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Original scientific paper

Agronomic performance of the Camelina sativa accession and its biogas production

Abstract

This research was set up in 2013 in agroecological conditions of continental Croatia (3 different locations). The extperiment was set as a split-plot design in four replicates, with three levels of the main treatments of soil tillage (CT - plowing; MD - reduced multiple disk harrowing; SD - reduced single disk harrowing) and levels of subtreatment fertilization (F0 - control; F1 - standard KAN fertilization; F2 - fertilization with 5% urea solution; F3 - Profert Mara; F4 - Profert NGT; F5 - Thiofer; F6 - EM Aktiv). The highest camelina grain and biomass yield was achieved in the subtreatment F6 when using microbiological fertilizer EM Aktiv, regardless of the applied agrotechnics. After the harvest experiment, anaerobic batch co-digestion of camelina and cow manure was conducted under thermophilic conditions to determine camelina's potential for biogas production. The biogas potential of camelina was expressed as biogas and methane yields which ranged from 382.00 and 246.04 cm3 g-1 VS, respectively. If compared to maize which is often used as a standard for comparison of methane yields, maize methane yields are higher by 21 to 40%.

Keywords: *anaerobic co-digestion, biogas, Camelina sativa L. Crantz, manure, organic farming.*

Introduction

The integration of short rotation crops in mixed cropping with grain legumes or cereals offers interesting chances to enhance the efficiency of the plant production by increasing biomass yields and resource efficiency (control of diseases, reduction of agrochemical and fertilizer inputs, reduced soil erosion, more effective use of water and nutrients) (Paulsen, 2008; Herrmann et al., 2016). Different rooting architecture depths and different periods of biomass development in mixed cropping systems can effectively increase the use of available resources and perhaps increase area productivity while simultaneously raising land equivalent ratios. In such cropping systems, a significant quantity of biomass is available and can serve as a source of renewable energy particularly biogas (Paulsen, 2008). Up to now, many European agricultural biogas farms use carbon-rich energy crops as feedstock in anaerobic co-digestion with ammonia-rich animal manures, resulting in a more balanced process that additionally increases biogas production (Herrmann et al., 2016; Kovačić et al., 2018). Though the production of bioenergy from crops is controversial since it requires agricultural land and it competes with food and feeds supply. Therefore, the integration of energy crops like *Camelina sativa* in crop rotations could represent one important measure toward sustainable biogas crop production (Herrmann et al., 2016).

Camelina (*Camelina sativa* L. Crantz), with the popular names false flax or gold of pleasure, is native to Central Asia and the Mediterranean Region and belongs to *Brassicaceae* (*Cruciferae*) family (Jankowski et al., 2019). Recently, interest in camelina has increased rapidly because, besides being short rotation crop (Joshi et al., 2017), it does not require high agricultural inputs,

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it is highly resistant to cold and drought stress, it grows well in semiarid regions, and in the soil, with low fertility (Jankowski et al., 2019; Abramovič and Abram, 2005) whereas it has the potential to provide a broad range of nutritional, medicinal and industrial products, including biofuels (Galasso, 2005). However, there are still unexplored aspects related to agricultural management optimization and its environmental impact so far (Matteo, 2020).

Camelina is an annual plant with both summer and winter biotypes that have different morphology and seed characteristics (Wittenberg et al., 2019; Kurasiak-Popowska and Stuper-Szablewska, 2019). The existence of both annual types allows camelina to be integrated as a rotational crop in cropping systems usually dominated by small grain cereals, corn, and soybean (Berti et al., 2016). Besides, farmers accommodated themselves to an EU Nitrate Directive which requires the implementation of good agricultural practices to limit the transfer of agricultural nitrate sources to water resources and implement fertilizer plans and intermediate cropping. Intermediate crops positively affect soil fertility, eliminate erosion and limit nutrient loss by fixing the remaining soil nutrients (especially mineral nitrogen) not used by the main crop. Recently, these cultures which are considered energetic catch crops are occasionally used as co-substrates in some agricultural biogas plants in combination with manure (Peu et al., 2013).

