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Progress in the Breeding of Eastern Galega, *Galega orientalis*, for Productivity and Quality in the Republic of Moldova

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ABSTRACT

As part of the plant resource mobilization activities, valuable forms of the species *Galega orientalis* were identified and used in the breeding program to improve the productivity and quality, as a result, the local cultivar 'Sofia' was created. We found that in the third year of vegetation the annual productivity of eastern galega local cultivar, for 3 cuts, reached 9.1 kg/m^2 green mass or 2.1 kg/m^2 dry matter with 14.5-20.0% crude protein, 9.53-10.40 MJ/kg metabolizable energy, 5.55-6.41 MJ/kg net energy for lactation. In the harvested green mass of eastern galega cultivar used for preparation of hay and haylage, in hay making process, the leaves remain on the stem, providing higher forage value: 16.5-17.1% crude protein, 577-625 g/kg digestible dry matter, 9.41-10.12 MJ/kg metabolizable energy, 5.42-6.13 MJ/kg net energy for lactation. The fermentation characteristics and quality indices of eastern galega haylage were: pH=4.60, 51.5 g/kg lactic acid, 8.8 g/kg acetic acid, butyric acid was not detected, 19.6% crude protein, 602 g/kg digestible dry matter, 9.78 MJ/kg metabolizable energy, 5.79 MJ/kg net energy for lactation. The results revealed that the eastern galega green mass and ensiled substrates for biogas production had optimal carbon nitrogen ratio and the estimated biochemical methane potential varied from 320 to 353 l/kg VS.

Keywords: biochemical composition, biochemical methane potential, forage quality, *Galega orientalis*, local cultivar 'Sofia', productivity.

INTRODUCTION

In a context of economic and environmental concerns in agriculture, non-traditional *Fabaceae* species appear to be suitable alternative crops to diversify the current cropping systems and reduce their dependence on synthetic nitrogen fertilizer, improve the physical properties of soil, are an important source of proteins, beneficial to human and animal nutrition, they are also an excellent source of pollen and nectar for honey bees and other useful insects (European Parliament resolution, 2011, 2018; ECPGR, 2021).

In order to expand the areas cultivated with *Fabaceae* species, it is necessary to research and implement new species from other floristic regions and to create high-yielding cultivars adapted to the local soil-climatic conditions.

Galega orientalis Lam., *Fabaceae* family is known commonly as eastern galega or fodder galega - is a perennial herbaceous plant native to the North Caucasus area. It develops robust upright stems, more or less wavy at the nodes, branched in the upper part, glabrous or with short white hairs, dispersed over the entire surface, about 0.8-2.0 m tall and 3-9 mm in diameter at the base. The leaves are dark green, alternate, pinnately compound or imparipinnate, stipules 5-20 cm long; with 5-10 pairs of leaflets, oblong acuminate, 21-60 mm long, mucronate. The inflorescence - terminal raceme, elongated, 18-43 cm long, dense, with 25-70 flowers, corolla blue-lilac, light blue or almost white; the banner oblong-obovate, obtuse, 7-12 mm long; the wings 9-13 mm long, with elongated auricles at base; keel obtuse, about equal to the wings. It blooms in May-June, bears fruit in July. The fruit is a brown, glabrous, erect or horizontal pod, 28-49 mm long and 2.5-3.2 mm wide, with 3-8 kidney-shaped seeds 2.5-4.0 mm long and 1.7-2.0 mm wide, yellow, brownish, smooth and slightly glossy.

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The weight of 1000 seeds - 3.2-6.5 g. Seed viability is 4-7 years. Entomophilous pollination. It produces good quantities of pollen and nectar available for bees for a long period, with a honey production potential of 400-600 kg/ha honey.

It develops a branched tap root system that reaches a depth of 50-135 cm, forming a dense network of roots with adventitious bristles, on which there may be up to 1500 nodules containing *Rhizobium galegae* bacteria. In the first year, the root system develops more, but the growth and development of the aerial part is very slow. In the following years, it develops strong rhizomes reaching a length of 30-40 cm, which extend horizontally to a depth of 2-6 cm and later grow suckers. Yearly, a plant can produce up to 20 suckers. At the same time, on the underground part of the stem, at the root collar, another 3-4 dormant buds are formed, which, under the necessary conditions, start developing new stems. Due to the ability to regenerate through suckers and dormant buds, the plant forms a vigorous bushy habit, reaching a density of about 200 stems/m^2 in the third year of vegetation.

