Abstract: This article analyses the impact of using ultrasound in the pretreatment of maize shoots on the process of anaerobic digestion. The analysis was conducted to demonstrate the impact of ultrasound to improve the methane fermentation of maize silage by the anaerobic degradation of structural lignocellulose. Tests were performed on a test bench consisting of a two-stage reactor system, the first stage of which served as a control, while the substrate used in the second stage was exposed to ultrasound. In the present two-stage methane fermentation system, a significant decrease in COD values from baseline values was observed (84 %), while in the case of the control system not treated with ultrasound, a pollutant removal efficiency of 77 % was observed. In the test system, an increase of 30 % in the amount of biogas produced was observed compared with the control system.

Keywords: anaerobic digestion, biogas, ultrasound, lignocellulosic biomass

The development of the renewable energy industry is of crucial importance for implementation of the basic aims of the energy policy in Poland. Energy production from renewable sources ensures positive ecological effects and contributes to the growth of under-developed regions. Currently, renewable energy resources make up about 14 % of globally-consumed energy, of which up to 10 % is derived from biomass. This source is considered to be an alternative to fossil fuels [1]. As regards biomass transformation, a commonly-applied method is methane fermentation, which is a cost-
-effective and environmentally-friendly method of energy generation [2]. In order to increase the efficiency of the fermentation process, it is necessary to perform preliminary treatment of substrates. Obtaining the highest possible decomposition of lignin and cellulose structures during the pretreatment process is very important for achieving the best results. Numerous studies have been carried out to improve the fermentation process, with the focus on examining the effects of various factors leading to obtaining methane-rich biogas [3]. The research described in this paper concerns the effects of pretreatment of maize shoots with ultrasound on the process of methane fermentation. The performed analyses aimed at demonstrating the effects of ultrasound on improvement of the methane fermentation of maize shoots through abiotic degradation of lignin and cellulose structures.

Ultrasound waves are acoustic waves in the frequency range from 16 kHz to 100 MHz. Ultrasound, due to its specific interaction with matter, is widely applied in medicine, technology, industry and cosmetology. In nature, it is used by animals for echolocation purposes and has both a passive and active impact on the environment in which it propagates. The most important passive applications include ultrasound defectoscopy, hydrolocation and (extremely important in modern medicine) ultrasound diagnostics. Passive application consists of generating and detecting ultrasound waves with an intensity which does not destroy the structure of the given medium. Each change to the status or the properties of the medium brings about a change in the conditions for acoustic wave propagation. A sufficiently high intensity of ultrasound waves can trigger cavitation capable of disintegrating microorganisms, viruses, bacteria as well as plant and animal cells [4, 5].

Ultrasound is increasingly often applied in the disintegration of plant structures to accelerate their hydrolysis [6]. As a result of ultrasound activity, intracellular substances are degraded and released to water. Ultrasound waves cause changes in the chemical structure and efficiency of biological membranes, which leads to disintegration of intracellular substances. It also has a favourable effect on releasing sugars from lignin and cellulose structures, making those sugars more easily accessible to microorganisms performing the fermentation process [4].

**Materials and methods**

Maize, previously ground and dried at 80 °C, was used as a substrate in the experiment. The substrate prepared in this manner was hydrated to 95 % and placed in a 15 dm³ tank. The content of the tank was continuously mixed with the use of an electric mixer. From the tank, the hydrated substrate was pressed with the use of peristaltic pumps into two anaerobic reactor systems. In the reactors, the introduced substrate was heated to 37 °C by means of electric heaters.

The test stand (Fig. 1) was composed of two two-stage reactor systems: the first system was used for control purposes, while the substrate used in the other system was subjected to ultrasound. The device emitting ultrasound waves was placed on a glass flow cylinder, into which the substrate was inserted before being sent to the reactor systems. The inflow of sewage to the reaction chambers was periodic. During a 2 h
cycle of sewage supply, the pumps operated for 8 minutes at a specified efficiency level. The reactor load averaged 1600 g/m³d.

The analyses were carried out after operating the reactors for 24h. The scope of analyses included examination of COD values, pH analysis and a quality and quantity examination of the biogas produced.

