THE BIOMASS QUALITY OF *EPILOBIUM ANGUSTIFOLIUM* L. AND PROSPECTS OF ITS USE IN MOLDOVA

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Abstract

This research was aimed at evaluating the quality indices of green mass forage and the substrates for the biomethane production from rosebay willowherb – Epilobium angustifolium. The local ecotypes of Epilobium angustifolium which grow in the experimental sector of the "Alexandru Ciubotaru" National Botanical Garden (Institute) MSU Chişinău served as subject of the research. The results revealed that the dry matter of Epilobium angustifolium whole plants contained: 12.99% crude protein, 5.83% crude fats, 28.33% crude cellulose, 44.92% nitrogen free extract, 5.23% sugars, 1.74% starch, 7.92 % ash, 1.11% calcium, 0.28% phosphorus with 10.06 MJ/kg ME and 5.64 MJ/kg NEl. The Epilobium angustifolium substrate for anaerobic digestion and biomethane production had optimal carbon to nitrogen ratio and the estimated biochemical methane potential reached 288 l/kg VS. Epilobium angustifolium can be used as an alternative source of nutrients in livestock nutrition, or as a source of biomass for biomethane production in renewable energy production and as organic fertilizer.

Key words: biochemical composition, biomethane potential, Epilobium angustifolium, green mass, nutritive value

Climate change-associated environmental stresses, such as extreme temperatures, lack of precipitation or erratic rainfall during the growing season will compromise the ability of agriculture to meet the food demands of an increasing global population. The mobilization and domestication of new plant species would promote agricultural diversity and would provide a solution to many of the problems associated with climate change resilience, food security, forage production, feedstock energy biomass and other industrial needs.

Rosebay willowherb or fireweed, *Epilobium angustifolium* L., is an herbaceous perennial plant from *Onagraceae* family, native to Eurasia, North America. In the European literature, the species is frequently referred to as *Chamaeneion angustifolium* (L.) Scop., *Chamerion angustifolium* (L.) Holub. The plants grow each spring from buds formed the previous year on lateral roots. The green stems, frequently reddish, usually unbranched and usually glabrous below and pubescent above with small white hairs, glabrous below and pubescent above, are erect, up to 2 m tall. The willow-like leaves are alternate, entire, 3-20 cm long and 1.0-2.5 cm wide, green above, pale and reticulate-veiny beneath, acuminate with a narrowed, sessile, to obscurely petiolate base.

Leaves are minutely and distantly toothed, or nearly entire, the lower ones are narrowed into short petioles. The inflorescence is a raceme, 15-35 cm long with 8 to 80 flowers, foliated at the base. The flower peduncles are 0.4-1.3 cm long, with small, linear bracts at the base. The calyx is incised down to the base, with the tube reaching 1 mm long, with lanceolate or linear, acute lobes, with small hairs on the outside, 10 mm long and 2 mm wide. The corolla is slightly zygomorphic, reddish-purple; the petals are 15 mm long and 7 mm wide. The seed capsules are canescent, 2.5-8.0 cm in length, and each may contain many small light brown seed, 0.8-1.3 mm in length, capped with a tuft of hairs up to 13 mm long. Flowers are pollinated by insects, the honey production 600-900 kg/ ha. It reproduces by seeds and vegetatively by rhizomes, and so it may be propagated from cuttings (Broderick D.H., 1990; Pavek D.S., 1992; Adamczak A. *et al*, 2019).

Rosebay willowherb *Epilobium angustifolium* it occurs sporadically throughout the entire territory of Bessarabia, in meadows along creeks, on sandy riverbanks, in forest glades, on roadsides and in deforested areas.

Epilobium angustifolium has gained a lot of attention, being studied as medicinal plant, honey plant, fodder crop, energy biomass crop, ornamental, soil stabilizer and agricultural weed in many research centres (Medvedev P.F. & Smetannikova A.I., 1981; Robbins C.T. *et al,* 1987; Broderick D.H., 1990; Hanley T.A. *et al,* 1992; Pavek D.S., 1992; Starkovsky B.N., 2003; Erhardt A. *et al,* 2005; Kshnikatkina A.N. *et al,* 2005; Polezhaeva I.V. *et al,* 2007; Guil-Guerrero J.L. *et al,* 2016; Bushueva G.R. *et al,* 2016; Tsarev V.N. *et al,* 2016; Adamczak A. *et al,* 2019; Smuga-Kogut M. *et al,* 2020; Irinina

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O.I.&Eliseeva S.A., 2021; Antonenko M.S.& Malankina E.L., 2022; Kamkin V.A. *et al*, 2023).