Eastern galega is a mesophyte, thus its tolerance to drought is lower as compared with alfalfa and it can hardly withstand long-term floods. It adapts to different types of soil, with pH between 6.0-7.5, well drained, reacts positively to fertilization with phosphorus, potassium and trace elements. It propagates by seeds. Freshly harvested seeds have a hard coat and need to be scarified and treated with preparations containing the bacteria *Rhizobium galegae*. The seeds in the soil germinate at 4-6°C, and for an optimal emergence of seedlings, temperatures of 10…12°C are necessary, besides they are able to tolerate low temperatures during the winter period of -20°C in open field and - 40°C under a snow layer. In early spring and late autumn, they are able to withstand frosts of -5…-7°C. Eastern galega is a multipurpose crop with many valuable characteristics, including the early beginning of vegetation, fast growth, high productivity, protein content and nutritional value, the plants possess an optimal capacity for regeneration after mowing, so that they can be cut 2-3 times per year. This species has been researched in several scientific centers as fodder plant, medicinal plant, honey plant, energy biomass (Radenovic, 1999; Balezentiene and Mikulionienė, 2006; Stjepanović et al., 2007; Dzyubenko and Dzyubenko, 2008; Adamovics et al., 2011; Domash et al., 2013; Povilaitis et al., 2016; Meripold et al., 2017; Aizman et al., 2019; Rakhmetov et al., 2021; Żarczyński et al., 2021; Ignaczak et al., 2022). In Common catalogue of varieties of agricultural plant species only 3 varieties of fodder galega *Galega orientalis* are registered ‘Gale’, ‘Lena’ and ‘Risa’.

At the “Alexandru Ciubotaru” National Botanical Garden (Institute), the species *Galega orientalis* it has been researched since the ‘80s of the past century, being identified valuable forms and created local cultivars (Teleuţă, 2010; Teleuţă and Ţîţei 2011, 2012).

The main objectives of this study were to evaluate the quality of green mass, hay and haylage from the local cultivar ‘Sofia’ of eastern galega, *Galega orientalis* created at the “Alexandru Ciubotaru” National Botanical Garden (Institute) of Moldova State University, and the prospects of its use as fodder for farm animals or as substrates for renewable energy production.

MATERIAL AND METHODS

The local cultivar ‘Sofia’ of eastern galega, *Galega orientalis*, grown in monoculture in the experimental plot of the 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 samples were collected in third growing season: first cut in the flowering stage-middle May, second cut in the bud stage - middle July and third cut - in the first part of September. The leaf/stem ratio was determined by separating leaves and flowers from the stem, weighing them separately and establishing the ratios for these quantities. Samples of 1.0 kg harvested plants were taken for this purpose. The dry matter content was detected by drying samples up to constant weight at 105°C. The prepared hay was dried directly in the field. The haylage was produced from wilted green mass, cut into small pieces and compressed in glass containers. The organoleptic assessment and the determination of the organic acid composition of the persevered forage were done in accordance with the Moldavian standard SM 108. For biochemical analyses, the fresh mass and fermented fodder samples were dehydrated in an oven with forced ventilation at a temperature of 60°C, at the end of the fixation, the biological material was finely ground in a laboratory ball mill. The quality of the biomass was evaluated by analyzing such indices as: crude protein (CP), crude fiber (CF), crude ash (CA), total soluble sugars (TSS), acid detergent fiber (ADF), neutral detergent fiber (NDF), acid detergent lignin (ADL) which have been determined by near infrared spectroscopy (NIRS) technique PERTEN DA 7200 of the Research and Development Institute for Grassland Braşov, Romania. The concentration of hemicellulose (HC), cellulose (Cel), digestible dry matter (DDM), digestible energy (DE), the metabolizable energy (ME), the net energy for lactation (NEl) and the relative feed value (RFV) were calculated according to standard procedures.

The carbon content of the substrates was determined using an empirical equation according to Badger et al. (1979). The biochemical methane potential was calculated according to Dandikas et al. (2015).

