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THE PRODUCTIVITY AND QUALITI OF *Arrhenatherum elatius* GRASSLANDS FROM THE ORHEI NATIONAL PARK, REPUBLIC OF MOLDOVA

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Abstract

This article presents new findings on the productivity of grasslands in Orhei National Park (Republic of Moldova). The research was conducted during 2021-2022 on a grassland dominated by Arrhenatherum elatius, located in the village of Neculaeuca, Orhei district. Hay yield ranged from 4.13 to 5.63 t/ha. The dry matter of the hay contained 107-142 g/kg CP, 343-373 g/kg CF, 93-106 g/kg ash, 373-395 g/kg ADF, 595-648 g/kg NDF, 43-44 g/kg ADL, 57-85 g/kg TSS, 330-351 g/kg Cel, and 22 g/kg HC. The nutritive and energy values were as follows: 58.1-61.9% DMD, RFV = 83-97, 11.53-12.21 MJ/kg DE, 9.47-10.03 MJ/kg ME, and 5.49-5.74 MJ/kg NEl. In addition to its fodder value, the hay substrate demonstrated an optimal lignin and hemicellulose content for anaerobic digestion, with an estimated biochemical methane potential ranging from 313 to 362 l/kg VS.

Key words: *Arrhenatherum elatius grasslands, biochemical methane potential, fodder values, hay productivity, Orhei National Park.*

INTRODUCTION

Grasslands hold significant ecological importance, as they comprise a substantial portion of terrestrial habitats. In Europe, grasslands cover approximately 1.8 million hectares, accounting for about 40% of the land surface. Natural grasslands play a crucial role in conserving European phytodiversity. They also provide essential ecosystem services, including carbon sequestration, erosion control, and habitat for a wide range of plant and animal species (Dengler et al., 2014). The sustainable management of grassland biomass has become a growing challenge across Europe. While the primary function of grasslands remains the production of forage for livestock, recent studies have shown that grassland biomass also serves as a valuable substrate for biofuel production and biorefining processes (Dindová et al. 2019; Von Cossel et al. 2019; Carni et al. 2021; Schaub et al. 2025).

Arrhenatherion meadows are among the most common grassland plant communities and serve as an important resource for the ecological restoration of species-rich grasslands. In Europe, these communities are often among the most biodiverse ecosystems, both at the microhabitat scale and across broader landscapes, underscoring the need for their protection and sustainable management. To preserve and enhance plant biodiversity, hay mowing followed by hay removal is generally recommended over grazing. Typically, *Arrhenatherum elatius* meadows are mown two to three times per year. Additionally, these meadows are frequently used as seed sources in grassland restoration efforts (Graiss et al. 2013, Scotton, 2016).

Currently, *Arrhenatheretum elatioris* meadows developed in a typical form are becoming more and more rare. *Arrhenatheretum elatioris* grassland are studied in different scientific centres and universities, and implemented with multiple uses in different regions of the Earth (D'Ottavio & Ziliotto, 2003; Wyłupek, 2006; Kryszak & Kryszak, 2007; Goliński & Goliński, 2013; Meserszmit et al. 2024).

Orhei National Park was founded in 2013 and operates under the Law on the Fund of Natural Areas Protected by the State and the National Strategy for the Conservation of Biological Diversity, it covers 33.8 thousand hectares and includes the territory of 18 communes from

four districts – Orhei, Straseni, Calarasi and Criuleni located in the Central Zone- Codrii being the first park of its kind in the Republic of Moldova. With a unique relief in Europe, Orhei National Park offers important scientific, educational and tourist opportunities, while contributing to stopping the degradation of forest ecosystems, illegal logging, deterioration of pastures and forests, sustainable management of natural ecosystems, as well as promoting organic agriculture and ecotourism. The variety of local natural conditions of relief and climate determined the diversity of the flora in the Orhei National Park, where over 700 species of flora belonging to 334 genera and 80 families from the *Pteridophyta* (0.2%) and *Magnoliophyta* (98.0%) phyla were inventoried, 52 rare plant species with varying conservation statuses were highlighted according to the International Union for Conservation of Nature IUCN. The plant species have a valuable phytoeconomic potential with multiple utility, such as fodder, food, ornamental, medicinal, melliferous, etc.
The aim of this research was to evaluate the hay productivity of *Arrhenatherum elatius* grasslands, as well as the economic value of the hay as livestock feed and as a substrate for biomethane production.