This research was aimed at evaluating the quality indices of green mass forage and the substrates for the biomethane production from rosebay willowherb, *Epilobium angustifolium*.

MATERIALS AND METHODS

The local ecotypes of rosebay willowherb *Epilobium angustifolium* that grow in the experimental sector of the "Alexandru Ciubotaru" National Botanical Garden (Institute) Chişinău served as subjects of the research. The traditional forage crops: common millet – *Panicum miliaceum* 'Marius', the sorghum and Sudan grass hybrid – *Sorghum bicolor* × *Sorghum sudanense "SAȘM-4,* the corn hybrid – *Zea mays 'Porumbeni 374'* and alfalfa – *Medicago sativa* were used as control variants. The *Epilobium angustifolium* plant samples were collected in the flowering stage. The dry matter content was detected by drying the samples up to constant weight at 105°C. For biochemical analysis, the samples were dried in a forced air oven at 60°C, milled in a beater mill equipped with a sieve with diameter of openings of 1 mm. The quality of the biomass was evaluated by analyzing such indices as: crude protein (CP) – by Kjeldahl method; crude fat (EE) – by Soxhlet method, crude cellulose (CF)– by Van Soest method; ash – in muffle furnace at 550°C and the nitrogen-free extract (NFE) was mathematically appreciated. The calcium (Ca) concentration of the samples was determined by using the atomic absorption spectrometry method, phosphorus (P) concentration – by spectrophotometric method. The gross energy (GE), metabolizable energy (ME), net energy for lactation (NEl) were calculated according to standard procedures:

$$GE = 23.9\, xCP + 39.8\, xEE + 20.1\, xCF + 17.5x\, NFE;$$

$$ME = 14.07 + 0.0206\, xEE - 0.0147xCF - 0.0114\, xCP;$$

$$NEl = 9.10 + 0.0098\, xEE - 0.0109\, xCF - 0.073xCP.$$

The carbon content of the substrates was determined using an empirical equation according to Badger C.M. *et al,* (1979). The biochemical methane potential was calculated using the gas forming potential of nutrients according to Baserga U., (1998), corrected by the nutrient digestibility.

RESULTS AND DISCUSSIONS

As a result of our observations, we found that at the flowering stage the local ecotypes of *Epilobium angustifolium* reached 132-148 cm in height. In the harvested mass of *Epilobium angustifolium*, the stems made up 59.5% and the leaves 40.5%. The dry matter content varied considerably, from 23.96% in leaves to 28.81% in stems. The biochemical composition, nutritive and energy value of the green mass from the *Epilobium angustifolium* are presented in Table 1. The comparative analysis of the nutrient composition of whole plants showed that *Epilobium angustifolium* natural fodder was characterized by a significantly higher content of crude protein than *Sorghum bicolor* × *Sorghum sudanense* and *Zea mays* green mass, but lower than in *Medicago sativa* fodder.

The concentration of crude fats in *Epilobium angustifolium* whole plants differed significantly as compared with traditional forage crops, reaching 58.3 g/kg dry matter. The content of crude cellulose in rosebay willowherb green fodder was lower than in sorghum x Sudan grass, alfalfa and common millet, but higher than in corn green fodder. The *Epilobium angustifolium* green fodder is characterized by optimal amount of nitrogen free extract (449.2 g/kg dry matter), but much lower than in corn and common millet green fodder. The concentration of soluble sugars in *Epilobium angustifolium* green fodder was higher than in *Medicago sativa* fodder, but lower than in *Sorghum bicolor* × *Sorghum sudanense*, *Panicum miliaceum* and *Zea mays* green mass. The starch concentration in rosebay willowherb green fodder was lower than in corn and sorghum x Sudan grass hybrids. The ash content in rosebay willowherb natural fodder was much higher than in corn and sorghum x Sudan grass fodder, and did not differ significantly as compared with alfalfa and common millet fodder.