RESULTS AND DISCUSSIONS

Analyzing the some agro-biological features of the local cultivar ‘Sofia’ of eastern galega, *Galega orientalis,* in the third growing season, it was established that the revival of plants from dormant buds was uniform, generative shoots developed in the first part of April and they were characterized by faster grow and development rates, the flower bud formation of plants started at the early of May. At the time when the green mass was cut, the *Galega orientalis* plants were 122-127 cm tall, the yield was 5.82 kg/m^2 green mass or 1.09 kg/m^2 dry matter, characterized by optimal content of leaves and flowers in the harvested mass (Table 1). After harvest the regeneration of eastern galega plants was slow until the end of May, but after the abundant rainfall recorded in June, the growth and development rates became faster. It was established that during 45 days, plants developed shoots that grew about 50-61 cm long, and the plants were cut in the bud stage for the second time, obtaining 1.81 kg/m^2 green mass or 0.61 kg/m^2 dry matter, the harvested mass was richer in leaves (71.7%). The unfavorable meteorological conditions, the lack of rainfall and the very high air temperatures (35-40ºC) during the 30 days after second mowing affected the regeneration and development rate of plants. A better growth and development was observed after the rainfall that occurred at the end of August, the formed shoots were semi-erect and over 65-70 cm long. The yield at the third cut was 1.48 kg/m^2 green mass or 0.42 kg/m^2 dry matter. The annual productivity from three cuts was 9.11 kg/m^2 green mass or 2.12 kg/m^2 dry matter.

Some authors have mentioned various findings about the productivity of *Galega orientalis.* So, as a result of a research conducted by Radenovic (1999) the annual yield was 105.5 t/ha of green mass or 26.7 t/ha hay on the chernozem soils of neutral reaction, 81 t/ha of green mass and 16 t/ha of hay on the soil of Humogley type and 46.5 t/ha of green mass or 9.3 t/ha on weakly acid and acid soils - eutric cambisol ilimerized. Adamovics et al. (2011) mentioned that the pure galega swards provided 50.81 t/ha fresh biomass or 12.16 t/ha organic dry matter. Avetisyan (2013) has revealed that the yield of *Galega orientalis* at the first cut was 28.6 t/ ha green mass or 7.72 t/ha dry matter and at the second cut - 14.0 t/ ha green mass or 3.3 t/ha dry matter, but yield of *Medicago sativa* at the first cut was 18.9 t/ ha green mass or 5.63 t/ha dry matter and at the second cut 11.26 t/ ha green mass or 2.60 t/ha dry matter, respectively. Teleuţă et al. (2015b) reported that the annual fodder productivity of *Galega orientalis* 'Speranţa' was 79.8 t/ha green mass or 16.2 t/ha dry matter. Povilaitis et al. (2016) mentioned that the dry matter productivity of fodder galega was 8.0-9.3 t/ha, but alfalfa produced 8.3-9.2 t/ha. In our previous publication (Ţîţei and Coşman, 2019), we found the the productivity of cv. Speranţa of fodder galega in the 7th growing season reached 101.5 t/ha green mass or 20.3 t/ha dry matter. Cherniavskih et al. (2020) reported that the dry matter productivity of *Galega orientalis* reached 639.0 g/m^2 at the first cut and 439.5 g/m^2 at the second cut. Rakhmetov et al. (2021), found that the created cultivars of *Galega orientalis* were characterized by 28.6-62.4 t/ha green mass productivity, as well as by 7.12-16.5 t/ha the yield of dry matter with 40.9-51.4% leaves and 11.6-14.9% inflorescences in phytomass. Ignaczak et al. (2022) found that *Galega orientalis* plants at the first cut reached 90-119 cm and the yield reached 0.544-0.748 kg/m^2 DM and at the second cut 58-67 cm and 0.257-0.315 kg/m^2 DM, but *Medicago sativa* plants at first cut was 79-96 cm, 0.530-0.650 kg/m^2 DM and at second cut 67-78 cm, 0.313-0.383 kg/m^2 DM, respectively.

The biochemical composition of dry matter is an important indicator in feed quality evaluation. The quality indices of the harvested green mass from local cultivar 'Sofia' of eastern galega are presented in Table 2. We found that the dry matter content of eastern galega whole plants and its quality indices varied depending on the mowing period: 145-200 g/kg CP, 108-121 g/kg ash, 292-355 g/kg CF, 315-390 g/kg ADF, 503-636 g/kg NDF, 49-56 g/kg ADL, 265-341 g/kg Cel, 188-346 g/kg HC with 58.5-64.4% DMD, RFV=90-129, 11.61-12.66 MJ/kg DE, 9.53-10.40 MJ/kg ME, 5.55-6.41 MJ/kg NEl. The first cut eastern galega dry matter had high content of crude protein, minerals and fibers, optimal content of acid detergent lignin. The green mass at the second cut was characterized by optimal concentration of crude protein, acid detergent lignin and low amount of structural carbohydrates, which had a positive effect on the digestibility, nutritional value and energy supply of the feed. The lowest level of crude protein and the highest concentration of acid detergent lignin were found in the third cut green mass.

