Black Sea Journal of Agriculture
doi: 10.47115/bsagriculture.1601603

Open Access Journal
e-ISSN: 2618 – 6578

Research Article
Volume 8 - Issue 2 : 152-157 / March 2025

INVESTIGATING THE POTENTIAL OF COMBINING CATTLE WASTE WITH SWITCHGRASS AND SUGAR BEET LEAVES FOR BIOGAS PRODUCTION

Cevat FİLİKCİ[1]*, Tamer MARAKOĞLU[2]

[1]*Kırşehir Ahi Evran University, Çiçekdağı Vocational School, Department of Plant and Animal Production, 40700, Kırşehir, Türkiye*
[2]*Selçuk University, Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering, 42130, Konya, Türkiye*

Abstract: This research aimed to determine the biogas potential produced as a result of different mixtures of cattle waste (CW), three different Switchgrass (SG) (*Panicum virgatum* L.) and beet leaves (BL). In the study, a laboratory-scale setup was established to determine the biogas potential. The experimental design used in this study consisted of three treatment groups. Biogas measurements were taken until the end of biogas production of the materials and recorded on computer at. In the first experimental group, biogas yields of all materials were determined separately. In the second experimental group, cattle waste (CW) (1:1 ratio) was mixed with other materials. It was observed how much the amount of gas produced by the cattle waste, which was kept constant, increased as a result of the mixture with which material, and the Switchgrass (*Panicum virgatum* L.) plant, which provided the highest yield, was selected. Then, in the third experimental group, the cattle waste (CW) was kept constant at fifty percent and different mixtures of Switchgrass (*Panicum virgatum* L.) plant and beet leaves were formed. It was revealed in which mixture the highest biogas yield was obtained. In the study, it was observed that the biogas yield rate of cattle waste was higher than the other materials within the framework of the literature information and the extent to which Switchgrass plants and beet leaves increased the biogas yield. During the measurements, the temperature and pH values were checked periodically and the mixing process was carried out by hand shaking every day. The experimentals were carried out considering a 10% dry matter rate. The highest biogas yield was found to be 3504.07 mL g DM^{-1} of CW (Cattle Waste) at the end of the 30^{th} day in the 1st experimental group. Biogas yield values for the other materials in the 1^{st} experimental group were determined as BL 2148 mL. gDM^{-1} , SG1 (Kanlow) 1971.4 mL.gDM^{-1} , SG2 (Shawne) 1058.4 mL g DM^{-1} and SG3 (Alamo) 822.5 mL.g DM^{-1} , respectively. In the 2^{nd} experimental group, after the gas outflows stopped at the end of the 16^{th} day, the highest biogas yield was determined as 707.82 mL.gDM^{-1} in the CW-SG1 mixture. In the 3^{rd} experimental group, at the end of the 43^{rd} day, a total of 1997.5 mL.gDM^{-1} was determined in the CW (50%)- SG (20%)- BL (30%) mixture.

Keywords: Biogas, Biomethane, Lignocellulosic biomass, Sugar beet leaf, Sustainable energy

***Corresponding author:** Kırşehir Ahi Evran University, Çiçekdağı Vocational School, Department of Plant and Animal Production, 40700, Kırşehir, Türkiye
E mail: cevat.filikci@ahievran.edu.tr (C. FİLİKCİ)
Cevat FİLİKCİ https://orcid.org/0000-0002-4169-8412
Tamer MARAKOĞLU https://orcid.org/0000-0002-2824-116X

Received: December 14, 2024
Accepted: January 15, 2025
Published: March 15, 2025

Cite as: Filikci C, Marakoğlu T. 2025. Investigating the potential of combining cattle waste with switchgrass and sugar beet leaves for biogas production. BSJ Agri, 8(2): 152-157.