The rosebay willowherb natural fodder was characterized by much higher concentration of calcium and phosphorus than in sorghum x Sudan grass, common millet and corn fodder. The energy supply of the feed from whole *Epilobium angustifolium* plants reached 10.06 MJ/kg metabolizable energy and 5.64 MJ/kg net energy for lactation, being higher than in the forage produced from sorghum x Sudan grass, common millet and alfalfa plants, but lower than in corn plants. It was found that the level of carotene in *Epilobium angustifolium* green mass was significantly higher as compared with controls forage crops.

Different results regarding the biochemical composition and the nutritive value of the harvested mass from *Epilobium angustifolium* species are given in the specialized literature. According to Medvedev P.F. & Smetannikova A.I., (1981) the harvested rosebay willowherb whole plants contained 10.5-14.0 % CP, 2.0-3.2 % EE, 18.2-20.2% CF, 4.3-9.9% ash. Robbins C.T *et al,* (1987) mentioned that the *Epilobium angustifolium* flowers had 13.7% CP. Hanley T.A. *et al,* (1992) remarked that *Epilobium angustifolium* plants contained 13.4% CP, 2.0% lignin, 1.2% cutin and 65.4% digestible dry matter. Pavek D.S. (1992)

revealed that the nutritional value of fireweed *Epilobium angustifolium* varied depending on season and site: 4-20% CP and 28-80% dry matter digestibility. Starkovsky B.N. (2003) found that the dry matter quality indices of *Epilobium angustifolium* whole plants were 170 g/kg DM, 18.3 % CP, 4.92% EE, 19.7% CF, 50.3 % NFE, 10.02% sugars, 2.03 % starch, 8.17% ash, 9.54 g/kg Ca, 6.01 g/kg P, 214 mg/kg carotene with 10.2 MJ/kg ME and 0.88 nutritive units. MJ/kg ME Kshnikatkina A.N. *et al*, (2005) reported that the forage quality of *Epilobium angustifolium* green mass harvested in the flowering period was 269.5 g/kg DM, 14.98 % CP, 3.05% EE, 26.61% CF, 7.47% ash, 11.00 g/kg Ca, 7.00 g/kg P, but *Medicago varia* – 154.5 g/kg DM, 24.47 % CP, 2.59% EE, 22.87% CF, 10.25% ash, 5.00 g/kg Ca, 1.80 g/kg P, respectively. Guil-Guerrero J.L. *et al*, (2014) remarked that the proximate composition and energy content of *Epilobium angustifolium* shoots was 18.8% CP, 55.0% carbohydrates, 10.0% fibre, 7.5% lipids, 5.0 % ash and 18.39 MJ/kg GE, but *Sorghum bicolor* inflorescence with seeds contained 9.0% CP, 72.0% carbohydrates, 3.0% lipids, 2.0 % ash, and 15.64 MJ/kg GE. Terranova M. (2018, 2011) found that the nutrient content and the fodder value of green mass from *Epilobium angustifolium* was 937-938 g/kg organic matter with 12.1-12.5 % CP, 1.5-1.9% EE, 40.2-47.3% NDF, 33.8-40.6% ADF, 9.4-10.8 % ADL, 61.6%IVOMD, 4.56 MJ/kg NEl and from *Lotus corniculatus* 912-914 g/kg organic matter with 13.5-13.9 % CP, 0.7-1.0% EE, 57.0-58.8% NDF, 43.4-46.0% ADF, 10.4-11.2% ADL, 64.9% IVOMD, 4.96 MJ/kg NEl, respectively. Irinina O.I.& Eliseeva S.A. (2021) reported that the above-ground mass of *Epilobium angustifolium* contained 16.4% CP and 13.13-26.01 % CF. Starkovsky B.N. *et al*, (2020) revealed that the forage produced from *Epilobium angustifolium* whole plants, in the first year of growth, contained 16.00 % CP, 4.29% EE, 8.75% sugars, 10.17 MJ/kg ME and 0.77 nutritive units/kg DM, while second-year forage – 15.27 % CP, 4.11% EE, 8.35% sugars, 10.19MJ/kg ME and 0.88 nutritive units/kg DM, respectively.

