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QUANTITATIVE AND QUALITATIVE ANALYSIS OF NEW ENERGY MAIZE CULTIVARS FOR ANAEROBIC FERMENTATION

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Summary. A number of biogas plants (BP) has rapidly increased in last few years. This is due to many factors. One of the most important was passing the law on renewable energy. For effective treatment of BP good supply of quality input materials is necessary. The seeds companies focus their breeders programs to get new energy cultivars. The aim of this work was to confirm the characteristics of new energy maize cultivars for biogas production. Three new energy maize cultivars Cassilas, Fernandez and Atletico were tested. They were cultivated by KWS company and were tested in anaerobic, mesophillic conditions. Tests were carried out in batch lab scale reactors of operational volume 0.12 m^3. Cassilas cultivar gave the highest production of biogas, which reached 0.356 $m^3 \cdot kg^{-1}$, followed by Atletico – 0.342 $m^3 \cdot kg^{-1}$ and Fernandez – 0.327 $m^3 \cdot kg^{-1}$ of total solids. The greatest methane production per m^2 was achieved by Fernandez cultivar 0.659 $m^3 \cdot m^{-2}$, followed by Atletico – 0.612 $m^3 \cdot m^{-2}$ and Cassilas – 0.601 $m^3 \cdot m^{-2}$.

Key words: Biogas plant, maize, fermentation, analysis

Introduction

We can notice that traditional fossil fuels are being replaced with renewable sources. This is due to diminishing supplies of fossil fuels, their rising prices, but also due to the fact that individual countries become self-sufficient and due to island energy systems, which are created in areas with poor infrastructure. Members of the European Union decided that in 2020 they provide 20% of their consumption by the energy of renewable resources. To accomplish these ambitious goals, it is necessary to look for resources that are readily available and stable. Energy from biomass meets these basic requirements. The region of Central Europe, including Czech Republic is characterized by intensive agriculture which, however, faces a long and problematic overproduction of food ingredients commodities. Energy production from biogas gives a chance for stabilization of the agricultural sector. Biogas can be produced from agricultural products and waste. Suitable substrates for the digestion in agricultural biogas plants are as follows: energy crops, organic waste, and animal manures [Oslaj et al. 2010]. Maize [*Zeamays* L.], herbage (*Poacae*), clover grass (*Trifolium*), Sudan grass (*Sorghum sudanense*), fodder beet (*Beta vulgaris*) and others may serve as energy crops [Rasi et al. 2007, Chynoweth DP et al. 1993; Gunaseelan VN 1997; Vindis et al. 2008]. Production of these plants is possible by using the existing technology and growing experiences. The produced biogas can be purified to natural gas quality and then fed into the gas public network or converted with cogeneration into electricity and heat, with subsequent deliveries of electricity to the public network and the use of heat for heating economic and resident buildings, to operate the dryers, and for other uses. Combustion of biogas in cogeneration unit in order to generate electricity and heat energy is the most common way of using biogas in Czech Republic [Kára 2007]. In Czech Republic there are more than 200 agricultural BP in operation and the number of new facilities in service increases every year. It is estimated that the final number of BP will be several times higher and it will reach 750 BP. Therefore, it is clear, that there is still a place for new BP on the market.

Biogas is a product of anaerobic degradation of organic substrates, it is commonly occurring in natural processes. Biogas is a mixed gas consisting of two major components i.e. CH_4 and CO_2, such gases like O_2, H_2S, NH_4 are also found there, but the increased content of these is undesirable.

Biogas and its use have been long known. In recent decades there has been a considerable intensification of the process in order to get a maximum efficiency, using the scientific knowledge and modern technology. Therefore, great effort is put into developing new technologies and also cultivating new energy crops cultivars. Technology of biogas production can be divided according to the content of total solids (TS) in the fermented material (liquid, non-liquid fermentation), a dosing method (continuous, semi-continuous and discontinuous), and the temperature (psychrophilic, mesophilic, thermophilic). From the above it is clear that there are a lot of technologies and their potential use depends on the processed material and the demands for final products.