Due to the relatively short vegetation time, from 85 to 100 days (Gesch and Cermak, 2011) it can be used more efficiently as a post-harvest crop during the warm part of the year, particularly after winter crops are harvested during June and July. As a post-harvest crop, camelina may have multiple roles, e.g. cover crop, catch crop, weeding crop, honey crop, biodiversity crop, etc. (Eberle, 2015).

Camelina does not require excessively deep basic tillage (Gesch and Cermak, 2011). It is usually sown to a depth of 0.6 to 1 cm. Like other crops in the *Brassicaceae* family, camelina responds to nitrogen (N), sulfur (S), and phosphorus (P) fertilizer applications (Fleenor, 2011). Previous studies showed that camelina has a lower N requirement than other oilseed crops such as sunflower and canola (Obeng and Obour, 2015). Targeted N nutrition should not exceed 60 kg ha^{-1}, up to a maximum of 80 kg ha^{-1} as above this level of fertilization the yield of camelina does not profitably increase (Davis et al., 2013). The research that was conducted by Agegenehu and Honermeier (1997) was increasing N levels from 60 to 130 kg ha^{-1} which resulted in a 30% yield increase but decreased oil concentration in camelina. Plant use efficiency of N from fertilizers is inhibited by deficiency of S which may cause increased losses of N. Therefore, fertilizers that contain S seem to be effective in camelina nutrition and subsequently in obtaining considerable yields of seed and oil (Joshi et al., 2017).

The standard camelina yield ranges from 1000 to 3000 kg ha^{-1} (Krzyżaniak and Stolarski, 2019). Since the cultivation of camelina has lower production costs than other oilseeds (e.g. sunflower, oilseed rape, etc.), this plant has potential from both agroecological and economic points of view (Stamenković et al., 2021). Due to the short vegetation, better soil use is possible which enables two harvests and continuous coverage of the soil with green plant mass. In this way, weed growth is prevented after the summer harvest until autumn sowing, which has a favorable economic and ecological impact.

In Croatian climate conditions, camelina can be cultivated both as a winter and spring crop. However, its commercial development and utilization as a crop in Croatia still did not happen. Only a couple of small producers on family farms are engaged in this production in smaller areas.

Camelina is widely used as a feedstock for the production of biodiesel and jet fuel due to its rich seed oil content which ranges from 30 to 49% (Berti et al., 2011; Pari et al., 2020) and is predominantly explored for biodiesel production. However, the production of biodiesel results in the generation of abundant quantities of by-products and residues (e.g. glycerol, biodiesel washing wastewaters, methanol, and solid residues like pressed seed cakes, spent earth, and agricultural wastes) which pose an environmental issue due to their high organic load. Therefore, those residues and by-products could be easily utilized for the production of chemical compounds or the production of energy by anaerobic digestion (Kolesárová et al., 2011; Plácido and Capareda, 2016). Besides, camelina's potential for biogas production should not be ignored since it has high biomass and grain yield potential with minimal agronomic costs and environmental impact.

Literature on biogas production from camelina and its by-products is scarce. There are two reported researches in the available literature related to this topic. In their research, Paulsen et al. (2009) conducted field and laboratory experiments of anaerobic thermophilic co-digestion of camelina oilcake, wheat straw, and cattle manure, while Herrmann et al. (2016) examined a wide range of energy crops including camelina, to identify the main parameters that influence biomass quality for biogas production.

This study aimed to evaluate the agronomic performance of the camelina accession through organic farming and afterward biogas production potential through anaerobic co-digestion with cow manure. In addition, this study aimed to point out the unutilized agronomic and bioenergy potential of camelina in Croatia.

To the best of our knowledge, this study is the first attempt to analyze both the agronomic production efficiency and biogas potential of oil crop species camelina in Croatia. Moreover, the results of this research will complement the knowledge of camelina as a bioenergy plant used in biogas production.