Different results regarding the biochemical composition and the nutritive value of the harvested mass from eastern galega, *Galega orientalis*, species are given in the specialized literature. According to Timofeev (2003), the *Galega orientalis* green mass contained 270 g/kg dry matter with 20.5% CP, 27.8% CF, 11.9% sugar and 10.2 MJ/kg ME, but *Trifolim pratense* green mass - 270 g/kg dry matter with 16.5% CP, 26.8% CF, 10.3% sugar and 10.0 MJ/kg ME. Skórko-Sajko et al. (2005) reported that the green forage dry matter from *Galega orientalis* had 906.9 g/kg OM, 245.5 g/kg CP, 57.4 g/kg PDIA, 150.1 g/kg PDIN, 103.4 g/kg PDIE, 0.77 UFL/kg, 0.70 UFV/kg, 1.19 CFU/kg. Domash et al. (2013) reported that the concentration of proteins in the leaves of the studied 19 varieties of *Galega orientalis* were 15.37-19.79%, the content of essential amino acids in proteins was as follows: 4.84-5.13% valine, 3.62-3.85% isoleucine, 8.17-8.56% leucine, 5.79-6.23% lysine, 0.94-1.14% methionine, 4.52-5.20% threonine and 5.59-5.96% phenylalanine. Teleuţă et al. (2015a) reported that the biochemical composition of the dry matter and the nutritional value of forage from *Galega orientalis* at the first cut was 17.80% CP, 3.55% EE, 30.56% CF, 39.47% NFE, 8.69% ash and 147 g digestible protein per nutritive unit, but - from *Medicago sativa* - 16.16% CP, 1.88% EE, 34.74% CF, 37.22% NFE, 10.00% ash and 145 g digestible protein per nutritive unit. Skórko-Sajko et al. (2016) revealed that the chemical composition and nutritive value of galega green forage were: 144.4-225.7 g/kg DM, 89.39-91.00% OM, 16.04-27.22% CP, 2.09-2.90% EE, 50.69-56.53% NDF, 29.43-38.01% ADF, 3.81-4.52% ADL lignin, 17.00-21.26% Cel, 25.26-33.49% HC, 34.68-43.63% NFE, 4.52-4.92% soluble sugars, 18.16-19.18 MJ/kg GE, 8.95-11.53 MJ/kg ME and 5.20-7.00 MJ/kg NEl. Coşman et al. (2017) found that the cultivar Speranţa of *Galega orientalis* at the first cut contained 125.2-180.7 g/kg DM with 16.18-22.94% CP, 3.26-3.90% EE, 31.95-36.85% CF, 46.5-

57.9% NDF, 28.8-37.7% ADF, 3.9-6.3% ADL, 32.18-38.06% NFE, 7.51-8.86% ash, 64.0-82.0% DDM, RFV=97-133. Meripõld et al. (2017) mentioned that the chemical composition of the pure eastern galega forage at the first cut was 17.0-17.8% CP, 48.9-49.5% NDF, 40.8-43.9% ADF, but of the eastern galega-grass mixtures - 9.4-13.4% CP, 50.9-55.4% NDF, 36.9-39.6% ADF, respectively. Kuchin and Ivashin (2019) remarked that the concentration of nutrients in the galega dry matter cut in the budding period was 19.4-21.6% CP, 2.29-3.07% EE, 19.6-23.0% CF, 46.5-51.6% NFE, 6.1-6.9% ash, 10.8-11.5 MJ/kg ME, but in flowering period 14.4-16.7% CP, 2.3-2.7% EE, 24.8-26.4% CF, 48.0-52.5% NFE, 5.2-6.2% ash, 10.2-10.6 MJ/kg ME. Nechunaev and Falaleeva (2020) reported that *Galega orientalis* forage contained 271.3 g/kg CP, 57.7 g/kg EE, 264.1 g/kg CF, 299.7 g/kg NFE, 109.4 g/kg ash, 16.2 g/kg Ca, 3.4 g/kg P and 9.8 MJ/kg ME, but from *Trifolium pratense* - 186.7 g/kg CP, 66.2 g/kg EE, 306.5 g/kg CF, 335.6 g/kg NFE, 106.7 g/kg ash, 12.6 g/kg Ca, 3.2 g/kg P and 8.9 MJ/kg ME. Darmohray et al. (2021) reported that the dry matter of *Galega orientalis* harvested at the beginning of the flowering period contained 21.09% CP, 2.95% EE, 27.29% CF, 60.55% NDF, 5.18% ash. Ignaczak et al. (2022) revealed that fodder galega whole plants at the first cut contained 168-278 g/kg DM with a nutritional value of 15.7-23.3% CP, 32.7-37.8% ADF, 45.8-52.7% NDF, 6.0-7.5% ash, 729-800 g/kg IVTD, and the second cut forage contained 227-245 g/kg DM with a nutritional value of 17.2-17.7% CP, 33.8-34.0% ADF, 48.7-49.9% NDF, 7.7-7.9% ash, 757-791 g/kg IVTD.