Semi-continuous, liquid anaerobic fermentation under mesophilic temperature conditions has many advantages for the operator, including the possibility of use of readily available raw materials, such as manure, and the process stability. A lower level of intensity of biogas production compared to the thermophilic technologies, that can better exploit the input materials, is its disadvantage. With the increasing level of technological progress and scientific knowledge technologies previously difficult for operating and managing are increasingly applied. Modern BP can be implemented very well without disturbing the surroundings by covered tanks or tanks below the ground level. Another possibility is the integration of various technological BPs units into a single object, thereby avoiding potential noise and odour emissions. Ingeniously integrated BP requires less building space and can be very well integrated into existing production facilities. Fig.1 shows a thermophilic BP. This compact solution with many innovative design features makes it one of the highly sophisticated and effective implementation of the BP.

Fig.1. Biogas plant of Enserv
Rys. 2 Biogazownia Enserv

Currently, agricultural BP mostly use as a feedstock mixture of maize silage and liquid manure for their simple availability and optimum performance of the anaerobic fermentation process. Liquid manure is used as inoculum, especially cattle manure contains quantities of methane-producing microorganisms, and in order to achieve optimal TS content of the fermented material. The optimal range of TS fermented material for liquid anaerobic fermentation is from 5 to 15% [Schulz et al. 2004]. TS content below 5% is economically inefficient, due to pumping and heating a large volume of water. The content of TS higher than 15% significantly increases energy consumption for mixing the fermented mixture. Maize is the most dominating crop for biogas production because it provides the highest yield of TS and methane per hectare [Amon et al. 2007]. The author also provides an optimum TS content of fermented maize silage from 30 to 35% of TS, which achieves the highest production of biogas. Quality requirements for maize silage used for biogas production are different from feeding silage. This is due to the different way of use. In BP high methane yield is the aim, but methane production by cattle ruminant is ecologically harmful and thus undesirable [Schittenhelm 2008].

We still lack documentation on the biogas production of new energy maize cultivars in order to design such BP. Therefore the aim of this work was to verify the suitability of new energy maize cultivars for the biogas production. Under laboratory conditions three new maize energy cultivars were tested. Quantitative-qualitative analysis was carried out and determined on the base of the biogas resp. methane production per area unit, which is based on the TS yield of the tested cultivars.

Materials and methods

Laboratory description

Tests were carried out in the reference biogas laboratory at Mendel University in Brno. The laboratory has six batch lab scale reactors with operational volume of 0.12 m^3. Reactors are equipped with heating and mixing system with probes for the application of additives for substrate and biogas sampling and probe for pH measurement. Biogas goes through PREMGAS BK G4 flow meter which measures the amount of the developed biogas. Then it is collected in a plastic bag with a capacity of one cubic meter. The bag is connected to a flame, to burn the biogas. In a slight increase of pressure in the biogas collecting bag, the biogas is pumped out of it and burned on a flame. Burning takes place in the hood and the waste gases are exhausted from the laboratory.

Maize for anaerobic fermentation

Three new energy maize cultivars from KWS company were tested: Cassilas, Atletico, Fernandez produced in Švabenice, South Moravia, Czech Republic. Maize was harvested at 20.9.2010, it was immediately silaged in to the numerically marked micro containers. After the time required for the course of the silage process the tests were initialised. TS content of dosed cultivars ranged from 35.3 to 38.2%. The pH was balanced and valued from 3.78 to 3.84

Inoculum for anaerobic fermentation

Tests were performed with co-fermentation. Material from agricultural BP in Čejč was used as inoculum. These BP's process a mixture of maize silage and pig manure. The substrate was removed in a sufficient quantity to achieve the same tests conditions in all reactors. The test reactor was filled immediately after the substrate transport. Before filling, the reactors were heated on the operating temperature of 39°C to avoid the influence of microorganism population, because of inoculum cooling.

Design of the tests

0.1 m^3 of inoculum was dosed to each reactor. Then, reactors were closed and left one day without the addition of maize silage, to confirm that the conditions for testing are the same in all reactors. In the same time TS and organic fraction of TS of inoculum and maize silage were also measured. It was done for the exact dosage of maize silage. The dose was chosen to achieve 6% of TS of the tested mixture. This value was determined as a constant, for all tests. Moreover the load of a reactor with organic fraction was taken into account. Inoculums content of TS ranged from 3.5 to 4.3%. A dose of maize silage, required to increase TS in the reactor at 6% ranged from 6 to 7 kg. In each series of tests there was one reference reactor without a dose of maize silage. The hydraulic retention time of the tests was 26 days, under mesophilic temperature conditions 39°C.

