THE GREEN MASS AND SILAGE QUALITY OF REED CANARY GRASS, *PHALARIS ARUNDINACEA* UNDER THE CONDITIONS OF MOLDOVA

Victor ŢÎŢEI[1], Andreea Cristina ANDREOIU[2], Adrian Vasile BLAJ[2], Teodor MARUȘCA[2], Sergiu COȘMAN[1, 3], Serghei COZARI[1]

e-mail: vic.titei@ gmail.com

Abstract

Reed canary grass *Phalaris arundinacea* is a cool-season, long-lived with good frost and drought tolerance, high-yielding C_3 grass species. The objective of this research was to evaluate the quality of green mass and prepared silage from reed canary grass, *Phalaris arundinacea*, cv. *Premier* grown under the conditions of the Republic of Moldova. In the third growing season, reed canary grass was characterized by high growth rate and regenerative capacity after being cut. Results revealed that harvested green mass first cut content 25.6% dry matter, but green mass second cut - 38.7% dry matter. The dry matter of the whole plant contained 109-139 g/kg CP, 74-98 g/kg ash, 368-411g/kg ADF, 616-685 g/kg NDF, 36-38 g/kg ADL, 330-375g/kg Cel and 248-274 g/kg HC. The nutritive value of natural fodder: 56.9-60.2% digestible dry matter, 11.32-11.91 MJ/kg digestible energy, 9.29-9.78 MJ/kg metabolizable energy and 5.31-5.79 MJ/kg net energy for lactation. The prepared silages were characterized by agreeable colour with pleasant smell and pH 3.98 - 4.10, it contained 30.8- 43.9 g/kg DM lactic acid, 5.8-7.2 g/kg DM acetic acid, 900-902 g/kg organic matter, 127-129 g/kg CP, 411-427 g/kg ADF, 683-704 g/kg NDF, 27-28 g/kg ADL with nutritive value: 55.6-56.9% dry matter digestibility, 11.09-11.32 MJ/kg digestible energy, 9.11-9.28 MJ/kg metabolizable energy and 5.07- 5.31 MJ/kg net energy for lactation. We found that the *Phalaris arundinacea* substrates for anaerobic digestion, have optimal C/N ratio, amount of lignin and hemicellulose. It has been established that the biomethane potential of the *Phalaris arundinacea* substrates varied from 335 to 362 l/kg ODM. Reed canary grass *Phalaris arundinacea* cv. *Premier* have good nutrient content, can be used as as natural fodder and silage for husbandry animals, also and feedstock for anaerobic digestion in biogas reactors and renewable energy production.

Key words: biochemical composition, biomethane potential, green mass, nutritive value, *Phalaris arundinacea.*

Currently, the interest in the conservation and efficient use of grassland has been restarted. Grasslands provide a variety of essential environmental benefits such as carbon storage, habitat function, limits soil erosion and improves water quality, have tremendous economic value ensuring humans food, forage for animals, and feedstock for renewable energy and biorefineries needs.

The genus *Phalaris*, family *Poaceae,* subfamily *Pooideae*, tribe *Poeae*, subtribe *Phalaridinae* contains 19-22 species, widely spread throughout the temperate and subtropical regions of the world with two centers of diversity: the Mediterranean Basin and western North America. The genus contains annual and perennial, endemic, cosmopolitan, wild, and invasive species with diploid, tetraploid and hexaploid cytotypes. In the spontaneous flora of the Republic of Moldova, there are also 2 species: *Phalaris arundinacea* L. and *Phalaris canariensis* L. (Negru A., 2007). Reed canary grass, *Phalaris arundinacea* L. (syn. *Baldingera arundinacea* (L.) Dumort; *Phalaroides arundinacea* (L.) Rauschert; *Typhoides arundinacea* (L.) (Moench) is a long-lived perennial grass, native to Europe, C_3 photosynthetic pathway. The stem is sturdy, hairless and hollow with some reddish coloring in the upper part, 60 to 200 cm tall. The leaf blades are flat with prominent ligules, usually green, flat, glabrous and taper gradually, 30-45 cm long and 0.8-1.2 cm wide. The leaves of the lower stem become light deprived as the plant grows and are replaced with new leaves higher up the stem. The inflorescence is branched panicles 7 to 40 cm long. Immature panicles are compact and resemble spikes, but open and become slightly spreading at anthesis. Spikelets are lanceolate, 5 mm long and