Hay is the oldest, and still the most important, conserved forage, despite its dependence on a suitable weather at harvest time. Hay is an essential part of livestock diet, a rich source of nutrients, vitamins and minerals, especially during winter period. The quality indices of the prepared hays from the local cultivar 'Sofia' of eastern galega are shown in Table 3. The eastern galega hays are characterized by 165-171g/kg CP, 106-124 g/kg ash, 327-363 g/kg CF, 339-401 g/kg ADF, 495-627g/kg NDF, 53-60 g/kg ADL, 286-341 g/kg Cel, 156-226 g/kg HC with 57.7-62.5% DMD, RFV=90-117, 11.46-12.32 MJ/kg DE, 9.41-10.12 MJ/kg ME, 5.42-6.13 MJ/kg NEl. We would like to mention that in the haymaking process, we noticed an increase in the concentration of crude fiber, acid detergent lignin and a decrease in the content of hemicellulose crude protein, digestibility, relative feed value and energy concentration as compared with the harvested green mass. It has been determined that the content of crude protein in the hay prepared from first cut eastern galega lowered in comparison with the initial mass, while the hay prepared at the second cut did not differ significantly in the concentration of crude protein. Several studies have evaluated the potential of *Galega orientalis* for haymaking. Radenovic (1999) reported that fodder galega hay contained 24-27% of crude proteins in dry matter. Stjepanović et al. (2007) mentioned that the galega hay had higher leaf content, containing 20.85% CP, 43.98% NDF, 39.09% ADF with RFV=124, while alfalfa hay - 17.61% CP, 45.21% NDF, 39.67% ADF with RFV=119. Teleuţă et al. (2015b) reported that the quality indices of galega hay from the first cut were as follows: 14.60% CP, 1.46% EE, 37.58% CF, 36.86% NFE, 9.50% ash and 132.2 g digestible protein per nutritive unit; second cut hay - 14.35% CP, 1.57% EE, 32.15% CF, 41.65% NFE, 10.58% ash and 125.5 g digestible protein per nutritive unit, while the third cut hay - 17.83% CP, 2.38% EE, 34.39 % CF, 36.92% NFE, 8.48% ash and 164.6 g digestible protein per nutritive unit. Coşman et al. (2017) found the galega hay at the first mowing contained 15.03% CP, 1.30% EE, 34.77% CF, 29.69% NFE, 6.46% ash, 30.12 mg/kg carotene. In our previous work (Ţîţei and Coșman, 2019) we assessed galega hay quality, and found that it varied significantly depending on the harvest time and contained 153-212 g/kg CP, 13-24 g/kg EE, 103-128 g/kg ash, 458-584 g/kg NDF, 315-386 g/kg ADF, 48-60 g/kg ADL, 62.7-

72.9% DMD, 57.4-67.7% OMD, 8.81-9.66 MJ/kg ME and RFV 95-131. Darmohray et al. (2021) reported that *Galega orientalis* hay was characterized by 770 g/kg DM, 71.85% OM including 13.56% CP, 1.66% EE, 29.46% CF, 27.15% NFE, 57.70% NDF and 41.40% ADF.

Table 1. Some biological peculiarities and the productivity of the local cultivar 'Sofia' of *Galega orientalis,* in the third growing season

Harvest time	Plant height, cm	Stem, g		Leaf + flowers, g		Total weight of a shoot, g		Yield, kg/m^2		Content of leaves and flowers in fodder, %
		fresh mass	dry matter	fresh mass	dry matter	fresh mass	dry matter	fresh mass	dry matter	
16.05.2022 first cut	124	30.44	4.46	27.56	6.38	58.0	10.84	5.82	1.09	58.9
19.07.2022 second cut	55	3.93	1.63	13.2	4.13	17.13	5.76	1.81	0.61	71.7
07.09.2022 third cut	67	6.12	1.41	6.18	2.04	12.30	3.45	1.48	0.42	59.3
Total								9.11	2.12	

Table 2. The biochemical composition and the fodder value of the green mass from the local cultivar 'Sofia' of eastern galega *Galega orientalis* depending on the harvest time