Measured parameters

Before the tests pH, TS, organic fraction of TS, buffer capacity-FOS/TAC were measured. During the tests, quantity and quality of the developed biogas (CH_4, CO_2 and H_2S) were measured each day. From the total biogas production of each reactor reference production was subtracted. This is the way to get biogas production of the tested energy maize varieties. The results were transferred to the cultivars content of TS. With this it is possible to convert the data to the appropriate biogas production of the tested energy maize varieties by their different hectare yield of TS. Comparison of these differences is then possible to determine which energy maize cultivars seem most appropriate for the cultivation for the biogas production in different production areas.

Results and discussion

Three new energy maize cultivars, which belong to the same FAO maturity class classification, were repeatedly tested. Fig. 2 and Fig. 3 show the cumulative biogas and methane production, related to the dose of TS of the tested maize silage. The highest biogas and methane production was reached by Cassilas cultivar then followed by Atletico and Fernandez. Tests were carried out in so many repetitions in order to obtain a conclusive test of the production with confidence level of 0.05.

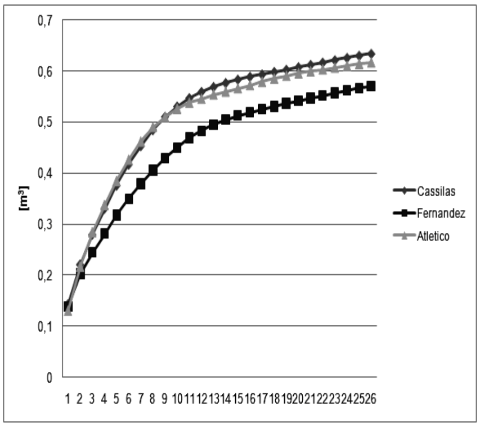

Fig. 2. Cumulative biogas production
Rys. 2. Skumulowana produkcja biogazu

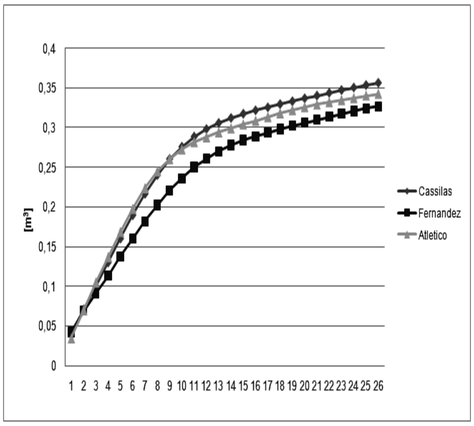

Fig. 3. Cumulative methane production
Rys. 3. Skumulowana produkcja metanu

Cassilas achieved biogas and methane production Cassilas 0.634 $m^3 \cdot kg^{-1}$ of biogas and 0.356 $m^3 \cdot kg^{-1}$ of methane, Atletico 0.617$m^3 \cdot kg^{-1}$ and 0.342 $m^3 \cdot kg^{-1}$, Fernandez 0.570 $m^3 \cdot kg^{-1}$ and 0.327 $m^3 \cdot kg^{-1}$.

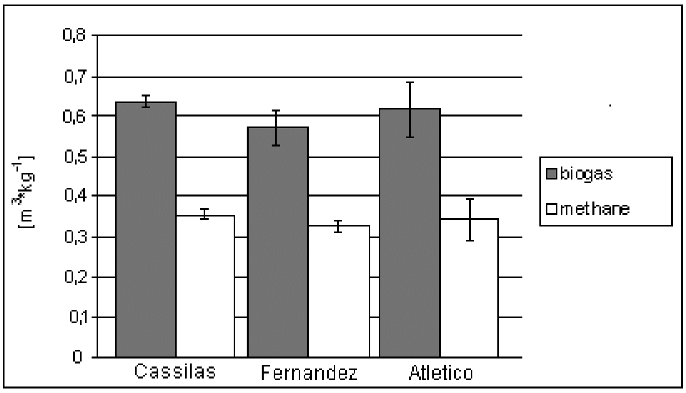

Fig. 4. Biogas and methane production of new energy maize varieties
Rys. 4. Produkcja biogazu i metanu z nowych odmian kukurydzy energetycznej