1. Introduction

Energy requirements is increasing with the technological developments in the world and in our country. As a result of this growing need in recent years, humanity has turned to different energy systems. The fact that exhaustible energy sources (oil, natural gas, coal, etc.) are unable to meet the need and harm the environment supports this trend. Along with renewable energy sources, has a move towards methods of obtaining energy that provide different and continuous use.

Developed countries are increasing, expanding energy diversity and continuing their search for alternative energy by trying to reduce dependence on certain types of energy sources. Biofuels are one of the most important new and rapidly expanding alternative sources (Eser et al., 2007).

Türkiye is negatively affected by the fact that 92% of our oil needs are met through imports and our economy is dependent on imports. This is a problem for all countries at risk in terms of energy security. In this context, the development of agriculture-based biofuels such as biodiesel, bioethanol, biomass and biogas attracts attention worldwide (Christian and Elbersen, 1998). Switchgrass was designated as a model plant among 37 species in the United States due to its utility as a feed source and its significant bioenergy potential. The cultivation of switchgrass is promoted for energy and animal feed production owing to its high net energy yield per unit area, low cultivation costs, low ash content, high water use efficiency, enhanced adaptability, facile seed production across diverse terrains, and substantial carbon sequestration capacity in the soil (Samson and Omielan, 1992; Sanderson et al., 1996).

The most important point of Switchgrass cultivation is the realization of a healthy plant. For this, the mechanization, soil preparation and sowing techniques to be applied are very important. With the experiences obtained from the results of previous projects in Türkiye, it was tried to create a system to utilize the existing agricultural tools and machinery in the most appropriate way for the cultivation and establishment of this plant (Soylu et al., 2010).

The research carried out within the scope of the TUBİTAK Project No. 114O941 titled "Adaptation of *Panicum virgatum* L. Plant, Creation of Adaptation Maps, Determination of Mechanization Characteristics, Energy Declaration and Biogas Production from Waste Bioethanol" was carried out in the Karapınar district of Konya province. The Kanlow variety of switchgrass demonstrated exceptional performance in terms of green biomass yield and dry grass yield. However, for the Haymana district of Ankara province, Cave in Rock, Shawnee and Shelter varieties were found promising for green biomass yield and the Kanlow variety was found promising for dry herbage yield. Alamo variety was recommended for green biomass yield at the Simav location (Soylu et al., 2010).

Switchgrass is a highly regarded plant for biofuel production worldwide, but unfortunately, it is not widely recognized in our country. If its cultivation is prioritized on a larger scale, significant gains in energy production could be achieved, positioning it as an important future energy source.

Sugar beet is an important agricultural crop with economic potential attributable to its high yield capacity. From literature sources, sugar beet yields range from 40 to 90 t ha^{-1} and beyond (Ungai and Győri, 2007).

In a study conducted by Pospišil et al. (2006), the production of 42 sugar beet hybrids was investigated. The results revealed a wide range of yields, varying from 61 t ha^{-1} to an exceptional high of 101.54 t ha^{-1}.

Annual weather conditions significantly influence the yield and technological quality of sugar beet, as demonstrated by Pospišil et al. (1999) when identical sugar beet varieties were utilized throughout the years of research.

In terms of sugar beet by-effluents, in addition to sugar primary production, sugar beet by-products include dry or wet sugar beet noodles, molasses, saturation sludge and about 60% of the green mass of sugar beet leaves and heads. Previously used as cattle feed, the leaves and heads are now used as green manure on arable land. Given the global energy crisis, sugar beet is increasingly seen as a suitable energy crop for biofuel production (Szakál et al., 2007). Sugar beet production in Türkiye reached 18.9 million tons in 2023. Consequently, 756 thousand tons of sugar beet-derived agricultural waste was generated. The energy equivalent value of this agricultural waste is quantified as 265,881.2 TOE $year^{-1}$ (Anonymous, 2023). In this context, it is anticipated that the utilization of agricultural wastes from sugar beet as a substrate in biogas production will yield significant energy gains.