[1] "Alexandru Ciubotaru" National Botanical Garden (Institute), Chişinău, Republic of Moldova.
[2] Research and Development Institute for Grasslands Braşov
[3] Scientific and Practical Institute of Biotechnologies in Animal Husbandry and Veterinary Medicine, Anenii-Noi, Maximovca, Republic of Moldova

pale. The fruit is a caryopsis covered by coriaceous pallets, grain 1.5-4.0 mm long, 0.7-1.5 mm wide, containing a single seed, subovoid brown with faintly striate surface, the weight of 1000 seeds averages 0.9 g. *Phalaris arundinacea* develops an extensive, rhizomatous root system. New rhizomes originate almost entirely below the soil surface from buds at the nodes of other rhizomes. A typical trait is to have quite internal airspace in roots with also very high aerenchyma amount, which facilitates both an increase of methane oxidation below ground and an increased passive methane flux to the atmosphere through the plant in wetland. Typical for this plant is its early season growth, rapid vegetative spread, high steam elongation potential, wide physiological tolerance, high architectural plasticity and longevity, adaptation to a wide range of soil types, habitats, and management systems. It is very competitive once established and will frequently develop a solid monoculture, is a valuable forage and decorative crop. The cultivation area of *Phalaris arundinacea* rapidly increases; new cultivars have reduced gramine concentrations and no tryptamine or β-carboline alkaloids. This species has been an important component of permanent and temporary grassland, it has been the subject of much agricultural research (Alway F.J., 1931; Cherney D.J.R. *et al,* 1993; Tosi H.R., Wittenberg K.M., 1993; Tokita N. *et al*, 2015; Bélanger G. *et al,* 2016). Reed canary grass has also the potential feedstock for different industrial applications, chemicals, pulp and paper production, or renewable energy (Anderson W. *et al,* 2008; Sepälä M. *et al,* 2009; Dien B.S *et al,* 2011; Kandel T.P. *et al,* 2013; Oleszek M. *et al*. 2019; Laasasenaho K. *et al*, 2020). The bulk density of reed canary grass briquettes is 746-964 kg/m^3 with calorific value 16–18 MJ/kg dry matter (Kronbergs A. *et al,* 2013; Usťak S. *et al.*, 2019).

The objective of this research was to evaluate the quality of green mass and prepared silage from reed canary grass, *Phalaris arundinacea,* and the possibility to use green mass and silage as feed for husbandry animals and feedstock for the production of biomethane.

MATERIALS AND METHODS

The cultivar *'Premier'* of reed canary grass *Phalaris arundinacea*, created in the Research-Development Institute for Grassland Brasov, Romania and grown in monoculture on the experimental land of National Botanical Garden (Institute) Chişinău, N 46°58′25.7″ latitude and E 28°52′57.8″ longitude, served as subject of the research.

The green mass was harvested manually. The samples were collected in pre-anthesis period in third growing season. The leaves/stems ratio was determined by separating the leaves from the stem, weighing them separately and establishing the ratios for these quantities (leaves/stems). For ensiling, the green mass was shredded and compressed in well-sealed containers. After 45 days, the containers were opened, and the sensorial and chemical characteristics of prepared silages were determined in accordance with standard laboratory procedures and Moldavian standard SM 108* for forage quality analysis. Dry matter content was detected by drying samples up to constant weight at 105°C. Some assessments of the main biochemical parameters: protein, ash, acid detergent fibre (ADF), neutral detergent fibre (NDF), acid detergent lignin (ADL), have been evaluated using the near infrared spectroscopy (NIRS) technique PERTEN DA 7200 of the Research-Development Institute for Grassland Brasov, Romania. The concentration of hemicelluloses (HC) and celluloses (Cel), digestible dry matter (DDM), dry matter intake (DMI), relative feed value (RFV), digestible energy (DE), metabolizable energy (ME), net energy for lactation (NEl)) were calculated according to standard procedures.

The carbon content of the substrates was obtained from data on volatile solids, using an empirical equation reported by (Badger C.M. *et al, 1979*). The biochemical biogas potential (Yb) and methane potential (Ym) were calculated according to the equations of Dandikas V. *et al,* 2015, based on the protein (CP), acid detergent lignin (ADL) and hemicellulose (HC) values:

biogas Yb=670+0.44CP+0.16HC-3.02ADL

biometan Ym=370+0.21CP+0.05HC-1.61ADL.