Materials and methods

Agronomic accession

The research was conducted at three different locations in the eastern part of Croatia (Poljanci - Brod-Posavina County, Široko Polje - Osijek-Baranja County, Vraneševci - Virovitica-Podravina County) which is located in the lowlands of the southern parts of the Pannonian region. The research was conducted during the summer of 2013 on soil types (Poljanci - humic gleysol, Široko Polje - eutric cambisol, Vraneševci - luvisol) determined according to IUSS Working Group WRB (2015).

The weather conditions during the session are given in Table 1, while precipitation data is given in Table 2. The mean air temperature in Poljanci (Slavonski Brod) from June to October was 18,7 °C (0,9 °C higher compared to the long term mean (LTM), while the total rainfall was 341,3 mm (27,5 mm less compared to the LTM). The mean air temperature in Široko Polje (Đakovo) was 19,4 °C (1 °C higher compared to the LTM), while the total rainfall was 373,2 mm (28,1 mm more compared to the LTM). The mean air temperature in Vraneševci (Slatina) was 18,4 °C (0,5 °C higher compared to the LTM), while the total rainfall was 296,1 mm (78 mm more compared to the LTM).

Organic cultivation of camelina was conducted in a post-harvest period (sowing after removal of pre-culture winter barley, end of June 2013). The experiments were set up in a split-plot design and replicated 4 times with 3 levels of tillage where the plot size for fertilization was 10 m^2. The three primary soil tillage treatments were as follows: conventional tillage (CT) executed by plowing at a depth of up to 20 cm; reduced tillage treatments executed by multiple disk harrowing (MD); reduced tillage treatments executed by single disk harrowing (SD). Only subtreatmens of fertilization were applied without base fertilization. The subtreatments of fertilization were as follows: no side fertilizer, control (F0); standard KAN fertilization (F1); fertilization with 5% urea solution (F2); application of 8 L ha^{-1} of foliar fertilizer Profert Mara

(F3); application of 2 kg ha^{-1} of foliar fertilizer Profert NGT (F4); application of 2 L ha^{-1} of microbiological fertilizer Thiofer (F5); application of 2 L ha^{-1} of microbiological fertilizer EM Aktiv (F6).

Harvest was performed in the first week of October 2013 manually by spreading seeds (10 kg ha^{-1}) on the surface of the cultivated soil and afterward an additional passage was made with a harrow to feed the seeds into the soil. The camelina aboveground biomass was cut with hedge trimmers at a height of 3 to 5 cm from a 1/4 m^2 frame at 4 randomly selected places. Harvested camelina biomass was weighed and subsampled and afterward, oven dried at 65 °C for 48 h for moisture content determination while the camelina seeds were air-dried for moisture determination.

Table 1. The main air temperature (°C) in 2013 Camelina sativa vegetation as compared to the Long Term Mean (LTM = 1963-2018) for meteorological stations Slavonski Brod, Đakovo, Vraneševci* (Croatian Meteorological and Hydrological Service, 2018)

	Poljanci (Slavonski Brod)		Široko Polje (Đakovo)		Vraneševci (Slatina)	
Month	Mean air T (°C)	LTM (1963-2018)	Mean air T (°C)	LTM (1963-2018)	Mean air T (°C)	LTM (1963-2018)
June	20.0	19.7	20.2	20.1	19.2	19.6
July	22.1	21.4	23.3	22.0	22.6	21.6
August	23.0	20.7	23.4	21.6	22.0	21.0
September	15.6	16.2	16.1	16.8	15.2	16.3
October	12.9	11.0	13.9	11.6	13.2	11.2
Mean	18.7	17.8	19.4	18.4	18.4	17.9

* closest meteorological stations to the experimental site

Table 2. The total rainfall (mm) in 2013 Camelina sativa vegetation as compared to the Long Term Mean (LTM = 1963-2018) for meteorological stations Slavonski Brod, Đakovo, Vraneševci* (Croatian Meteorological and Hydrological Service, 2018)