In this study, it was aimed to determine the biogas potential produced as a result of different mixtures of cattle waste (CW), three different Switchgrass (*Panicum virgatum* L.) plants (SG1 (Kanlow), SG2 (Shawne), SG3 (Alamo)) and sugar beet leaves (BL).

2. Materials and Methods

2.1. Materials

2.1.1. Organic Materials Used in Biogas Production

The switchgrass varieties Kanlow, Shawnee, and Alamo were obtained from Konya Selçuk University, Faculty of Agriculture, Department of Field Crops. Switchgrass samples were ground and stored under optimal storage conditions (ideal humidity, temperature, etc.). Likewise, sugar beet leaf samples used in biogas production studies were obtained from different regions in Konya province. Sugar beet leaf samples were stored under optimal storage conditions (ideal humidity, temperature, etc.).

2.1.2. Establishment of Experimental Setup and Determination of Application Pattern to Determine Biogas Potential

To determine the biogas potential, the experimental setup (Figure 1) consisting of the glass jar, 10x7 polyurethane hose (Blue) (10m), 10 mm hose inlet ball valve (5 pieces), 10 pneumatic tees (5 pieces), 1/4 - 10 pneumatic rotary elbows (20 pieces) was installed.

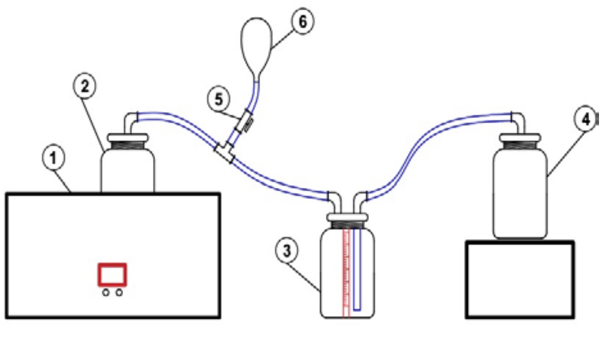

Figure 1. Experimental setup (1. Water bath device, 2. Reactor (Glass jar), 3. Acidified water (Gas outlet), 4. Water Inlet, 5. Gas sampling valve, 6. Gas storage balloon)

Within the scope of the research, an experimental design was created as the 1st experimental group, 2nd experimental group and 3rd experimental group. The experimental design is given in Figure 2.

First Group					Second Group				Third Group		
CW	SG-1 (Kanlow)	SG-2 (Shawne)	SG-3 (Alamo)	BL	CW-SG-1	CW-SG-2	CW-SG-3	CW-BL	CW(%50)- SG(%25) - BL(%25)	CW(%50)- SG(%30) - BL(%20)	CW(%50)- SG(%20) - BL(%30)

Figure 2. Experimental design

2.1.3. Instruments and Devices Used in Experiments

2.1.3.1. Water Bath Devices

JSR - JSIB-22T Series / Circulating Water Bath device and BW-10H Heating Bath (11.5L) device were used to maintain the reactor operating temperature as mesophilic (37±1) in the biogas setup. The BW-10H Heating Bath (11.5L) represents an economically viable solution for maintaining optimal temperature control in laboratory settings. This digital water bath exhibits remarkable temperature stability, making it a dependable choice for scientific and research experimentals

2.1.3.2. Precision Balance

Weighing of the samples and mixtures prepared to be used in the determination of biogas potentials was carried out with the help of "Denver Instrument" brand precision measuring balance with a maximum capacity and sensitivity of 0.1 mg and 210 g, respectively.

2.1.3.3. pH Measurement Paper

pH 0 - 14 pH-Indicator strip universal indicator Mcolorphast pH Paper was used to determine the pH values of the materials and mixtures in the experimental groups.

2.2. Metods

2.2.1. Performing Basic Characterization Analyses

A preliminary analysis were conducted to establish the dry matter and organic matter content for the energy crops switchgrass, sugar beet leaves, and cattle wastes. These were done to determine the appropriate quantities of these materials needed for the experimental setup, which is aimed at assessing biogas production and achieving the desired solids concentration in the reactor (refer to Table 1).

