Utilization of Biomass and Mixtures for the Gas Production

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Abstract - **The article describes experimental and analytical work carried out with aim of selection the best grass species for anaerobic digestion as a source of methane for energetical purposes. Nine species of grasses or their mixtures cultivated under controlled conditions were used for laboratory fermentation experiments. Theoretical production of methane calculated from analyses of biodegradable carbon and methane production from values of chemical oxygen demand are compared with results of laboratory experiments.**

Index Terms – energy grasses, combustion, analyses

INTRODUCTION

In areas situated at the foot of mountains in the Czech Republic, current economic agricultural production is not oriented to classical agricultural crops. Cultivation of phytoenergetical grasses for anaerobic digestion or combustion is one of the possibilities of agricultural land exploitation. This article is focused on a selection of optimal grass from the point of view of the most important criteria that are influencing the process of anaerobic digestion in its individual phases. The process of anaerobic digestion can be divided into four phases. From the point of view of major components content hydrolysis is very important. A decomposition of lipides, proteins and polysacharides takes place during this phase and water-soluble sugars are liberated. The process of anaerobic digestion is influenced during the first phase also by content of dry matter in grass, presence of microorganisms captured by grass, and also by buffer capacity. The buffer capacity indicates the ability of plant to resist the variation of acidobasic reaction and it is varying in dependence of plant age. From the point of view of methane production, the most important parameter is lignin. It forms component of very low biodegradability and its content is increasing during vegetation period.

CHARACTERISTICS OF SELECTED GRASS SPECIES

The following energy crops were grown and supplied by OSEVA PRO s.r.o - Grass Research Institute in Rožnov – Zubří: Redtop (Agrostis gigantea Roth.), Reed Canary Grass var. Lera, Palaton and Chrifton (Phalaroides arundinacea L.), Tall Fescue var. Kora (Festuca arundinacea Schreb.), Tuber Oat Grass (Arrhenatherum elatius L.), Mountain Brome var. Tacid (Bromus marginatus Nees ex Steud) and the following two meadow mixtures: mixture for moister sites and mixture for dried sites. The species composition of the moist site mixture was as follows: Timothy Grass var. Rožnov (14% wt.), generic hybrid Felina (27.8% wt.), Tall Fescue var. Kora (11% wt.), Kentucky Bluegrass var. Slezanka (8.2% wt.), Fowl Meadow Grass var. Rožnov (5.6% wt), Perennial Rye Grass var. Tarpan (11.1% wt), Red Clover var. Kvarta (16.7% wt.), Alsike Clover var. Táborský (5.6% wt.). The species composition of the dry site mixture was as follows: Tall Fescue var. Kora (12.5% wt.), generic hybrid Felina (25% wt.), Perennial Rye Grass var. Bača (5% wt.), Kentucky Bluegrass var. Slezanka (10% wt.), Red Clover Kvarta (12.5% wt.), White Clover var. Huia (10% wt.).

PARAMETERS IMPORTANT FOR COMBINED FERMENTATION OF GRASSES

The harvest time has important influence on the increase of some major components. The increase of cellulose, lignin, sacharides, lipides, starch, proteins and dry matter content was analyzed for 9 grass species during period from June to September. In addition, changes in water-soluble sugar concentration (WSC) and buffer capacity were analyzed. Plants with lower sugar concentrations have higher buffer capacity and they are resistant to the change of pH value more than biomass with higher sugar concentrations. The lowest buffer capacity was found for Reed Canary Grass, the higher values were determined for meadow mixtures. The youngest grasses have highest buffer capacity values. The buffer capacity is significantly influenced by moisture (correlation coefficient $r = 0.78$). WSC is increasing in dependence on plant age, but it is substantially influenced also by weather variability. It is known that WSC is increasing with increasing dose of nitrogen in fertilizers. Although WSC is determined by chromatography, we have used the parameter DOC (Dissolved Organic Carbon) for estimation of water-soluble sugars concentrations. It is apparent from the behaviour of DOC in water leachate that its concentrations are increasing with plant age. The highest concentrations of DOC were found for Redtop and all varieties of Reed Canary Grass.
The process of fermentation is influenced also by content of dry matter. A moisture is influencing number of bacteria (mainly Gram-negative) and microorganisms in grass which can influence substantially the speed of fermentation process. Legumes and grasses with content of dry matter > 50 % wt. have limited ability for fermentation. On the other hand, extremely wet biomass (< 25 % wt. of dry matter) is prolongating the fermentation time due to high buffer capacity and possible formation of acetic acid which is

retarding the fermentation process. From the point of view of moisture optimal for fermentation (content of dry matter 30 to 50% wt.), grasses can be divided into three groups: Grasses with optimal dry matter content from June to August – Redtop, all varieties of Reed Canary Grass, Tuber Oat Grass and Mountain Brome avr. Tacid, grasses with optimal moisture during August – meadow mixtures and grass with optimum in June – Tall Fescue.