	Poljanci	(Slavonski Brod)	Široko Polje	(Đakovo)	Vraneševci	(Slatina)
Month	Monthly rainfall (mm)	LTM (1963-2018)	Monthly rainfall (mm)	LTM (1963-2018)	Monthly rainfall (mm)	LTM (1963-2018)
June	68.9	87.0	84.9	87.6	68.5	90.0
July	86.5	80.7	50.5	55.3	13.7	64.8
August	57.5	69.8	58.8	67.6	74.0	69.7
September	83.8	69.8	123.5	69.2	114.6	83.9
October	44.6	61.5	55.5	65.4	25.3	65.7
Total	341.3	368.8	373.2	345.1	296.1	374.1

* closest meteorological stations to the experimental site

Statistical analysis

The results were statistically analyzed using SAS software for Windows (SAS Institute Inc., Cary, NC, USA). When statistically significant differences were determined ($p > 0.05$) the means were further separated using Fisher's multiple-range test. All results were presented as mean values.

Biogas production

Camelina biomass was collected from the fields after trial from the locality Vraneševci and brought to the laboratory. After collection, camelina biomass was chopped, oven dried (Memmert UFE 600) at 60 °C for 24 h and afterward were ground with a laboratory knife mill (Retsch SM 100, GmbH) into particles with a mean diameter of 3 mm. Cow manure was collected from a local cow farm from the reception pit of a biogas plant in 15 dm^3 plastic pails, brought to the laboratory just before the experiment, and used as inoculum. Two groups of samples were subjected to anaerobic digestion – group C (inoculum – cow manure, which served as a control), and group E (experimental group, composed of camelina biomass and cow manure).

Anaerobic batch co-digestion was performed in a thermophilic regime (55 °C) in apparatus which is comprised of 48 reactors placed in 2 thermostatic water baths which are connected with calibrated glass bottles (with numbered markings from 0 to 720 cm^3) via rubber hoses. Calibrated glass bottles are placed, with a gap facing the bottom, in a glass aquarium which is filled with saturated NaCl solution in order to prevent biogas to dissolve (Figure 1). As biogas production begins and increases, biogas passes from reactors through rubber hoses and accumulates in glass bottles, which results in salt liquid displacement and a rise of the liquid level in the aquarium. The volume of collected biogas can be read from the numbered marking on the bottle. When a glass bottle is filled with biogas, it is closed with a plastic lid while still submerged in the NaCl solution and replaced with a new one. The co-digestion was finished after 36 days when a daily production of less than 1% of the whole production occurred. The total volume of the reaction mixture was 500 cm^3. The substrate/inoculum ratio was 1/5 (based on volatile solids (VS)). The total solids (TS) of all prepared mixtures were in the range of 11 to 13.3%. Each experiment was performed in triplicate. To maintain homogeneity, all reactors were mixed manually five times a day. Cow manure was used as inoculum.

TS were determined after drying at 105 °C in the laboratory oven (Memmert UFE 600) to constant weight. VS were determined by complete combustion in a muffle furnace for 4 h at 550 °C.

Biogas volume and composition were measured every day. The total volume of biogas produced in 1 day was obtained by summing the volumes of accumulated biogas in all bottles which were filled with gas, and the composition of biogas (CH_4, N_2, and CO_2) was analyzed according to a modified method HRN ISO 6974-4:2000 using a GC (Varian 3900) equipped with capillary column CP-PoraPLOT Q fused silica PLOT 25 mm × 0.53 mm, df = 20 µm.

Figure 1. Experimental setup for anaerobic batch co-digestion of camelina and cow manure.

Results and discussion

Grain and biomass yields

Depending on the treatments, camelina grain yield (Table 3) ranged from 935 to 963 kgha^{-1} and it was significantly influenced by soil tillage treatments and fertilization subtreatments. Namely, within each soil tillage treatment, a statistically significant impact of fertilization subtreatment was determined. Thus, in the CT treatment, the statistically significantly higher grain yield was determined on the F6 subtreatment and the lowest on the F0 and F1 subtreatments. In the treatments of MD and SD soil tillage, the influence of fertilization subtreatments was even more noticeable and the statistically significantly higher yield was determined on treatment F6, and the lowest on treatment F0. Depending on fertilization subtreatments, average camelina grain yields ranged from 700 to 1158 kg ha^{-1}.