Table 1. Basic Characterization (Dry Matter, Organic Matter) Analysis

Sample Name	Organic Matter (%)	Sample (g)	Oven Dry (g)	Dry Matter (%)
SG-1 (Kanlow)	6.92	4.6506	4.3286	93.08
SG-2 (Aloma)	6.42	3.1603	2.9573	93.58
SG-3 (Shelter)	6.30	3.7667	3.5295	93.70
Sugar Beet Leaves	85.71	20.4167	2.9174	14.29
Cattle Waste	90.12	14.8338	1.4657	9.88

2.2.2. Determination of Dry Matter and Mixture Ratios

One of the desired reactor conditions to make the best use of bacteria groups fermenting in an oxygen-free environment to produce biogas and methane content is the dry matter level of the feed materials used (Von Mitzlaff, 1988). Biogas production is best when the total dry matter content of the feed materials is in the range of 6-13% (Šarapatka, 1993). Accordingly, the dry matter content was set to 10% in all treatments. Different mixing ratios were determined by optimizing with cattle waste, which was kept constant, and three different switchgrass varieties and beet leaf samples (Nagamani and Ramasamy, 1999).

2.2.3. Determination of the Amount of Biogas Produced

In the experiments, 1000 ml glass jar bottles served as reactors to assess the biogas quantity. The experimental setup was placed in a secluded area to shield it from sunlight. The reactors were maintained at mesophilic (37±°C) conditions. To maintain a constant temperature, JSR - JSIB-22T Series/recirculating water bath device and BW-10H heating bath (11.5 l) were used. To measure the biogas production, two glass jars were connected with pneumatic seals according to the water displacement principle. The first jar connected to the reactor was filled to the brim with water treated with sulfuric acid (H_2SO_4) (pH < 2) and sealed (Durgut, 2020). The volumes were determined by drawing on the glass jars from the Solidworks program on the PC, and the volumes corresponding to each mm length were determined and added to the glass jars for readings. The gas content of the space between the reactor and the glass jar filled with acidified water was measured by adding a valve to the connection line between the two containers. After the experiments, the gas collected via the valve was extracted from the gas containment flask and its content was analyzed. To ascertain the volume of biogas generated during the experiments, measurements were taken using scales placed under glass jars filled with water. In the conducted experimental setup, measurements of biogas production were monitored continuously for 30 days in experimental 1, 16 days in experimental 2, and 43 days in experimental 3 following the completion of biogas production from the materials. The collected biogas data was meticulously recorded and stored within a computerized system for analysis.

2.4. Statistical Analysis

This study was conducted according to the random plots trial design. Statistical analysis was performed using the JMP package version 5.0. Results were presented as means±standard errors (n=3) for the treatments. Differences between means were analyzed by one-way analysis of variance (ANOVA) followed by the LSD test, and the degree of difference was indicated by letters at the 5 % level. Heat map of Pearson's correlation coefficient matrix and principal component analysis of the evaluated attributes were produced by OriginPro 2019b (32Bit).

3. Results and Discussion

3.1. Biogas Values Produced from Materials

After completing the biogas production process in the experimental setup, measurements of biogas were taken continuously for 30 days in the 1st experimental, 16 days in the 2nd experimental, and 43 days in the 3rd experimental. These measurements were carefully recorded in the computer system. The biogas yield values obtained after 30 days in the 1st treatment group are presented in detail in Table 2 below.