RESULTS AND DISCUSSIONS

We could mention that, cultivar *'Premier'* of reed canary grass *Phalaris arundinacea* in third growing season resumed growth and development in the end March when temperatures above 5-6 C were established. The weather conditions in April-May 2019, with an optimal amount of rainfall, and lower air temperatures as compared with the previous year, helped the plants produce more shots and were favourable for their growth, development, and biomass production. We would like to mention (*table 1*), that the reed canary grass '*Premier'*, at the first cut time of harvest, end May, reached 116.1cm, but at the second cut time, middle August – 93.4 cm. The leaves content in the harvested biomass first cut the leaves content was 29.9 - 64.0%, the amount of dry matter - 25.1-37.6%. The green mass yield from first cut was 4.89 kg/m^2, but in second cut – 2.34 kg/m^2. In third growing season the dry mass productivity reached 2.11 kg/m^2.

According to results obtained in Denmark in the third year after establishment the dry mater productivity of *Phalaris arundinacea* one-cut management reached 12 t/ha, but two-cut management -16 t/ha (Kandel T.P. *et al*, 2013). In Romania the productivity of the cv. '*Premier' Phalaris arundinacea* were 65-80 t/ha green mass or 16 - 20 t/ha dry matter (Maruşca T. *et al*, 2011).

Analyzing the results of the green mass quality of the *Phalaris arundinacea* '*Premier'* in third growing season (*table 2*), we found that dry matter of the harvested green mass contained 109-139 g/kg CP, 74-98 g/kg ash, 368-411g/kg ADF, 616-685 g/kg NDF, 36-38 g/kg ADL, 330-375g/kg Cel and 248-274 g/kg HC. The natural fodder has RFV= 77-90, 11.32-11.82 MJ/kg DE, 9.29-9.70 MJ/kg ME and 5.31-5.72 MJ/kg NEl. The concentrations of crude protein and minerals were high in the natural fodder second cut. The level of structural carbohydrates, cellulose and hemicellulose decreased substantially in the fodder second cut, which had a positive effect on dry matter digestibility, relative feed value and energy content. The nutritive value of green mass: 56.9-60.2% digestible dry matter, 11.32-11.91 MJ/kg digestible energy, 9.29-9.78 MJ/kg metabolizable energy and 5.31-5.79 MJ/kg net energy for lactation.

Some authors mentioned various findings about the green mass quality of the reed canary grass, *Phalaris arundinacea*. According to results obtained in New York state US, the reed canary grass contained 13.1-17.6% CP, 48.4-55.1% NDF, 27.5-30.6% ADF, 2.37-3.49% lighin with 76.8-81.9% IVDMD (Cherney D.J.R. *et al.*, 1993). The reed canary grass grown on saline soil and harvested in heading period were characterized by 97 g/kg CP, 343/kg ADF, 597 g/kg NDF and 2.4 g/kg phosphorus (Glover D.E. *et al*, 2004).

Table 1.

Some agrobiological peculiarities of the *Phalaris arundinacea* '*Premier'* third growing season

Harvest period	Plant height, cm,	Leaf, g		Stem, g		Yield, kg/ m^2	
		green mass	dry matter	green mass	dry matter	green mass	dry matter
First cut	116.1	3.92	1.03	9.79	2.42	4.89	1.25
Second cut	93.4	2.18	0.75	0.96	0.43	2.34	0.88

The nutrients contents of reed canary-grass harvested at pre-blooming stage were: 20.1% CP, 57.0% NDF, 32.5% ADF, 2.7% ADL, 27.3% Cel and 24.5% HC (Tokita N. *et al*, 2015). In Costa Rica nutritional value of reed canary grass were 16.65-19.47% CP, 53.18-57.77% NDF, 34.60-36.86% ADF, 3.78-4.42% lignin, 18.79-20.91% hemicellulose, 31.04-32.34% cellulose, 63.38-70.55% IVDMD with estimated energy content 2.72-2.81 Mcal/kg DE, 2.10-2.18 Mcal/kg ME, 1.29-1.34 Mcal/kg NEl (Villalobos L., 2012). The *Phalaris arundinacea* plants cut in late July contained 103.4 g/kg ash, 11.2 g/kg nitrogen, 2.4 g/kg phosphorus, 619 g/kg NDF, 414 g/kg ADF, 40.0 g/kg soluble carbohydrates, 664 g/kg in-vitro true digestibility of dry matter and 459 g/kg in-vitro NDF digestibility (Bélanger G. *et al*, 2016).