Table 3. Camelina grain yield (kg ha^{-1})*

	CT	**MD**	**SD**	**mean**
F0	719^{c}	694^{e}	686^{g}	700
F1	934^{c}	910^{cd}	908^{e}	917
F2	1064^{ab}	1040^{b}	1038^{b}	1047
F3	998^{ab}	975^{bc}	973^{c}	982
F4	982^{ab}	960^{d}	956^{d}	966
F5	868^{bc}	845^{d}	841^{f}	851
F6	1178^{a}	1153^{a}	1145^{a}	1158
mean	940	935	963	
LSD	205.79	103.19	107.12	

*The means in the columns followed by different letters are statistically significantly different (Fisher, LSD test, $p < 0.05$)

Similar results of camelina grain yield (899 kg ha^{-1}) were confirmed in the study of 5 different camelina cultivars where grain yields were not affected by cultivars (Neupane et al., 2020). In the study of the influence of the term and method of sowing camelina, the yields ranged from 503 to 921 kg ha^{-1} and were significantly influenced by both investigated parameters (Neupane et al., 2019). The influence of tillage systems on camelina grain yield was determined in the study of camelina production under conventional and conservation tillage practices. Yields ranged from 731 kg ha^{-1} under conservation tillage to 920 kg ha^{-1} under conventional tillage practices (Afshar et al., 2016). The yield of camelina plant mass (Table 4) was also influenced by treatments and subtreatments and ranged from 5447 to 5478 kg ha^{-1} (treatments), and 5231 to 6637 kg ha^{-1} (subtreatments). Namely, within all soil tillage treatments and fertilization subtreatments, the same trend was found with the statistically highest yield achieved on F6 subtreatment in all soil tillage treatments, and the lowest yield on F0 subtreatment.

Table 4. The yield of camelina plant mass (kg ha^{-1})*

	CT	**MD**	**SD**	**mean**
F0	3686^{g}	3664^{g}	3657^{g}	3669
F1	5291^{d}	5264^{e}	5256^{e}	5270
F2	6566^{b}	6544^{b}	6541^{b}	6550
F3	5329^{f}	5304^{d}	5298^{d}	5310
F4	5569^{c}	5536^{c}	5532^{c}	5546
F5	5252^{e}	5224^{f}	5218^{f}	5231
F6	6654^{a}	6632^{a}	6625^{a}	6637
mean	5478	5453	5447	
LSD	88.13	89.10	1327.11	

*The means in the columns followed by different letters are statistically significantly different (Fisher, LSD test, $p<0.05$)

The obtained results were consistent with other studies on the effects of different agrotechnical measures on the yield of camelina biomass ranging from 5494 to 7016 kg ha^{-1} depending on the treatments applied (Walia et al., 2018).

The influence of the application of different types and doses of fertilizers on the camelina biomass yield is evident in a large number of studies, with a special impact on the influence of nitrogen fertilization. Thus, the yields of camelina biomass, under the influence of nitrogen fertilization, can range from 2693 kg ha^{-1} on control to 8265 kg ha^{-1} at a dose of 300 kg N ha^{-1} (Solis et al., 2013). In our study, the yield of camelina biomass was also strongly influenced by subtreatment of fertilization, with the special significance of fertilization with microbiological fertilizer EM Activ (F6) and 5% urea solution (F2), although all yields on fertilization treatments were higher if compared to control (F0). The obtained results confirmed the high efficiency of nitrogen fertilizers on biomass yield. Following the biomass yield, the influence of fertilization on grain yield was also confirmed, with the mentioned subtreatments of fertilization F2 and F6 having the greatest influence.

The application of additional doses of nitrogen fertilizer can almost double the yields of camelina, and some authors have recorded an increase in yield of 0.89 t ha^{-1} compared to the control (0.99 t ha^{-1} control without fertilization, 1.88 t ha^{-1} + 60 kg N ha^{-1}) (Hryhoriv et al., 2020).