MATERIALS AND METHODS

The research was conducted during 2021-2022 on an *Arrhenatherum elatius* grassland located in the village of Neculaeuca, Orhei District, within Orhei National Park, Republic of Moldova. Samples were collected from the first hay cut. Mowing was performed at the inflorescence emergence stage of the dominant species, tall oat grass (*Arrhenatherum elatius*). The harvested phytomass was dried directly in the field. Hay yield was determined by weighing the total dry phytomass from plots measuring 10 m² (5 × 2 m), with five replications. The dry matter content was assessed by oven-drying samples at 105 °C until a constant weight was achieved. For chemical analysis, hay samples were chopped into pieces 1.5-2.0 cm in length, dried in a forced-air oven at 60 °C, and then milled using a beater mill equipped with a 1 mm sieve. The primary biochemical parameters – crude protein (CP), ash, acid detergent fibre (ADF), neutral detergent fibre (NDF), acid detergent lignin (ADL), and total soluble sugars (TSS) – were determined using near-infrared spectroscopy (NIRS) with a Perten DA 7200 analyzer at the Research and Development Institute for Grasslands, Brașov, Romania. The concentrations of hemicellulose (HC), cellulose (Cel), digestible dry matter (DDM) digestible energy (DE), metabolizable energy (ME), net energy for lactation (NEl) and relative feed value (RFV) were calculated following 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 the equations of Dandikas et al. (2015).

RESULTS AND DISCUSSIONS

It is well established that forage yield and quality are primarily influenced by the floristic composition of the grassland, soil characteristics, precipitation patterns and distribution, temperature conditions, and light availability. Hay is a low-cost source of roughage and essential nutrients, playing a critical role in maintaining livestock health and productivity, particularly from autumn through mid-spring. The prepared hay from *Arrhenatherum elatius* grasslands contained 87.8–90.4% dry matter. The results of the hay quality analysis from *Arrhenatherum elatius* grasslands are presented in Table 1. The hay dry matter contained 107-142g/kg CP, 343-373 g/kg CF, 93-106 g/kg ash, 373- 395g/kg ADF, 595-648 g/kg NDF, 43-44 g/kg ADL,57-85 g/kg TSS, 330-351 g/kg Cel, 22 g/kg HC, with nutritive and energy value 58.1-61.9% DMD, RFV=83-97, 11.53-12.21 MJ/kg DE, 9.47-10.03 MJ/kg ME, 5.74-5.49 MJ/kg NEl. The hay prepared during the 2021 growing season was characterized by a higher content of crude protein and minerals, and a lower concentration of total soluble sugars, cellulose, and hemicellulose, which contributed to improved digestibility and a higher energy concentration compared to the hay prepared in the 2022 growing season.