Indices	Harvest time		
	first cut	second cut	third cut
Crude protein, g/kg DM	200	163	145
Crude fiber, g/kg DM	355	292	320
Minerals, g/kg DM	133	108	108
Acid detergent fiber, g/kg DM	390	315	351
Neutral detergent fiber, g/kg DM	636	503	588
Acid detergent lignin, g/kg DM	49	50	56
Cellulose, g/kg DM	341	265	295
Hemicellulose, g/kg DM	246	188	237
Digestible dry matter, g/kg DM	585	644	616
Relative feed value	90	129	98
Digestible energy, MJ/ kg	11.61	12.66	12.16
Metabolizable energy, MJ/ kg	9.53	10.40	9.98
Net energy for lactation, MJ/ kg	5.55	6.41	6.41

Table 3. The biochemical composition and the fodder value of the hay from the local cultivar 'Sofia' of eastern galega *Galega orientalis* depending on the harvest time

Indices	Harvest time	
	first cut	second cut
Crude protein, g/kg DM	171	165
Crude fiber, g/kg DM	363	327
Minerals, g/kg DM	124	106
Acid detergent fiber, g/kg DM	401	339
Neutral detergent fiber, g/kg DM	627	495
Acid detergent lignin, g/kg DM	60	53
Cellulose, g/kg DM	341	286
Hemicellulose, g/kg DM	226	156
Digestible dry matter, g/kg DM	577	625
Relative feed value	90	117
Digestible energy, MJ/ kg	11.46	12.32
Metabolizable energy, MJ/ kg	9.41	10.12
Net energy for lactation, MJ/ kg	5.42	6.13

Under year-round uniform feeding, fermented forage, silage and haylage are the most effective types of diet. In recent years, legume haylage has become an important component of livestock diets, bening an excellent source of protein and amino acids, particularly in the late autumn - middle spring period. When opening the glass vessels with galega haylage prepared, there was no gas or juice leakage from the preserved mass, it had pleasant smell and colour, the consistency was retained in comparison with the initial green mass, without mould and mucus. The results regarding the quality indices of the prepared galega haylage are shown in Table 4. The fermentation characteristics of galega haylage were: pH=4.60, 51.5 g/kg lactic acid, 8.8 g/kg acetic acid, butyric acid was not detected. The nutrient and feed energy value of haylage dry matter were: 19.6% CP, 14.8% ash, 34.0% CF, 36.9% ADF, 61.1% NDF, 4.4% ADL, 32.5% Cel, 24.2% HC, 60.2% DMD, RFV=92, 11.91 MJ/kg DE, 9.78 MJ/kg ME, 5.79 MJ/kg NEl.