The behaviour of some major components in plants is influenced by addition of inorganic fertilizers. Fertilizers are increasing the yield per hectar, but they are deteriorating the biomass degradability. The major components of phytomass are influenced mostly by weather conditions and by period between fertilizing and harvest. The dependence on vegetation period is substantial for some components (cellulose, lignin). MacDonald et al. (1991) report the cellulose increase in Phleum pratense L. from May to September by 50 %, from 17 to 34 % wt. The highest increase of cellulose (> 20 %) was found for meadows mixtures, Reed Canary Grass var. Palaton and Reed Canary Grass var. Lera. It was proved for studied samples that grasses cultivated on unfertilized soil have higher cellulose content. The difference between cellulose concentrations in grasses planted on fertilized and unfertilized soil is around 2 %. The cellulose concentrations are no further changing during August and September which is probably related to the end of vegetation period for studied grasses. The highest average concentrations of cellulose were determined in Tuber Oat Grass and Tall Fescue.

Concentrations of lignin are variable according the species and age of plant. They are changing also with the position of sampling site. Lignin concentrations are increasing with plant age. The lowest lignin concentrations during vegetation period were determined in Redtop, Tall Fescue and Tuber Oat Grass var. Rožnov. The meadow mixtures have the highest lignin concentrations. Lignin concentrations in Redtop are identical in August and September, and for Tuber Oat Grass they are not varying already from July. For other grasses, concentrations are increasing until the end of vegetation period. The average increase is approximately 20 %.

Concentrations of proteins are decreasing during vegetation period for all studied grasses. Only meadow mixtures and Mountain Brome var. Tacid cultivated on fertilized soil have higher protein concentrations, for other grasses this relationship was not confirmed.

ANAEROBIC DIGESTION

Anaerobic digestion of phytomass is more complicated due to higher concentrations of low polymerized hydrocarbons that are easily transformable microbiologically to organic acids. This is causing excessive acidification, and other problematic parameter is relatively low buffer capacity of biomass (Sttaford et al. 1981).

The formation of methane from phytomass is influenced by degree of significance of cell walls. Lignin is almost not decaying in anaerobic conditions. Inhibition of biological decomposition of organic substances is influenced mainly by presence of lignite. In the literature, there exists general agreement on the higher biological resistance to the anaerobic biodegradation for the material with higher lignin concentration. Converti et al. (1999) report that higher lignin concentrations in biomass (> 15 % wt.) inhibit distinctively the anaerobic decomposition. The lignin decomposition is inhibited almost three times in anaerobic environment. It is expressed by the coefficient 0.028 which is used in Chandler equation. From the study of Komilis et al. (2002) it is apparent that hemicellulose is decomposed entirely (100 %) in anaerobic conditions, while cellulose is decomposed by decrease of cellulose concentration in the range between 15 and 66%.

The biogas production from combined fermentation of grass and sludge was tested on bioreactors (made by WTW) at the following conditions: sludge from WWTP Ostrava (100 ml raw sludge, 400 ml rotten sludge + 100 ml water + 4 g dry matter of grass), period of fermentation 21 days.

The best biogas yield in laboratory conditions provided Reed Canary Grass var. Palaton and Redtop. The worst results were obtained for Tall Fescue and Mountain Brome. Values in Table No.2 indicate that differences in biogas production calculated from biodegradable carbon represents up to 25%. The differences are higher (up to 33%) for laboratory results. The most important difference appears when biogas production is converted into values related to the yield of grass dry matter per hectare. The best results are then obtained for Reed Canary Grass var. Lera and Palaton, and Redtop.

CONCLUSION

Anaerobic digestion is influenced by many parameters which are related to the concentrations of major components (lignin, cellulose, hemi cellulose), further sugars, proteins etc. as well as variability of their concentrations during vegetation period.

The highest concentrations of biodegradable fraction were found in grasses harvested in June. Concentrations of biodegradable carbon are decreasing by maximum 10 % for most grasses during July. The differences are lower for Tall Fescue, Mountain Brome and meadow mixture for dry sites. At an end of vegetation period, concentration of biodegradable carbon is decreasing by maximum 20 %.

- The lowest concentration of biodegradable fraction for the whole vegetation period (average value) was found for grasses of meadow mixtures and Mountain brome var. Tacid.
- Theoretical production of methane at the 100 % conversion of biodegradable carbon for the studied set of grasses ranges from 0.37 to 0.50 dm3/g of dry matter. The highest production was estimated for Redtop and Reed Canary Grass.
- Real production of methane obtained from laboratory tests in fermentor was approximately four times lower (0.1 to 0.2 dm3/g of dry matter and decomposition of approximately 50 % of dry matter during period of 20 days).

- After conversion of methane production into methane yield per hectare, there are most suitable Reed Canary Grass var. Lera and Palaton, together with Redtop due to the high yield of dry matter.

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