In the specialized literature, there are various data on the forage quality of *Arrhenatherum elatius* plants. Medvedev & Smetannikova (1981) mentioned that *Arrhenatherum elatius* hay contained 7.6-12.7% CP, 1.6-3.4% EE, 23.2-32.0% CF, 36.0-50.0% NFE, 7.0-10.0% ash. D'Ottavio & Ziliotto (2003) reported that forage from grassland with most abundant species *Arrhenatherum elatius*, *Agropyron repens*, *Dactylis glomerata*, *Lolium perenne*, *Trisetum flavescens*, *Trifolium pratense*, *Trifolium repens* and *Taraxacum officinale* achieved at 1st cut dry matter yield 6.48 t/ha with 5.08% CP, 1.54% EE, 6.09% ash, 35.66% CF, 61.34% NDF, 35.43% ADF, 6.09% ADL, 3.19 MJ/kg NEL, while from the 2nd cut – 3.66 t/ha DM, 7.19% CP, 2.19% EE, 7.46% ash, 31.10% CF, 59.58% NDF, 31.35% ADF, 5.166.09% ADL, and 4.60 MJ/kg NEL. Wyłupek (2006) mentioned that content of some nutrients in selected *Arrhenatheretum elatioris* phytocenoses biomass was 11.37% CP, 1.22 g/kg P, 7.1 g/kg K, 2.04 g/kg Mg, 3.36 g/kg Ca. Heinsoo et al. (2010) found that the nutritive value of forage from mesic meadows was 9.4% CP, 59.7% NDF, 6.1% ash, 18 MJ/kg GCV. Skládanka et al. (2008, 2010) found that the forage dry matter from *Arrhenatherum elatius* plants contained 7.92-9.49% CP, 29.34-30.25% CF, 55.48-61.20% NDF, 35.9% ADF, 71.80-78.0% OMD and 5.46 MJ/kg NEl. Tomić et al. (2005) reported that the grass quality of *Arrhenatherum elatius* grown the pasture associations was 6.28% CP, 30.07% CF, 8.11% ash. Cop et al. (2009) reported that dry matter from *Arrhenatherum elatius* grassland contained 11.74-15.91% CP, 24.48-29.67% CF, and 5.4-6.0 MJ/kg NEl. Grygierzec (2012) reported that hay from the *Arrhenatheretum elatioris typicum* community meadow contained 111-121 g/kg CP, 61.6-63.2 g/kg ash, 510-512 g/kg NFE, 129.9-130.1 g/kg EE, 446-474 g/kg NDF, 338-340 g/kg ADF, 62 g/kg ADL, and 268-283 g/kg cellulose. Goliński and Goliński (2013) noted that biomass from semi-natural grasslands, primarily represented by the *Arrhenatherion* alliance, had 308 g/kg dry matter, with 10.35% CP, 6.36% ash, 50.98% NDF, 31.61% ADF. Von Cossel et al. (2019) reported that the first-cut biomass from *Arrhenatherion* grasslands was characterized by 240-297 g/kg DM with 7.0-8.1% ash, 4.7-5.7% lignin, 29.3-31.9% Cel, 20.7-25.2% HC and 1.4-1.7 % N. Meserszmit et al. (2021) mentioned that the herbage from *Arrhenatherum elatius* and *Dactylis glomerata* plant community contained 8.00% CP, 3.17% EE, 57.30% NDF, 16.56% HC, 29.47% Cel, 11.24% lignin, 7.73% ash. Reiné et al. (2020) remarked that *Arrhenatherum elatius* contained 421 g/kg DM with 7.6% CP, 4.5% ash, 1.6% EE, 66.5% NDF, 35.2% ADF, 3.0% ADL, 61.5% DDM, 0.13% P, 0.50% Ca. Țîței (2024) found that the hay prepared from tall oatgrass plants grown in monoculture contained 77 g/kg CP, 414 g/kg CF, 80 g/kg ash, 436 g/kg ADF, 740 g/kg NDF, 40 g/kg ADL, 98 g/kg TSS, 396 g/kg Cel and 304 g/kg HC, with nutritive and energy value of 54.1% DDM, 10.82 MJ/kg DE, 8.88 MJ/kg ME and 5.02 MJ/kg NEl.

The use of phytomass from grassland as substrate for biogas production has recently become of major interest in Europe. The results regarding the quality indices of studied hay substrates for anaerobic digestion and the its potential for obtaining biomethane are shown in Table 2. We found that in the investigated hay substrates, according to the C/N ratio, which constituted 21.86-29.43, the amount of acid detergent lignin (43-44 g/kg) and hemicellulose (222-25 3g/kg) met the established standards and biochemical methane potential achieved 303-306 l/kg DM. Several literature sources describe the methane yield of the biomass substrates from *Arrhenatheretum elatioris* grasslands. According to Prochnow et al. (2009) biomethane yield varied from 155 to 293 l/kg VS. Ebeling et al. (2013) reported that dependent of harvest dates and levels of fertilizer application the specific methane yield Goliński and Goliński (2013) reported a methane yield of 338 l/kg VS from substrates originating from semi-natural grasslands dominated by the *Arrhenatherion* alliance. Herrmann et al. (2013) found that methane yields of grassland biomass decreased substantially with later harvest, from up to 309 l/ kg organic dry matter in May to below 60 l/ kg organic dry matter in February, in correlation with increasing crude fibre contents. Boob et al. (2019) found that the methane yield of the biomass from *Arrhenatherion* grasslands was 300 l/kg VS. Von Cossel et al. (2019) remarked that methane yield of the first-cut

biomass substrate from *Arrhenatherion* grasslands ranged from 289 to 297 l/kg VS. Meserszmit et al. (2021) mentioned that the methane yield of herbage from *Arrhenatherum elatius* and *Dactylis glomerata* was 249 l/kg VS. Ababii et al. (2019) revealed that biomethane production potential of hay substrates from *Festuca arundinacea was* 346 l/kg VS, but of substrate from *Arrhenatherum elatius* hay *343* l/kg VS. In our previous study, Miron et al. (2023) found that the best methane yield from hay substrates collected from grasslands dominated by *Poa pratensis* ranged from 282 to 314 l/kg VS. Brandhorst et al. (2024) observed that the specific methane yield of substrates from orchard meadows decreased linearly with delayed cutting dates, from dates from 0.325 to 0.237 m^3/kg ODM.