Table 2

Biochemical composition and fodder value of the *Phalaris arundinacea* '*Premier' green mass*

Indices	First cut	Second cut
Crude protein, g/kg DM	109	139
Minerals, g/kg DM	74	98
Acid detergent fibre, g/kg DM	411	368
Neutral detergent fibre, g/kg DM	685	616
Acid detergent lignin, g/kg DM	36	38
Digestible dry matter,%	56.9	60.2
Dry matter intake,% BW	1.75	1.95
Relative feed value	77	91
Digestible energy, MJ/ kg DM	11.32	11.91
Metabolizable energy, MJ/ kg DM	9.29	9.78
Net energy for lactation, MJ/ kg DM	5.31	5.79

The fermented fodder - silage is the basis of most animal farm feeding systems. The production of well-preserved, high-quality silages depends mainly on the composition of the forage at ensiling and the application of appropriate silage-making practices.

When opening the glass vessels with silage made from green mass of *Phalaris arundinacea* obtained after the first and second harvests, there was no gas or juice leakage from the preserved mass. The forage materials obtained after at all the harvests resulted in silages with agreeable colour and aroma, the consistency was retained, in comparison with the initial green mass, without mould and mucus. During the sensorial assessment, it was found that the colour of the silage obtained after the first cut was dark green leaves and green-yellow stems with pleasant smell specific to pickled vegetables, but the silage made from the second cut – homogeneous olive colour with pleasant smell like pickled fruits. It has been determined that the amounts of organic acids and nutrients in the prepared silages, differed essentially depending on the cut period (*table 3*). The silages material consolidated well and the fermentation was complete with pH values 3.98 - 4.10, most organic acids in fixed form. The content of lactic acid increased from 30.8 g/kg to 43.9 g/kg DM and acetic acid - from 5.8 to 7.2 g/kg DM in the silage obtained after the second cut. The butyric acid not was detected in prepared silages. The results of the investigations (*table 3*) indicate that silages from *Phalaris arundinacea* '*Premier'*, contained 127-129 g/kg CP, 411-427 g/kg ADF, 683-704 g/kg NDF, 27-28 g/kg ADL with nutritive value: 55.6-56.9% DDM, 11.09-11.32 MJ/kg DE, 9.11-9.28 MJ/kg ME and 5.07- 5.31 MJ/kg NEl. Thus, the preparation of the silage from the second cut resulted in increase the content of crude protein and net energy for lactation.

Several literature sources describe the nutritional performance of reed canary-grass silage. The silage obtained from reed canary-grass harvested at pre-blooming stage were characterized by 14.4% DM, pH 5.7, 20.7% CP, 60.2% NDF, 34.0% ADF, 3.2% ADL, 26.8% Cel and 26.5% HC, 58.7% DDM, but the silage produced with addition of formic acid - 14.0% DM, pH 4.7, 24.3% CP, 52.3% NDF, 29.9% ADF, 2.5% ADL, 25.6% Cel and 22.4% HC, 67.2% DDM, respectively (Tokita N. *et al*, 2015). In Canada the reed canary-grass silage obtained in late July have pH 4.1, 10.4 g/kg nitrogen, 41.2 g/kg lactic acid, 4.7 g/kg acetic acid (Bélanger G. *et al,* 2016). In Poland the chemical composition of ensiled reed canary grass was: 11.7% CP, 2.6% EE, 10.2% ash, 7.7% NFC, 32.2% Cel, 26.6% HC, 8.6%ADL (Oleszek M. and Matyka M., 2017).

Table 3

The fermentation quality, biochemical composition and fodder value of the *Phalaris arundinacea* silages

Indices	First cut	Second cut
pH index	3.98	4.10
Content of organic acids, g/kg DM	36.6	51.1
Free acetic acid, g/kg DM	2.7	3.4
Free butyric acid, g/kg DM	0.0	0.0
Free lactic acid, g/kg DM	13.0	18.2
Fixed acetic acid, g/kg DM	3.1	3.8
Fixed butyric acid, g/kg DM	0.0	0.0
Fixed lactic acid, g/kg DM	17.8	25.7
Acetic acid,% of organic acids	15.85	14.09
Lactic acid,% of organic acids	84.15	85.91
Crude protein, g/kg DM	129	127
Minerals, g/kg	100	98
Acid detergent fibre, g/kg DM	427	411
Neutral detergent fibre, g/kg DM	704	683
Acid detergent lignin, g/kg DM	27	28
Digestible dry matter,%	55.6	56.9
Dry matter intake,% BW	1.70	1.76
Relative feed value	74	77
Digestible energy, MJ/ kg DM	11.09	11.32
Net energy for lactation, MJ/ kg DM	5.07	5.31