Anaerobic co-digestion of camelina

Daily biogas production curves of the inoculum and experimental group are presented in Figure 2. It is evident that concentrated biogas production began around the 7th day and lasted until around the 15th day of digestion, and declined gradually from around the 20th day in both groups of samples. The difference between samples is evident in peaks during this period which was constantly higher in the experimental group which contained camelina.

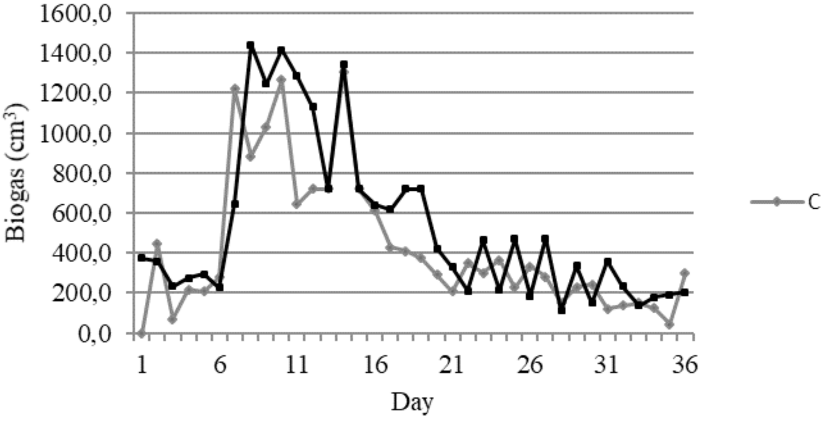

Figure 2. The biogas daily yields were obtained during anaerobic co-digestion of inoculum C and experimental group E.

The biogas production potential is expressed as biogas and methane yields which are presented in Figure 3. There was no significant difference ($p < 0.05$) in the increase of biogas and methane yields between the control and experimental groups. If compared to our results, after a 40-day batch of thermophilic anaerobic co-digestion of cattle manure, wheat straw, and camelina oilcake, Paulsen et al. (2009) reported lower biogas yields (240 and 260 cm^3 g^{-1} VS, for cattle manure and wheat straw (8% TS) mixed with 0.5% of total material weight false flax oilcake, and cattle manure and wheat straw (8% TS) mixed with 5% of total material weight false flax oilcake, respectively). The authors also performed a field experiment in two mesophilic 1000 L-volume digesters in which the effects of camelina oilcake on biogas production were tested in two variants: digester I contained cattle manure and wheat straw (8% TS), whereas digester II contained cattle manure and wheat straw (8% TS) mixed with 5% of total material weight camelina oilcake. Anaerobic co-digestion in digester I resulted in 240 cm^3 g^{-1} VS biogas yield, while in digester II addition of camelina oilcake significantly affected the biogas production process which resulted in 370 cm^3 g^{-1} VS biogas yield. The authors also determined the biogas yield for the pure camelina oilcake and it ranged between 580 and 800 cm^3 g^{-1} VS, while the measured mean methane content of the biogas ranged around 60%. In our experiment mean methane content of the biogas in both experimental groups ranged around 65%.

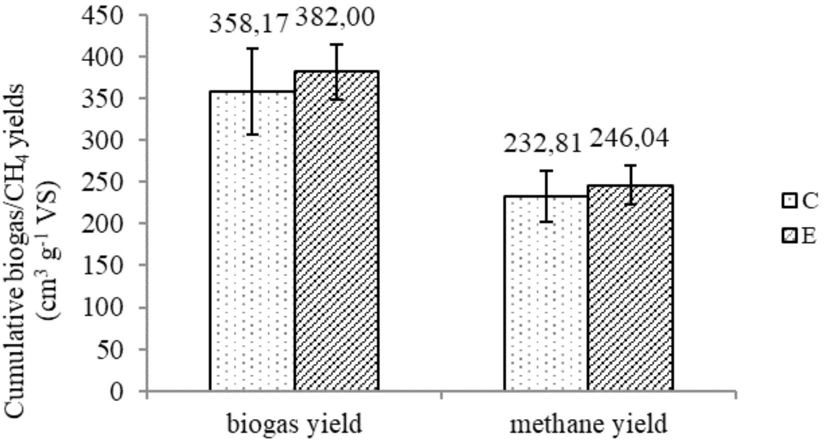

Figure 3. Biogas and methane yields after anaerobic co-digestion of inoculum C and experimental group E. The *error bars* show the standard deviation (*n* = 3).