Table 2. Total biogas yield values of the 1st experimental

Material	Biogas Yield Values (mL gDM^{-1})
CW	3504.07
SG1(KANLOW)	1971.4
SG2(SHAWNE)	1058.4
SG3(ALAMO)	822.5
BL	2148.8

When evaluating biogas yields, the highest yield of 3504.07 mL gDM^{-1} in CW was observed after 30 days. The other total biogas yield values obtained after 30 days from BL, SG1 (Kanlow), SG2 (Shawne), and SG3 (Alamo) materials were 2148.8 mL.gDM^{-1}, 1971.4 mL.gDM^{-1}, 1058.4 mL.gDM^{-1}, and 822.5 mL.gDM^{-1}, respectively. In the study conducted by Liew et al. (2012), the potential for methane production from various biomass feedstocks, including corn cobs, wheat straw, garden waste, and leaves, was examined through the process of anaerobic fermentation. Maximizing methane production was 81.2 L kg.VDM^{-1} from corn cobs, followed by wheat straw (66.9 L kg.VDM^{-1}), leaves (55.4 L kg.VDM^{-1}), and garden waste (40.8 L kg.VDM^{-1}). Within the scope of the experiments, the total biogas yield values determined from the 2nd and 3rd experimental group mixtures are shown in Table 3 below.

Table 3. Total biogas yield values determined from mixtures in the 2nd and 3rd experimental groups

Material	Biogas Yield Values (mL gDM^{-1})
CW-SG1	707.82
CW-SG2	119
CW-SG3	198
CW-BL	462.7
CW(%50)- SG(%25)-BL(%25)	151
CW(%50)- SG(%30)-BL(%20)	1913
CW(%50)- SG(%20)-BL(%30)	1997.5

In the second group, the highest biogas yield recorded was 707.82 mL. gDM^{-1} from the CW-SG1 mixture. Other biogas yields were 462.7 mL. gDM^{-1} from the CW-BL mixture, 119 mL. gDM^{-1} from the CW-SG2 mixture, and 198 mL. gDM^{-1} from the CW-SG3 mixture, respectively. Ahn et al. (2010) investigated the biogas production potential of switchgrass and a mixture of animal manure (cattle, poultry, and pig). They found the maximum methane yield to be 337 $mLCH_4.gVKM^{-1}$ in pig manure, 28 $mLCH_4.gVKM^{-1}$ in cattle manure, and 2 $mLCH_4.gVKM^{-1}$ in poultry manure. In the third experimental, the highest biogas yield observed was 1997.5 mL. gDM^{-1} from the CW(50%)-SG(20%)-BL(30%) mixture. Other biogas yields in the third cohort were 1913 mL. gDM^{-1} from the CW(50%)-SG(30%)-BL(20%) mixture and 119 mL. gDM^{-1} from the CW(50%)-SG(25%)-BL(25%) mixture, respectively. Lehtomäki et al. (2007) investigated the anaerobic treatment of energy crops, crop wastes, and manure mixtures in a semi-batch complete mixed reactor. They found that the highest methane yield from cow manure alone was 155 $mLCH_4.gVKM^{-1}$, while the highest methane yields achieved from anaerobic fermentation of cow manure with grass, sugar beet, and oat straw in certain proportions were 268, 229, and 213 $mLCH_4.gVKM^{-1}$, respectively.

3.2. Evaluation of Analysis

In light of the variance analysis, a statistically significant disparity was observed among the examined variables ($p < 0.01$) (Table 4). Subsequently, the LSD test was applied to these notable findings (Table 5).

Table 4. Results from Variance Analysis

Application	Average Biogas Yield (ml/gDM)	Standard Deviation	Standard Deviation Square (Variance)	Minimum (ml/gDM)	Maximum (ml/gDM)
CW-SG1	686.205	15.87	251.94	670.4	707.82
CW-BL	440.225	22.61	511.42	412	462.7
CW(50%)-SG(30%)-BL(20%)	135.4	16.27	264.72	112.4	151
CW(50%)-SG(20%)-BL(30%)	1731.667	198.92	39569.6	1455.2	1913
CW(50%)-SG(25%)-BL(25%)	1914.867	88.18	7775.68	1822.3	1997.5

Table 5. Results of LSD Test

Material	N	Standard Error Mean	Mean [(1)]
CW-SG1	4	8.093	686.205[b]
CW-BL	4	11.694	440.225[c]
CW(50%)- SG(25%)- BL(25%)	3	11.741	1914.867[a]
CW(50%)- SG(30%)- BL(20%)	3	140.455	135.4[d]
CW(50%)- SG(20%)- BL(30%)	3	50.819	1731.667[a]

[(1)]The means shown with different upper case letters in the same column are statistically significant (a-d: $p<0.01$, LSD=181.33).