Table 1.

The biochemical composition and the fodder value of *Epilobium angustifolium* green mass

Indices	*Epilobium angustifolium*	*Panicum miliaceum*	*Sorghum bicolor × Sorghum sudanense*	*Zea mays*	*Medicago sativa*
Crude protein, % DM	*12.99*	*10.62*	*8.47*	*7.26*	*16.28*
Crude fats, % DM	*5.83*	*2.81*	*2.75*	*2.83*	*2.75*
Crude cellulose, % DM	*28.33*	*30.69*	*37.61*	*18.40*	*33.25*
Nitrogen free extract, % DM	*44.92*	*47.60*	*45.19*	*67.92*	*39.50*
Soluble sugars, % DM	*5.23*	*7.31*	*10.56*	*7.55*	*4.28*
Starch, % DM	*1.74*	*2.67*	*1.50*	*22.79*	*1.65*
Ash, % DM	*7.92*	*8.01*	*5.99*	*3.59*	*8.22*
Calcium, % DM	*1.11*	*0.30*	*0.20*	*0.24*	*1.43*
Phosphorus, %	*0.28*	*0.23*	*0.13*	*0.22*	*0.22*
Gross energy, MJ/ kg	*18.94*	*18.21*	*18.27*	*18.46*	*18.56*
Metabolizable energy, MJ/ kg	*10.06*	*9.29*	*8.13*	*11.13*	*8.26*
Net energy for lactation, MJ/ kg	*5.64*	*5.23*	*4.63*	*6.34*	*4.57*
Carotene, mg/kg	*174.0*	*32.92*	*32.92*	*14.30*	-

Table 2

The biochemical methane production potential of green mass substrate from *Epilobium angustifolium*

Indices	*Epilobium angustifolium*	*Panicum miliaceum*	*Sorghum bicolor × Sorghum sudanense*	*Zea mays*	*Medicago sativa*
Organic dry matter, g/kg	*920.8*	919.0	894.4	964.1	917.8
Digestible matter, g/kg	*662.7*	662.3	640.5	678.0	580.9
Digestible proteins, g/kg	*101.2*	80.7	59.2	42.1	122.1
Digestible fats, g/kg	*36.7*	17.4	12.3	19.2	12.7
Digestible carbohydrates, g/kg	*524.8*	564.2	569.0	616.7	446.1
Carbon, g/kg	*511.6*	510.6	496.9	535.6	509.8
Nitrogen, g/kg	*20.8*	17.0	13.6	11.6	26.0
Ratio carbon/nitrogen	*24.6*	30.0	36.5	46.2	19.6
Biochemical methane potential, L/kg OM	*288*	303	296	291	268

Biomass plays a key role in the development and utilization of renewable energy resources and has become a major component of sustainable global energy strategies, energy security and climate change mitigation. Biogas production is receiving growing attention in the circular economy aspects, may appear on a variety of markets, including electricity, heat and transportation fuels.

The results of the determination of the quality indices and biochemical methane production potential of green mass substrate from the *Epilobium angustifolium* are presented in Table 1. The digestible organic matter concentration in the *Epilobium angustifolium* substrate reaches 662.7 g/kg dry matter, being higher than in *Medicago sativa* substrate but lower than in *Zea mays* substrate. The C/N ratio in the *Epilobium angustifolium* substrate is more favourable as compared with *Sorghum bicolor* × *Sorghum sudanense* and *Zea mays* substrates. The biochemical methane potential of the studied *Epilobium angustifolium* substrate was 288 l/kg organic matter, being about the same as in corn and sorghum x Sudan grass substrates, but lower than in common millet substrate.

CONCLUSIONS

The green mass from the local ecotypes of *Epilobium angustifolium* can be used as an alternative source of nutrients in livestock nutrition, or as a source of biomass for biomethane production in renewable energy production and as organic fertilizer.

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