Amon et al. 2007 achieved methane production at Pioneer maize cultivars in terms of Lower Austria: PR39G12 – 0.292 $m^3 \cdot kg^{-1}$, Sandrina – 0.375 $m^3 \cdot kg^{-1}$, Clarica – 0.329 $m^3 \cdot kg^{-1}$, Monalisa – 0.274 $m^3 \cdot kg^{-1}$ and Ribera – 0.311 $m^3 \cdot kg^{-1}$. The other authors Oslaj et al. [2007]

in terms of Slovenia found the similar methane production of maize cultivars of different FAO maturity class: PR38F70 – 0.312 $m^3 \cdot kg^{-1}$, PR38H20 – 0.300 $m^3 \cdot kg^{-1}$, NKTHERMO – 0.251 $m^3 \cdot kg^{-1}$, NKCISKO – 0.290 $m^3 \cdot kg^{-1}$

Dynamics of biogas production corresponds to the applied batch technology, when after high initial quantities of the developed biogas it has to stabilize fig. 5. The quality of biogas was high fig. 6, methane content in biogas reached to 70% vol. Dynamics of methane production had a normal course for the anaerobic fermentation process fig. 7, when after the initial decrease in production, the number of methanogenic microorganisms causing increase of methane production grew.

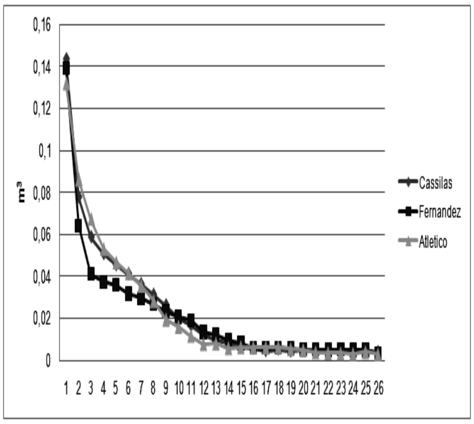

Fig. 5. Daily biogas production
Rys. 5. Dzienna produkcja biogazu

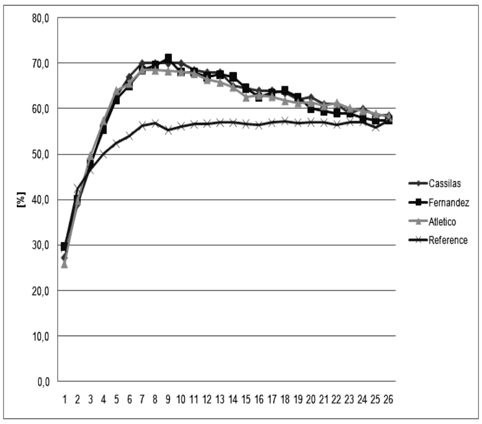

Fig. 6. Methane content in biogas
Rys. 6. Zawartość metanu w biogazie

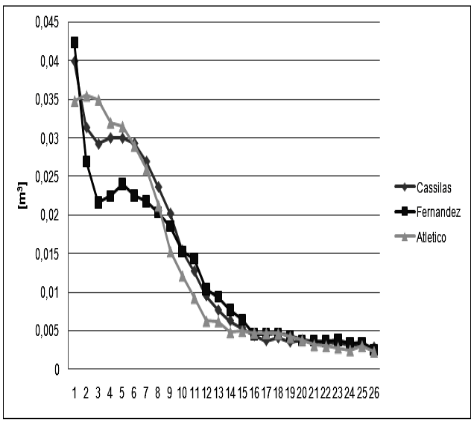

Fig. 7. Daily methane production
Rys. 7. Dzienna produkcja metanu

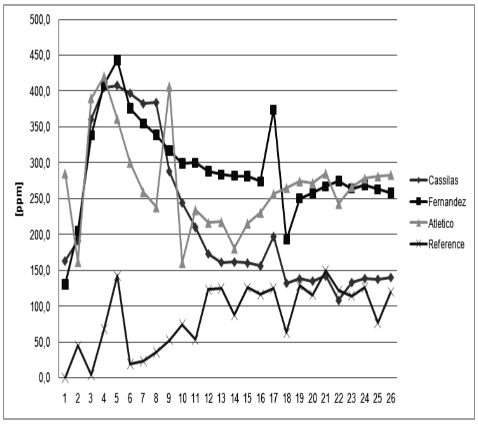

Fig. 8. Hydrogen sulphide content in biogas
Rys. 8. Zawartość siarkowodoru w biogazie