The increased interest in renewable energy production during the last decades has forced scientific research to estimate biomass energy potential. The technology of biomass conversion through anaerobic digestion and biomethane production represents the source of renewable energy with great potential, environmentally friendly and rapidly expanding in the latest years. Biogas can be used for heating, electricity and as vehicular fuel depending on its quality (Badger C.M. *et al*, 1979; Korres N.E *et al*, 2010). The concentrations of organic constituents in the biomass and their availability, the carbon nitrogen ratio (C/N) plays a crucial role in the process of biomethane production (Vintilă T. and Neo S., 2011; (Butkuté B. *et al.* 2014; Dandikas V. *et al*, 2015; Laasasenaho K. *et al*, 2020). We found that investigated substrates from *Phalaris arundinacea* '*Premier'*, according to the C/N ratio, which constituted 22.5-29.4, met the established

standards. The essential differences were observed between the content of cellulose, hemicellulose and lignin. The silage substrate contained high amount of structural carbohydrates, cellulose and hemicellulose, an acceptable content of lignin. The biochemical methane potential of investigated green mass substrates – 349-351 l/kg, but silage substrate reached 365-367 l/kg ODM (*table 4*).

Table 4

Biochemical biogas and biomethane production potential of *Phalaris arundinacea* substrates

Indices	Green mass substrate		Silage substrate	
	First cut	Second cut	First cut	Second cut
Crude protein, g/kg DM	109	139	129	127
Minerals, g/kg DM	74	98	100	98
Nitrogen, g/kg DM	17.5	22.3	20.6	20.3
Carbon, g/kg DM	514.4	501.1	500.0	501.1
Ratio carbon/nitrogen	29.4	22.5	24.3	24.7
Cellulose, g/kg DM	375	330	400	383
Hemicellulose, g/kg DM	274	248	277	272
Acid detergent lignin, g/kg DM	36	38	27	28
Bio gas potential, L/kg VS	653	656	690	685
Biomethane potential, L/kg VS	349	351	367	365

According to results obtained in Denmark, the specific methane yields of reed canary grass decreased significantly with crop maturity ranging from 384–315 and 412–283 l/kg VS for leaves and stems, respectively methane was produced by the two-cut management 5430 m^3/ha compared to the maximum methane production from the one-cut management 3735 m^3/ha (Kandel T.P. *et al*, 2013). Rancane S. *et al*, 2017, mentioned that reed canary grass first cut contained: 477.92g/kg carbon, 16.58 g/kg nitrogen and 66.3 g/kg ash, but in second cut - 466.84g/kg carbon, 17.15 g/kg nitrogen and 73.13 g/kg ash, respectively. Pocienė L., Kadžiulienė Z., 2016 remarked that reed canary grass mowing in July contained *7*3.6-9.44 g/kg ADL, 330-375g/kg Cel and 141.7-208.3 g/kg HC. Krzystek L. *et al.* 2020, indicated the biogas potential of reed canary grass silage 490 l/kg and an annual methane productivity 2558 m^3/ha. Alvinge S., 2010 mentioned that the methane yield for *Phalaris arundinacea* was 323 l/kg, but *Typha latifolia*- 300 l/kg. Sepälä M. *et al.* 2009 obtained 296 l/kg from *Phalaris arundinacea.* The reed canary grass biomass contained: 37.2-42.2% cellulose, 19.0-22.9.0% hemicellulose, 3.17-7.66% ADL, with C/H=21.9-33.1 and its biomethane potential 316-426 l/kg VS (Butkuté B. *et al.* 2014). In Czech Republic the *Phalaris arundinacea* silage substrate contained 288.0 g/kg DM, 22.36 g/kg nitrogen, 75.85 g/kg fibre, 30.37 g/kg ash, 22.20 g/kg lactic acid, 3.20 g/kg acetic acid and methane efficiencies 102.3 l /kg silage; in *Elymus elongatus* subsp. *ponticus* cv. Szarvasi-1 silage substrate there was 240.5 g/kg DM, 23.89 g/kg nitrogen, 71.40 g/kg fibre, 30.38 g/kg ash, 19.54 g/kg lactic acid, 3.84 g/kg acetic acid and methane efficiencies 94.9 l/kg silage (Bernas J. *et al.* 2019). Laasasenaho K. *et al*, (2020) have found that the element and chemical composition of *Phalaris arundinacea* herbage harvested in first cut were 15-16 g/kg nitrogen, 455 g/kg carbon, 62-63 g/kg hydrogen, 147-151 g/kg Klason-lignin and methane yields reached 348 l/kg, but from the second cut 13-14 g/kg nitrogen, 452 g/kg carbon, 61-62 g/kg hydrogen, 167-178 g/kg Klason-lignin and the methane yields 324 l/kg respectively.

