 and once in 2006 per plot. Harvesting was made in two different maturity stages corresponding to the vegetative stage (V) and flowering stage (F) in different plots (Table 1). The purpose was to harvest both plots twice a year also in 2006, but extended drought during the summer destroyed the second yield. Total solids (TS) of crops varied from 21.5 % to 40.8 % (Table 1).

Table 1. Characteristics of inoculum and reed canary grass used in BMP assays (V means harvested at vegetative stage and F at flowering stage).

Material	Day of harvesting	TS (%)	VS (%)
Inoculum			
Used in 2005	-	5.4	4.1 - 4.2
Used in 2006	-	6.2 - 7.5	4.9 - 6.0
Reed canary grass			
V:1st harvest in 2005	22.6.2005	21.5	19.8
V:2nd harvest in 2005	19.8.2005	22.6	20.4
F:1st harvest in 2005	13.7.2005	37.3	34.2
F:2nd harvest in 2005	12.9.2005	25.1	22.7
V:harvest in 2006	21.6.2006	40.8	36.6
F:harvest in 2006	10.7.2006	26.8	24.7

After harvesting, fresh crop samples were transported to the laboratory and maintained at 4 °C and chopped to approximately 1-2 cm particle size with scissors immediately before starting the biological methane potential (BMP) assays. BMP of samples was determined in triplicate 1 l glass bottles at 35 °C during 70-76 days incubation. Inoculum was obtained from a dairy farm digester (Laukaa, Finland) mesophilically digesting cow manure and confectionery by-products (Table 1) and an inoculum-substrate volatile solids (VS) ratio of one was used in BMP assays. Bottles were flushed with nitrogen before closing. Tubing made of PVC or PVC-based material with plasticizer (Masterflex Tygon® fuel & lubricant) was used in BMP assay gas collection lines, and produced biogas was collected into aluminium gas bags.

2.2 Analysis and calculations

TS and VS were analysed according to Finnish standard method (SFS 3008). Methane content of biogas was analysed with gas chromatograph (Perkin Elmer Arnel Clarus 500, Alumina column 30 m * 0.53 mm) equipped with flame-ionisation detectors. Operating conditions were: oven 100 °C, injection port 250 °C, detector 225 °C. Argon was used as carrier gas (14 ml/min). Volume of biogas produced was measured by water displacement. Methane content and produced biogas were measured two to three times a week.

BMP of substrates was calculated as $lCH_4/kgVS_{add}$ by dividing the cumulative methane produced by amount of substrate VS added per bottle minus the methane potential of the inoculum. Methane yield per hectare (m^3CH_4/ha) was calculated based on the yields of fresh matter per hectare (one or two harvests per plot, data supplied by Jyväskylä University of Applied Sciences).

3 Results and Discussion

The methane potentials of reed canary grass samples were determined at different maturity stages. In the BMP assays, the methane production of all samples of crops started without delay (Figure 1). Samples from the first harvests at vegetative stages in both years (V:1st/05 and V/06) had the highest BMPs (340 – 350 $lCH_4/kgVS_{add}$), while samples from the second harvests at vegetative stage in year 2005 (V:2nd/05) had lowest (180 $lCH_4/kgVS_{add}$). Methane production potential of 340 $lCH_4/kgVS_{add}$ (incubation time 125 d) for reed canary grass harvested at early flowering stage and 430 $lCH_4/kgVS_{add}$ (incubation time 194 d) harvested at late flowering stage have been earlier reported e.g. by Lehtomäki (2006).