Results

The level of chemical oxygen demand (COD) in the test systems is presented in Fig. 2. The control system was characterized by a 21 % lower value of COD in untreated sewage than the test system, in which sewage was subjected to ultrasound. In the test system, reduction of COD in the first reactor was 54 % in comparison with sewage subjected to ultrasound, while in the control system it was only reduced by 35 % in comparison with untreated sewage. The value of COD at the end of the systems was 456 mgO₂/dm³ for the control system, which was 77 % lower than the initial value, while for the test system it amounted to 400 mgO₂/dm³ and was 84 % lower than the initial value.

The pH in case of both systems in the reactors fluctuated around 6 and in reactor 2 – around 7.

The quality analysis of the biogas (Fig. 3) revealed that the quality of biogas produced was better in the test system, for both sequences, in both the first and second reactor.
The quantity analysis of the biogas demonstrated that an average daily increase of the gas produced in the test system in reactor 1 was 1.7 dm$^3$, while this value for in the same reactor in the control system amounted to 1.2 dm$^3$, i.e. it was by 30 % lower. In reactor 2 in the system with ultrasound, the average daily increase was 1.6 dm$^3$, and in the control reactor it was 1.1 dm$^3$, which was lower by 31 %.

**Results and discussion**

The application of ultrasound is a very efficient pretreatment method commonly applied to increase sludge susceptibility to biodegradation. This method has been successfully used to solve problems related to the sludge management of sewage treatment plants. Alastair et al reported that as a result of ultrasound, the production of biogas grows by 34 % compared with sludge not treated with USG [7]. Similar
conclusions were drawn by Benandallah et al who, observed that ultrasound was able to remove harmful benzopyrene and naphthalene from sludge, in addition to an increase in daily production of biogas by 23 % [8]. These phenomena were observed while carrying out fermentation under both thermophilic and mesophilic conditions. Bougrier et al examined the effect of ozoning, ultrasound and thermal treatment on increases in the efficiency of anaerobic sludge fermentation [9]. The three kinds of treatment mentioned above were carried out under the same conditions, on the same sludge samples. Ultrasound proved the most efficient as regards susceptibility to anaerobic decomposition. Taking into account methane production, the results obtained with ultrasound were similar to the thermal treatment; in both cases methane production grew by about 34 %. Erden et al examined the application of low frequency ultrasound for pretreatment of sewage originating from meat production. The application of this type of treatment improved methane production by 24 % [10]. As follows from the data quoted in the literature and from results of own research, the application of ultrasound is justified in the case of pretreatment of sludge, sewage and biomass before the process of biogas production.

**Conclusions**

The analysis of the results demonstrated that ultrasound had a favourable effect on quality improvement and on an increase in the amount of biogas produced during fermentation of maize shoots.

A significant drop in the COD values (84 %) was observed in the analysed two-staged system of methane fermentation. In the case of the control system not subjected to ultrasound, the recorded efficiency of impurity removal was 77 %. The test system revealed an increase in the amount of the produced biogas (by 30 %) in comparison with the control system. The composition of the gas obtained for both sequences was very similar.

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**References**


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Wpływ ultradźwiękowej dezintegracji kiszonki kukurydzy na efektywność fermentacji metanowej

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Abstrakt: Badania opisane w artykule dotyczą wpływu wstępnej obróbki kiszonki kukurydzy za pomocą ultradźwięków na proces fermentacji metanowej. Prowadzone analizy miały na celu wykazanie wpływu ultradźwięków na poprawę fermentacji metanowej poprzez abiotyczny rozkład struktur lignino-celulozowych. W analizowanym dwustopniowym układzie fermentacji metanowej zaobserwowano znaczny spadek wartości ChZT w stosunku do wartości wyjściowej, było to 84 %, w przypadku układu kontrolnego nie poddawanego działaniu ultradźwięków zanotowano sprawność usuwania zanieczyszczeń na poziomie 77 %. W układzie badawczym zaobserwowano wzrost ilości produkowanego biogazu o 30 % w porównaniu z układem kontrolnym.

Słowa kluczowe: fermentacja metanowa, biogaz, ultradźwięki, biomasa lignocelulozowa