

UTJECAJ NAČINA SKLADIŠTENJA NA UČINKOVITOST PROIZVODNJE BIOPLINA IZ VIŠEGODIŠNJIH ENERGETSKIH KULTURA

Sažetak

Rastuća potražnja za obnovljivim izvorima energije i potreba za smanjenjem emisija stakleničkih plinova intenzivirali su istraživanje održivih sirovina za proizvodnju bioplina. Takvim sirovinama smatraju se one koje utječu na smanjenje negativnog utjecaja na proizvodnju hrane i okoliš, a istovremeno mogu zamijeniti konvencionalne kulture kao što je kukuruz. Višegodišnje poljoprivredne energetske kulture, poput miskantusa (*Miscanthus × giganteus*), divljeg proso (*Panicum virgatum*) i divovske trske (*Arundo donax*), prepoznate su kao potencijalne alternativne sirovine zbog visokog prinosa biomase i mogućnosti uzgoja na marginalnim tlima. Međutim, njihovu primjenu u procesu anaerobne digestije ograničava složena lignocelulozna struktura biomase, odnosno povećan sadržaj lignina koji smanjuje stupanj biorazgradivosti i energetske iskoristivost.

Cilj ovog doktorskog rada bio je utvrditi utjecaj načina skladištenja biomase anaerobnom fermentacijom, u obliku silaže i sjenaže, na promjene kemijskog, fizikalno-kemijskog i strukturnog sastava biomase. Istraživanje je obuhvatilo tri višegodišnje poljoprivredne energetske kulture: miskantus, divlje proso i divovsku trsku pri čemu je istražen utjecaj anaerobne fermentacije na sadržaj lignina te ukupni bioplinski i metanski potencijal kao i kvalitetu proizvedenog bioplina.

U okviru istraživanja provedena je kemijska, fizikalno-kemijska i strukturna analiza uzoraka biomase. Učinkovitost proizvodnje bioplina određena je laboratorijskim pokusima anaerobne digestije, pri čemu su analizirani prinos bioplina, prinos metana i kvaliteta proizvedenog bioplina. Rezultati istraživanja pokazuju da način skladištenja značajno utječe na učinkovitost anaerobne digestije. Specifična proizvodnja bioplina kretala se od 78,86 do 250,59 NL kg⁻¹, dok se specifična proizvodnja metana kretala od 24,95 do 152,20 NL kg⁻¹. Najveći prinos bioplina i metana ostvaren je kod silirane divovske trske, dok su najniže vrijednosti zabilježene kod sjenaže divovske trske. Sadržaj metana u proizvedenom bioplinu kretao se od 31 i 62 % pri čemu je najveća kvaliteta bioplina uočena kod divovske trske.

Na temelju dobivenih rezultata može se zaključiti da način skladištenja predstavlja važan čimbenik optimizacije proizvodnje bioplina iz višegodišnjih poljoprivrednih energetske kulture. Anaerobna fermentacija tijekom skladištenja dovela je do povećanja biorazgradivosti biomase i povećane učinkovitosti proizvodnje bioplina. Time se potvrđuje potencijal višegodišnjih poljoprivrednih energetske kulture kao održive sirovinke baze za sustave proizvodnje bioplina.

Ključne riječi: bioplin, anaerobna digestija, anaerobna fermentacija, lignocelulozna biomasa, poljoprivredne energetske kulture, miskantus, divlje proso, divovska trska, skladištenje biomase, proizvodnja metana

THE INFLUENCE OF THE PRESERVATION METHOD ON THE EFFICIENCY OF BIOGAS PRODUCTION FROM DEDICATED PERENNIAL ENERGY CROPS

Extended summary

Introduction and research motivation

The growing demand for renewable energy sources and the need to reduce greenhouse gas emissions have intensified research into sustainable feedstocks for biogas production. Maize silage remains one of the most used substrates in biogas plants; however, its use raises concerns about competition with food production, environmental impacts and long-term sustainability. Consequently, perennial lignocellulosic energy crops such as miscanthus (*Miscanthus × giganteus*), switchgrass (*Panicum virgatum*), and giant reed (*Arundo donax*) have attracted attention as alternative substrates due to their high biomass yield, low agronomic input requirements, and ability to grow on marginal land.

Despite these advantages, the use of perennial lignocellulosic biomass in anaerobic digestion is limited by its complex structural composition, particularly its high lignin content, which reduces biodegradability and methane yield. One possible approach to improving biomass utilization is the application of anaerobic fermentation during storage, which may simultaneously preserve biomass and act as a

biological pretreatment by altering its structural properties. Therefore, the aim of this research was to evaluate the influence of preservation methods on the efficiency of biogas production from selected perennial energy crops.

Aim and structure of the doctoral thesis

The aim of this doctoral research was to determine the influence of biomass preservation by anaerobic fermentation, in the form of silage and haylage, on changes in chemical and structural composition, as well as on biogas and methane production potential. The research included three perennial energy crops: miscanthus, switchgrass, and giant reed. Emphasis was placed on the influence of preservation method on the lignin content and overall efficiency of anaerobic digestion.

Materials and methods

The experimental part of the research included biomass sampling, preparation, and preservation using different preservation methods. Chemical, physico-chemical, and structural analyses were conducted to determine dry matter and ash content, elemental composition, micro and macrolelements, as well as structural components including cellulose, hemicellulose, and lignin. The efficiency of biogas production was evaluated through laboratory anaerobic digestion tests, in which specific biogas production (SBP), specific methane production (SMP), and biogas quality were determined.

Results

The results showed that the preservation method significantly affected both the structural properties of biomass as well as the efficiency of anaerobic digestion. Specific biogas production ranged from 78.86 to 250.59 NL kg⁻¹, while specific methane production ranged from 24.95 to 152.20 NL kg⁻¹. The highest biogas and methane yields were obtained from ensiled giant reed, while the lowest values were obtained from haylage

samples. Methane content in the biogas produced ranged from approx. 31% to 62%, with the highest biogas quality recorded for giant reed.

The results suggest that anaerobic fermentation during preservation contributed to partial degradation of lignocellulosic structures and improved substrate availability for microbial activity, leading to increased biogas production efficiency. Differences among the crops investigated confirmed that both, biomass composition and preservation method are key factors in determining the suitability of perennial energy crops for biogas production.

Contribution of the doctoral research and conclusions

The research confirms that the biomass preservation method is an important factor in optimising biogas production from perennial energy crops. It was found that anaerobic fermentation during preservation improves biomass biodegradability and increases process efficiency, demonstrating that perennial energy crops can serve as a sustainable feedstock for future biogas production systems. The results contribute to a better understanding of the relationship between biomass preservation and anaerobic digestion efficiency and provide a basis for further optimisation of biomass utilisation in sustainable bioenergy systems.

Keywords: biogas, anaerobic digestion, anaerobic fermentation, lignocellulosic biomass, perennial lignocellulosic energy crops, miscanthus, switchgrass, giant reed, biomass preservation, methane production