Herrmann et al. (2016) examined 405 silages and 43 different crop species for chemical composition and methane production, among which was camelina silage mixed with oat and forage pea. Batch 30-day anaerobic mesophilic co-digestion was conducted using inoculum which consisted of digestate of previously completed batch digestion tests with crop materials. Anaerobic co-digestion of camelina resulted in methane yield that ranged between 271 and 333 cm^3 g^{-1} VS with a mean methane yield that ranged 304 cm^3 g^{-1} VS. If compared to our results, we obtained lower methane yields, up to 26%. However, they co-digested three different crops with inoculum (a more diverse chemical composition of the digested material) which could be a reason for higher yields.

Moreover, maize is often used as a standard for the comparison of methane yields therefore we compared our results with maize. In the above-mentioned study, authors co-digested 59 different maize silages and their specific methane yields ranged between 312 and 408 cm^3 g^{-1} VS. However, results in the literature reveal large variations in maize methane yield. Mayer et al. (2014) assessed the large set of maize silage samples for methane yield and they ranged from 276 to 557 cm^3 g^{-1} VS, while Gao et al. (2012) gained considerably lower yields which ranged from 196 to 335 cm^3 g^{-1} VS.

Conclusion

After the field experiment that was set as a split-plot design in four replicates, with three levels of the main treatments of soil tillage and levels of subtreatment fertilization, the highest camelina grain, and biomass yield was achieved in the subtreatment F6 (in which microbiological fertilizer EM Aktiv was applied), regardless of the applied agrotechnics. Depending on fertilization subtreatments, average camelina grain yields ranged from 700 to 1158 kg ha^{-1}, whereas the yield of camelina plant mass ranged from 5447 to 5478 kg ha^{-1} (treatments), and 5231 to 6637 kg ha^{-1} (subtreatments). The anaerobic co-digestion of camelina and cow manure were expressed in terms of biogas and methane yields which ranged from 382.00 and 246.04 cm^3 g^{-1} VS, respectively. If compared to maize which is often used as a standard for comparison of methane yields, maize methane yields are higher by 21 to 40%.

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Izvorni znanstveni rad

Agronomska performanca i iskoristivost Cameline sative u svrhu proizvodnje bioplina

Sažetak

Istraživanje je postavljeno 2013. godine u agroekološkim uvjetima kontinentalne Hrvatske (3 različite lokacije). Pokus je postavljen po split-plot shemi u četiri ponavljanja, s tri razine glavnih tretmana obrade tla (CT - oranje; MD - reducirano višestruko tanjuranje; SD - reducirano drljanje jednom tanjuračom) i razinama gnojidbe podtretmana (F0 - kontrola; F1 - standardna gnojidba KAN-om; F2 - gnojidba 5% otopinom uree; F3 - Profert Mara; F4 - Profert NGT; F5 - Thiofer; F6 - EM Aktiv). Najveći prinos zrna i biomase kameline ostvaren je u podtretmanu F6 uz korištenje mikrobiološkog gnojiva EM Aktiv, neovisno o primijenjenoj agrotehnici. Nakon eksperimenta žetve, provedena je anaerobna šaržna kodigestija kameline i kravlje gnojovke u termofilnim uvjetima s ciljem određivanja potencijala kameline za proizvodnju bioplina. Bioplinski potencijal kameline izražen je preko prinosa bioplina i metana koji su se kretali od 382.00 odnosno 246.04 cm3 g-1 OT. U usporedbi s kukuruzom koji se često koristi kao standard za usporedbu prinosa metana, prinosi metana proizvedenog iz zrna kukuruza veći su za 21 do 40 %.

Ključne riječi: *anaerobna kodigestija, bioplin, Camelina sativa L. Crantz, gnojovka, organski uzgoj.*