An increased content of H_2S, which can be explained by the decomposition of proteins contained in maize silage, was found fig. 8. Hydrogen sulphide is a potentially lethal gas produced by bacterial anaerobic decomposition of protein and other sulphur-containing organic matter [Straw et al. 2006].

Different yield of TS per area unit was found in the new energy maize cultivars. If we included these area yields of TS in the evaluation, we would find that Fernandez cultivar has achieved the highest biogas production, followed by Atletico and Cassilas cultivars. Fig.9 presents yields of TS of the tested energy maize cultivars per area unit. For selection of the cultivars for biogas production such factors like class maturity, yield of TS per unit area, agri-technical demands of variety should be included, to fully use the potential of the grown material and to achieve high production of the quality biogas.

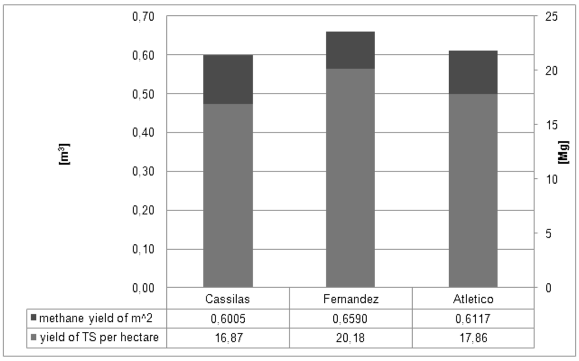

Fig. 9. Yields of TS per area unit of the tested maize cultivars

Rys. 9. Uzysk substancji stałych na jednostkę obszaru badanych odmian kukurydzy

The aim of this work was to verify the performance of new energy maize cultivars, cultivated for biogas production under mesophilic temperature conditions. This goal was achieved and high production of quality biogas at all tested energy maize cultivars was found. These test results constitute a reliable basis for designing BP that would use these new energy maize cultivars in the composition of its substrate. Such materials missed practice.

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ANALIZA ILOŚCIOWA I JAKOŚCIOWA NOWYCH ODMIAN KUKURYDZY ENERGETYCZNEJ DLA CELÓW FERMENTACJI BEZTLENOWEJ

Streszczenie. Liczba biogazowni wzrosła w ostatnich latach. Spowodowane jest to wieloma czynnikami. Jednym z najważniejszych było wydanie ustawy dotyczącej odnawialnej energii. Zapewnienie wysokiej jakości materiałów wsadowych jest konieczne dla skutecznego działania biogazowni. Firmy nasienne skupiają się na programach hodowlanych tak by osiągnąć odmiany energetyczne: Celem pracy było potwierdzenie charakterystyki nowych odmian kukurydzy energetycznej do produkcji biogazu. Zbadano trzy nowe odmiany kukurydzy energetycznej Cassilas, Fernandez i Atletico. Wyhodowano je w firmie KWS i zbadano w warunkach beztlenowych mezofilicznych. Badania prowadzono w laboratoryjnym reaktorze SBR o objętości roboczej wynoszącej 0,12 m^3 .Odmiana Cassilas jest odpowiedzialna za najwyższą produkcję biogazu, która osiągnęła 0,356 $m^3 \cdot kg^{-1}$, następnie odmiana Atletico – 0,342 $m^3 \cdot kg^{-1}$ oraz Fernandez 0,327 $m^3 \cdot kg^{-1}$ całkowitej zawartości substancji stałych. Odmiana Fernandez osiągnęła największą produkcję metanu na m^2 i wyniosła 0,659 $m^3 \cdot m^{-2}$, następnie odmiana Atletico – 0,612 $m^3 \cdot m^{-2}$ i odmiana Cassilas – 0,601 $m^3 \cdot m^{-2}$.

Słowa kluczowe: biogazowania, kukurydza, fermentacja, analiza

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