CONCLUSIONS

The green mass productivity of *Phalaris arundinacea* '*Premier'*, in third growing season, reached 7.23 kg/m^2 green mass or 2.13kg/m^2 dry matter.

The dry matter of the whole plant contained 109-139 g/kg CP, 74-98 g/kg ash, 368-411g/kg ADF, 616-685 g/kg NDF, 36-38 g/kg ADL, 330-375g/kg Cel and 248-274 g/kg HC. The nutritive value of natural fodder: 56.9-60.2% digestible dry matter, 11.32-11.91 MJ/kg DE, 9.29-9.78 MJ/kg ME and 5.31-5.79 MJ/kg NEl.

The prepared silages were characterized by agreeable colour with pleasant smell of pickled vegetables and fruits, pH 3.98 - 4.10, it contained 30.8- 43.9 g/kg DM lactic acid, 5.8-7.2 g/kg DM acetic acid, 127-129 g/kg CP, 411-427 g/kg ADF, 683-704 g/kg NDF, 27-28 g/kg ADL with nutritive value: 55.6-56.9% dry matter digestibility, 11.09-11.32 MJ/kg DE, 9.11-9.28 MJ/kg ME and 5.07-5.31 MJ/kg NEl.

Phalaris arundinacea substrates for anaerobic digestion characterized by optimal C/N ratio, amount of lignin and hemicellulose, the biomethane potential of the green mass substrates

349-351 l/kg ODM, but silage substrate reached 365-367 l/kg ODM.

Under the conditions of the Republic of Moldova, the cv. *'Premier'* of *Phalaris arundinacea* produces high yields with good nutrient content, can be used as natural fodder and silage for husbandry animals, also and feedstock for anaerobic digestion in biogas reactors and renewable energy production.

REFERENCES

Always F.J., 1931 - *Early trials and use of reed canary grass as a forage plant.* Journal of the American Society of Agronomists, 23: 64-66.

Alvinge S., 2010 - *Evaluation of emergent macrophytes as a source for biogas production after mechanical, alkaline and fungal pretreatments.*

Anderson, W., Casler, M., Baldwin, B.S. 2008 - *Improvement of perennial forage species asfeedstock for bioenergy.* Publications from USDA-ARS / UNL Faculty. 248.

Badger C.M., Bogue M.J., Stewart D.J., 1979 - *Biogas production from crops and organic wastes.* New Zeland Journal of Science, 22: 11-20.

Bélanger G., Tremblay G.F., Bertrand A., Mongrain D., Parent G., Savoie P., Massé D., Gilbert Y., Babineau D., 2016 - *Reed canarygrass crop biomass and silage as affected by harvest date and nitrogen fertilization.* Canadian Journal of Plant Science, 96(3): 413-422.

Bernas J., Moudrý J. Jr., Kopecký M., Konvalina P., Štěrba Z., 2019 - *Szarvasi-1 and its potential to become a substitute for maize which is grown for the purposes of biogas plants in the Czech Republic.* Agronomy, *9*(2), 98;

Butkuté B., Lemežienė N., Kanapeckas J., Navickas, K., 2014 - *Cocksfoot, tall fescue and reed canarygrass: dry matter yield, chemical composition and biomass convertibility to methane.* Biomass and Bioenergy, 66: 1-11.

Cherney D.J.R., Cherney J. H., Lucey R. F., 1993 - *In vitro digestion kinetics and quality of perennial grasses is influenced by forage maturity.* Journal of Dairy Science, 76:790-797.