Different results regarding the biochemical composition and the nutritive value of the ensiled mass from *Galega orientalis* are given in the specialized literature. According to Skórko-Sajko et al. (2005) the wilted silage was characterized by 37.2% DM, pH 4.68, 98 points on the Flieg-Zimmer scale and the dry matter contained 877.2 g/kg OM, 201.6 g/kg CP, 61.1 g/kg PDIA, 120.4 g/kg PDIN, 87.3 g/kg PDIE, 0.70 UFL/kg, 0.62 UFV/kg, 0.91 CFU/kg. Balezentiene and Mikulionienė (2006) found that galega pure silage had pH=5.3, 271 g/kg DM, 21.9% CP, 3.7% EE, 25.1% CF, 0.5% sugar, 41.9% NDF, 10.78 MJ/kg ME, 6.42 MJ/kg NEl, but the silage with additives - pH=4.9, 272 g/kg DM, 22.6% CP, 3.1% EE, 26.2% CF, 0.55% sugar, 42.6% NDF, 10.58 MJ/kg ME, 6.48 MJ/kg NEl. Coşman et al. (2017) mentioned that galega haylage was characterized by pH=5.18, 4.1 g/kg acetic acid, 29.2 g/kg lactic acid, 384.7 g/kg DM with 16.56% CP, 3.72% EE, 40.61% CF, 29.63% NFE, 9.48% ash and 24.0 mg/kg carotene. Karamaev et al. (2020) mentioned that the quality indices of galega haylage were: pH=4.37, 7.1 g/kg acetic acid, 35.2 g/kg lactic acid, 2.2 g/kg butyric acid, 465 g/kg DM including 83.52 g/kg CP, 60.24 g/kg DP, 140.35 g/kg CF and 3.99 MJ/kg ME, but alfalfa haylage - pH=4.46, 7.5 g/kg acetic acid, 34.9 g/kg lactic acid, 1.5 g/kg butyric acid, 446 g/kg DM including 79.83 g/kg CP, 41.62 g/kg DP, 147.36 g/kg CF and 3.98 MJ/kg ME. Nechunaev and Falaleeva (2020) reported that the nutritive value of *Galega orientalis* haylage was 475 g/kg DM, 74.8 g/kg crude protein, 46.5 g/kg digestible protein, 12.7 g/kg crude fat, 128.2 g/kg crude fiber, 181.8 g/kg NFE, 13.4 g/kg sugar, 4.2 g/kg Ca, 1.0 g/kg P, 4.4 MJ/kg ME and 30 mg/kg carotene, but the haylage from *Trifolium pretense* - 463 g/kg DM, 62.7 g/kg crude protein, 39.8 g/kg digestible protein, 13.4 g/kg crude fat, 134.3 g/kg crude fiber, 196.5 g/kg NFE, 24.3 g/kg sugar, 4.8 g/kg Ca, 0.9 g/kg P, 3.5 MJ/kg ME and 30 mg/kg carotene. Fattakhova et al. (2021) reported that *Galega orientalis* haylage without adding a preservative was characterized by 548.2 g/kg DM, pH=4.85, 2.09% lactic acid, 0.19% acetic acid, 0.00% butyric acid, 170.52 g/kg digestible protein, 37.03 g/kg sugar, 20.39 g/kg Ca, 2.41 g/kg P, but the haylage with chemical supplements and microbial additive - 555-560 g/kg DM, pH=4.36-4.89, 0.87-2.47% lactic acid, 0.13-0.25% acetic acid, 0-0.01% butyric acid, 178.59 g/kg digestible protein, 14.30-32.79 g/kg sugar, 20.20-21.78 g/kg Ca, 1.30-2.21 g/kg P. Starkovskiy et al. (2020) mentioned that the haylage from *Galega orientalis* plants cut in the budding - beginning of blooming stage was characterized by 424 g/kg DM, 14.59% digestible protein, 68% lactic acid, 32% acetic acid and 10.4 MJ/kg ME; from the plants cut in full blooming - beginning of fruit formation - 471 g/kg DM, 14.21% digestible protein, 71% lactic acid, 29% acetic acid and 10.3 MJ/kg ME, but from second cut plants - 426 g/kg DM, 9.91% digestible protein, 81.4% lactic acid, 18.6% acetic acid and 8.1 MJ/kg ME. Darmohray et al. (2021) reported that *Galega orientalis* haylage contained 465 g/kg DM including 62 g/kg CP, 11 g/kg EE, 218 g/kg CF, 131 g/kg NFE, 69.40% NDF, 58.90% ADF.

Table 4. The biochemical composition and the fodder value of the haylage from local cultivar 'Sofia' of eastern galega *Galega orientalis*

Indices	First cut
pH index	4.60
Organic acids, g/kg DM	60.3
Free acetic acid, g/kg DM	3.0
Free butyric acid, g/kg DM	0
Free lactic acid, g/kg DM	8.1
Fixed acetic acid, g/kg DM	5.8
Fixed butyric acid, g/kg DM	0
Fixed lactic acid, g/kg DM	43.4
Total acetic acid, g/kg DM	8.8
Total butyric acid, g/kg DM	0
Total lactic acid, g/kg DM	51.5
Acetic acid, % of organic acids	14.59
Butyric acid, % of organic acids	0
Lactic acid, % of organic acids	85.41
Crude protein, g/kg DM	19.6
Crude fiber, g/kg DM	34.0
Minerals, g/kg DM	14.8
Acid detergent fiber, g/kg DM	36.9
Neutral detergent fiber, g/kg DM	61.1
Acid detergent lignin, g/kg DM	4.4
Cellulose, g/kg DM	32.5
Hemicellulose, g/kg DM	24.2
Digestible dry matter, g/kg DM	602
Relative feed value	92
Digestible energy, MJ/ kg	11.91
Metabolizable energy, MJ/ kg	9.78
Net energy for lactation, MJ/ kg	5.79

Since ancient times, people have struggled to find and utilize energy resources to meet their basic needs for food, heating, shelter. The demand for energy and associated services, to meet social and economic development and improve human welfare and health, is increasing. Because along with the economic development came an increasing the risk of depletion of fossil energy sources and their harmful impact on environment, a tendency towards replacing oil, coal, natural gas with renewable energy alternatives has emerged recently. Energy security has been a permanent concern, with government policies and regulations being implemented, but it has become an increasingly severe issue in recent years.