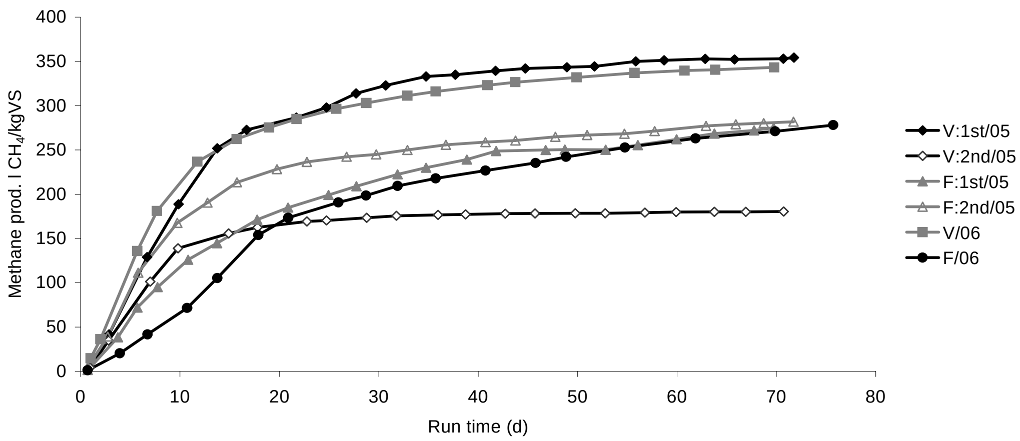

Figure 1. Methane production potential (lCH_4/kgVS) of reed canary grass cultivated during 2005 and 2006 (V:1st/05, V:2nd/05 and V/06 harvested at vegetative stage and F:1st/05, F:2nd/05 and F/06 harvested at flowering stage).

The biomass TS yield per hectare was 79 % higher when harvesting twice per plot at flowering stage compared to harvesting twice per plot at vegetative stage in 2005 (Table 2). In 2006, the biomass TS yield per hectare was same in both plots. The yields of TS in both years were in the same range as earlier reported for reed canary grass harvested at spring in US (1.6-12.2 tDM/ha) and in Europe (7-13 tDM/ha, Lewandowski et al. 2003).

In 2005, ca 10 % higher methane production per ton of TS was gained when harvested at vegetative stage (270 m^3CH_4/tTS) compared to harvesting at flowering stage (250 m^3CH_4/tTS). However, the total methane production potential per hectare was 64 % higher when harvesting at flowering stage because of higher TS yield compared to harvesting at vegetative stage (Table 2). The difference between methane productions per ton of TS was higher in 2006 when the samples at vegetative stage produced 310 m^3CH_4/tTS and the samples at flowering stage 260 m^3CH_4/tTS, which means that the plot harvested at vegetative stage yielded 20 % more methane per hectare than the plot harvested at flowering stage (Table 2). The potential methane yields of reed canary grass per hectare per year corresponded to energy yields of 20 – 36 MWh/ha.

Studies have shown that plants are often more easily degradable in anaerobic digestion, when harvested at vegetative stage, but the yield of biomass is often lower, which may cause lower methane yield per hectare (Lewandowski et al. 2003 and Lehtomäki 2006) as observed in the present study in 2005. In contrast, the yields of dry matter were equal in both harvests in year 2006, but because the methane production potential of samples harvested at vegetative stage were higher than at flowering stage, the methane production potential per hectare was also higher.

As a conclusion, methane production potential per ton of VS of reed canary grass was higher when harvested at vegetative stage than at flowering stage, but the methane yield per hectare is also affected by the yield of biomass. It is also notable that different climatic conditions during growing period may affect significantly the biomass yields and further the methane yields per hectare.

Table 2. Yields of fresh matter (FM), TS and methane per hectare of reed canary grass harvested at vegetative (V:1st/05, V:2nd/05 and V/06) and flowering stages (F:1st/05, F:2nd/05 and F/06) in 2005 and 2006.

Maturity stage, harvest time and year	Yield (tFM/ha)	Yield (tTS/ha)	Methane prod./ha (m^3CH_4/ha)
V:1st/05	24	5.2	1700
V:2nd/05	13	2.9 (1st+2nd: 8.1)	500 (1st+2nd: 2200)
F:1st/05	27	10.1	2500
F:2nd/05	17	4.3 (1st+2nd: 14.5)	1100 (1st+2nd: 3600)
V/06	19	7.8	2400
F/06	29	7.8	2000

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