Dandikas V., Heuwinkel H., Lichti F., Drewes J.E., Koch K., 2015 - *Correlation between biogas yield and chemical composition of grassland plant species.* Energy Fuels, 29(11): 7221-7229.

Dien B.S., Casler M.D., Hector R.E., Iten L.B., Nancy N.N., Mertens J.A., Cotta M.A., 2011 - *Biochemical processing of reed canarygrass into fuel ethanol.* International Journal of Low-Carbon Technologies, 7 (4):338-347.

Glover D.E., Kielly G.A., Jefferson P.G., Cohen R. D.H., 2004 - *Agronomic characteristics and nutritive value of 11 grasses grown with irrigation on a saline soil in southwestern Saskatchewan.* Canadian Journal of Plant Science, 84: 1037–1050.

Kandel T.P., Sutaryo S., Møller H.B., Jørgensen U., Lærke P.E., 2013 - *Chemical composition and methane yield of reed canary grass as influenced by harvesting time and harvest frequency.* Bioresource Technology, 130:659–666.

Korres N.E., Singh A.P., Nizami A., Murphy J.D., 2010- *Is grass biomethane a sustainable transport biofuel.* Biofuels, Bioproducts and Biorefining, 4:310-325.

Kronbergs A., Kronbergs E., Repsa E., 2013- *Evaluation of reed canary grass shredding and compacting properties.* Agronomy research, 11 (1):61–66.

Krzystek L., Wajszczuk K., Pazera A., Matyka M., Slezak R., Ledakowicz S., 2020 - *The influence of plant cultivation conditions on biogas production: energy efficiency.* Waste and Biomass Valorization, 11: 513–523.

Laasasenaho K., Renzi F., Karjalainen H., Kaparaju P., Konttinen J., Rintala J., 2020 - *Biogas and combustion potential of fresh reed canary grass grown on cutover peatland*. International Mire Conservation Group. Mires and Peat, 26, 10.

Maruşca T., Tod M., Silistru D., Dragomir N., Schitea M., 2011 - *Principalele soiuri de graminee şi leguminoase perene de pajişti*. Braşov. Capolavoro, p.52.

Oleszek M., Kowalska I., Oleszek W., 2019 - *Phytochemicals in bioenergy crops.* Phytochemistry Reviews, 18: 893–927.

Oleszek M., Matyka M., 2017 - *Nitrogen fertilization level and cutting affected lignocellulosic crops properties important for biogas production. BioResources,* 12(4): 8565-8580.

Pocienė L., Kadžiulienė Z., 2016 - *Biomass yield and fibre components in reed canary grass and tall fescue grown as feedstock for combustion.* Zemdirbyste-Agriculture, 103(3):297–304.

Rancāne S., Kārkliņš A., Lazdiņa D., Bērziņš P., Bārdule A., Butlers A., Lazdiņš A., 2017 - *Biomass yield and chemical composition of Phalaris arundinacea L. using different rates of fermentation residue as fertiliser.* Agronomy Research, 15(2): 521–529.

Seppälä M., Paavola T., Lehtomäki A., Rintala J., 2009 - *Biogas production from boreal herbaceous grasses - specific methane yield and methane yield per hectare.* Bioresource Technology, 100 (12): 2952-295.

Tokita N., Ogata M., Oshiro S., Hirayanagi N., Hatori M., Sato S., Kurita T., Yoshimura I., Tokita T., 2015 - *Quality of reed canary-grass (Phalaris arundinacea L.) silage produced using glucose, formic acid, and tannic acid*. Asian Journal of Plant Science and Research, 5(11):21-25.

Tosi H.R., Wittenberg K. M. 1993 - *Harvest alternatives to reduce the alkaloid content of reed canarygrass forage.* Canadian Journal of Animal Science, 73: 373-380.

Usťak S., Šinko J., Muñoz J., 2019 - *Reed canary grass (Phalaris arundinacea L.) as a promising energy crop.* Journal of Central European Agriculture, 20(4):1143-1168.

Villalobos L., 2012 - *Fenología, producción y valor nutritivo del pasto alpiste (Phalaris arundinacea) en la zona alta lechera de Costa Rica.* Agronomía Costarricense, 36(1):25-37.

Vintilă T., Neo S., 2011 - *Biogas in Romanian agriculture, present and perspectives. Scientific Papers: Animal Science and Biotechnologies*, 44(1):465-473.