Biomass is an attractive and convenient energy resource that can be used in the processes of decarbonisation and energy transition. Biofuel in the form of biogas can be produced from phytomass feedstocks. The production of biogas by anaerobic digestion (biomethanation) of phytomasses is of growing importance in the context of renewable energy production, is socio-economically cost-efficient and environmentally efficient by reducing greenhouse gas emissions. The feedstock can be used as an individual substrate for anaerobic digestion or co-digested with two or more substrates. Biogas generators produce not only methane for heat and electricity, but also digestate and fugate, which are believed to be good fertilizers in organic farming systems. The use of legume biomass for biogas plays an important role in replacing scarce energy sources in the transition from a fossil economy to a biobased economy. The carbon and nitrogen are vital for the microbial cell growth and functioning, the nitrogen present in the feedstock facilitates the synthesis of amino acids, proteins and nucleic acids, while carbon acts as the structural unit as well as the energy source for microbes. A balanced carbon to nitrogen (C/N) ratio is necessary for the optimization of methane generation, ratios higher than 30:1 were found to be unsuitable for optimal digestion, and ratios lower than 10:1 were found to be inhibitory, due to low pH, poor buffering capacity and high concentrations of ammonia in the substrate.

Table 5. Biochemical biomethane production potential of substrates from the local cultivar 'Sofia' of *Galega orientalis*

Indices	Green mass			Haylage first cut	Hay	
	first cut	second cut	third cut		first cut	second cut
Organic dry matter, g/kg	867.00	892.00	892.00	852.00	876.00	894.00
Minerals, g/kg DM	133.00	108.00	108.00	148.00	124.00	106.00
Crude protein, g/kg DM	200.00	163.00	145.00	196.00	171.00	165.00
Nitrogen, g/kg DM	32.00	26.08	23.20	31.36	27.36	26.40
Carbon, g/kg DM	481.67	495.56	495.56	473.33	486.67	496.67
Ratio carbon/nitrogen	15.05	19.00	21.36	15.09	17.79	18.81
Cellulose, g/kg DM	341.00	265.00	295.00	325.00	341.00	286.00
Hemicellulose, g/kg DM	246.00	188.00	237.00	242.00	226.00	156.00
Acid detergent lignin, g/kg DM	49.00	50.00	56.00	44.00	60.00	53.00
Biomethane potential, L/kg DM	299	297	287	301	281	293
Biomethane potential, L/kg ODM	345	334	322	353	320	328

The results regarding the quality indices of the studied *Galega orientalis* substrates and their biochemical methane potential are presented in Table 5. In the eastern galega green mass substrates, according to the C/N ratio, which constituted 15-21, the concentration of acid detergent lignin (49-56 g/kg) and hemicellulose (188-246 g/kg) met the established standards; the biochemical methane potential of the studied green mass substrates varied from 322 to 345 l/kg ODM. As we have mentioned above, the process of ensiling decreased the lignin content and the hemicellulose did not change significantly, which have a positive effect on the activity of methanogenic bacteria. The biochemical biomethane potential of eastern galega haylge mass substrates reached 353 L/kg. It has been found that *Galega orientalis* hay substrates have higher concentration of acid detergent lignin and lower concentration of hemicellulose, which played a part in lowering the biochemical methane potential as compared with the other investigated substrates.

Several publications have documented the biomethane production potential of substrates from *Galega orientalis*. Dubrovskis et al. (2008) reported that the methane production potential of galega haylage substrate reached 384.2 l/kg VS. Adamovics et al. (2011) mentioned that the substrate of 75% galega and 25% cow manure in anaerobic fermentation process produced the highest biogas yield of 628 m^3/t DOM with a methane content of 61.2%. Povilaitis et al. (2016) found that fodder galega herbage contained 2.71-2.99% N, 43.67-47.35% C, 0.13-0.17% S and C/H=15.91-16.33, alfalfa herbage 2.69-2.75% N, 43.70-47.12% C, 0.14-0.17% S and C/H=16.51-17.24, respectively, fertilized maize plant mass 1.30-1.63% N, 44.60-45.29% C, 0.14-0.15% S and C/H=28.01-35.46. Hunady et al. (2021) revealed the theoretical methane yield of biomass from *Galega orientalis*, *Lathyrus pratensis*, *Trigonella foenum-graecum* and *Melilotus alba* ranged from 0.161 to 0.172 m^3/kg VS.

CONCLUSIONS

The local cultivar 'Sofia' of eastern galega *Galega orientalis* is characterized by high productivity and can be used in monoculture or as component of the mix of grasses for the creation of temporary grasslands. The harvested mass may be used as feed for livestock as natural fodder, hay, haylage, also as substrates in biogas reactors via anaerobic digestion for renewable energy production.

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