When the table obtained according to the LSD results is examined, the highest biogas yield was obtained in the CW(50%)-SG(25%)-BL(25%) mixture, and the lowest biogas yield was obtained in the CW(50%)-SG(30%)-BL(20%) mixture.

4. Conclusion

This In this research, the biogas potential of the Switchgrass plant, previously analyzed for mechanization criteria in the TUBİTAK project was determined when it was combined with the high-yielding sugar beet plant, particularly abundant in Konya and its surrounding areas(Filikci, 2018). The resulting biogas yield was determined through its mixture with cattle waste. In the 1st experimental group, the highest biogas yield was determined as 3504.07 mL. gDM^{-1} in cattle waste (CW) at the end of the 30th day. The biogas yield values in the other materials in the 1st experimental group were determined as BL mL. gDM^{-1}, SG1(Kanlow) 1971.4 mL. gDM^{-1}, SG2(Shawne) 1058.4 mL. gDM^{-1} and SG3(Alamo) 822.5 mL. gDM^{-1}, respectively. In the 2nd experimental group, the highest biogas yield was determined as 707.82 mL. g DM^{-1} in the CW- SG1 mixture at the end of the 16th day. In the mixtures in the 2nd and 3rd experimental groups, the second was determined as 1997.5 mL.gDM^{-1} from the CW (50%)-SG (20%)-BL (30%) mixture. After reviewing the LSD test and variance analysis results, there is no significant statistical difference observed between the biogas yield values of the CW (50%)-SG (25%)-BL (25%) and CW (50%)-SG (30%)-BL (20%) mixtures. However, it was concluded that the biogas yield values of the CW (50%)-SG(25%)-BL(25%) and CW(50%)-SG(30%)-BL(20%) mixtures were the highest.
The use of BL mixtures resulted in high biogas yields and biomethane rates. When considering agricultural waste, beet leaves are a significant byproduct, especially in the sugar beet farming areas of Konya province and its surroundings. Although some beet leaves are used in animal feeding, complete disposal is not feasible. The substantial biomass from beet leaves can be converted into biogas energy through anaerobic fermentation, offering significant benefits. Agricultural mechanization and animal husbandry are key components of our economy. Currently, a large portion of energy needs in agricultural enterprises are met using non-renewable sources. Utilizing biogas, which is eco-friendly and reduces production inputs, is becoming increasingly important in meeting energy demands in agricultural enterprises. Biogas sources in agricultural enterprises include animal manure, various energy crops, and agricultural wastes. This not only enhances business efficiency but also mitigates environmental damage by reducing carbon dioxide (CO_2) emissions (Ayhan, 2013)

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	C.F.	T.M.
C	60	40
D	60	40
S	60	40
DCP	50	50
DAI	60	40
L	55	45
W	60	40
CR	55	45
SR	55	45
PM	50	50

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because there was no study on animals or humans.

Acknowledgments

This study was summarized from a part of the PhD Thesis titled *"Investigation of biogas yield of some vegetable and animal wastes and Switchgrass (Panicum virgatum L.) mixtures".*

References

Ahn HK, Smith MC, Kondrad SL, White JW. 2010. Evaluation of biogas production potential by dry anaerobic digestion of switchgrass–animal manure mixtures. Appl Bioc Biot, 160: 965-975.

Anonymous 2023. Biogas formation stages, biogas usage areas. T.C. Enerji ve Tabii Kaynaklar Bakanlığı, https://enerji.gov.tr/eigm-yenilenebilir-enerji-kaynaklar-biyokutle (accessed date: December 14, 2025)

Ayhan A. 2013. A study on determining the amount of biogas that can be produced by mesophilic fermentation from cattle manure and corn silage at different mixing ratios. PhD thesis, Bursa Uludağ University, Institute of Science and Technology, Bursa, Türkiye, pp: 52.

Christian D, Elbersen H. 1998. Prospects of using Panicum virgatum (switchgrass) as a biomass energy crop. N. ElBassam (ed.), New York, USA pp: 257-263.

Durgut FT. 2020. Fabrication of a prototype biogas reactor for experimental purposes and evaluation of its performance in different biomass mixtures and media. PhD thesis, Tekirdag Namik Kemal University, Tekirdağ, Türkiye, pp: 47.

Eser V, Sarsu F, Altunkaya M. 2007. Current status and future of plants used in biofuel production. Biofs Biof Techn, 51: 61.

Filikci C. 2018. Determination of swıtch grass production mechanization features, MSc thesis, Selçuk University, Institute of Science and Technology, Konya, Türkiye, pp: 42.

Lehtomäki A, Huttunen S, Rintala J. 2007. Laboratory investigations on co-digestion of energy crops and crop residues with cow manure for methane production: effect of crop to manure ratio. Resour Conserv Recycl, 51(3): 591-609.

Liew LN, Shi J, Li Y. 2012. Methane production from solid-state anaerobic digestion of lignocellulosic biomass. Biomass Bioenergy, 46: 125-132.

Nagamani B, Ramasamy K. 1999. Biogas production technology: an Indian perspective. Current Sci, 44-55.

Pospišil M, Mustapić Z, Pospišil A, Tot I, Salaj M. 1999. Ispitivanje gospodarskih svojstava novih hibrida šećerne repe. Sjemenarstvo, 16(5): 403-413.

Pospišil M, Pospišil A, Mustapić Z, Butorac J, Tot I, Žeravica A. 2006. Proizvodne vrijednosti istraživanih hibrida šećerne repe. Poljoprivreda, 12(1): 16-21.

Samson RA, Omielan, JA. 1992. Switchgrass: A potential biomass energy crop for ethanol production. In: The Thirteenth North American Prairie Conference, 6-9 August, Windsor, Ontario, Canada, pp: 253-257.

Sanderson MA, Reed R, McLaughlin S, Wullschleger SD, Conger BV, Parrish D, Wolf D, Taliaferro C, Hopkins A, Ocumpaugh W. 1996. Switchgrass as a sustainable bioenergy crop. Bioresour Technol, 56(1): 83-93.

Šarapatka B. 1993. A study of biogas production during anaerobic fermentation of farmyard manure. Biomass Bioenergy, 5(5): 387-393.

Soylu S, Sade B, Öğüt H, Akınerdem F, Babaoğlu M, Ada R, Eryılmaz T, Öztürk O, Oğuz H. 2010. Investigation of agronomic potential of Switchgrass (Panicum virgatum L.) as an alternative biofuel and biomass crop for Turkey. European Biomass Conferance and Exihibition Proceedings, 9-12 June 2025, Valencia Italy, pp: 230-234.

Szakál P, Schmidt R, Lesny J, Kalocsai R, Barkóczi M. 2007. Quality parameters of wheat. Bio ethanol versus bread? Cereal Res Commun, 35: 1137-1140.

Ungai D, Győri Z. 2007. Possibility of increasing sugar yield by foliar treatments for crop production sustainability. Cereal Res Commun, 35, pp: 1241-1244.

Von Mitzlaff K. 1988. Engines for biogas. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH (Braunschweig Vieweg is a subsidiary company of the Bertelsmann Publishing Group), Eschborn, Germany, pp: 1-132.