Table 1. The biochemical composition and the nutritive value of the hay from *Arrhenatherum elatius* grasslands

Indices	growing seasons	
	2021	2022
Crude protein, g/kg DM	142	107
Minerals, g/kg DM	106	93
Crude fibre, g/kg DM	347	373
Acid detergent fibre, g/kg DM ,	373	395
Neutral detergent fibre, g/kg DM	595	648
Acid detergent lignin, g/kg DM	43	44
Total soluble sugars, g/kg DM	57	85
Cellulose, g/kg DM	330	351
Hemicellulose, g/kg DM	222	253
Digestible dry matter, g/kg DM	619	581
Relative feed value	97	83
Digestible energy, MJ/ kg	12.21	11.53
Metabolizable energy, MJ/ kg	10.03	9.47
Net energy for lactation, MJ/ kg	5.74	5.49

Table 2. The biochemical biomethane production potential of the investigated hay substrates from *Arrhenatherum elatius* grasslands

Indices	growing seasons	
	2021	*2022*
Crude protein, g/kg DM	142.00	107.00
Nitrogen, g/kg DM	22.72	17.12
Minerals, g/kg DM	106.00	93.00
Organic matter, g/kg	894.00	907.00
Carbon, g/kg DM	496.67	503.89
Ratio carbon/nitrogen	21.86	29.43
Acid detergent lignin, g/kg DM	43.00	44.00
Hemicellulose, g/kg DM	222.00	253.00
Biomethane potential, L/kg VS	342	334
Biomethane potential, L/kg DM	306	303

Table 3. The economic value of the investigated hay from *Arrhenatherum elatius grasslands*

Indices	growing seasons	
	2021	*2022*
Hay yield, t/ha	5.63	4.13
Dry matter hay yield, t/ha	4.94	3.73
Crude protein, kg/ha	702	400
Digestible protein, kg/ha	421	240
Metabolizable energy, GJ/ ha	49.5	35.3
Net energy for lactation, GJ/ ha	28.4	20.5
Biomethane yield, m^3/ha L/kg VS	1512	1130

Grassland yield and its quality indices are economically significant aspects of relevant forage and energy production. The economic value of hay collected from *Arrhenatherum elatius* grasslands is presented in Table 3. The estimated economic potential of hay from the first cut is reflected in the following indicators: 400-700 kg/ha/year of crude protein, 240-421 kg/ha/year of digestible protein, 35.3-49.5 GJ/ha/year of metabolizable energy, and 20.5-28.4 GJ/ha/year of net energy for lactation. The biomethane yield potential from hay substrates is estimated at 1130-1512 m^3/ha/year.

Several literature sources have described the productivity of *Arrhenatheretum elatioris* grasslands. Wyłupek (2006) found that average yield of dry mass from the spring regrowth of semi-natural *Arrhenatheretum elatioris* was 3.14 t/ha. Kryszak & Kryszak (2007) reported that yield of meadows with *Arrhenatheretum elatioris dactylidosum glomeratae* were 7.5-9.0 t/ha hay, while in meadows which *Arrhenatheretum elatioris brizosum mediae* sub-association were low productivity 1.5-2.5 t/ha dry matter. Cop et al. (2009) mentioned that annual productivity of non-fertilized *Arrhenatherum elatius* grassland was 5.17-6.15 t/ha dry matter. Grygierzec (2012) mentioned that total yields of dry mass from the *Arrhenatheretum elatioris* meadow fluctuated from 4.92 to 6.57 t/ha, whereas hay yield from the first cut ranged from 3.14 to 4.26 t/ha. Tomić et al. (2018) revealed that the hay productivity of nonfertilized *Arrhenhenatherum elatius* grasslands was 3.50 t/ha, but fertilization treatments applied 5.98-8.31 t/ha. Meserszmit et al. (2024) mentioned that *Arrhenatherum elatius* and *Dactylis glomerata* plant community achieved yield 3.55-3.77 t/ha and methane yield 1564-1649 m^3 /ha. Miron et al. (2023) found that methane productivity of *Elymus repens* grassland ranged from 1217 to 2273 m^3/ha, grassland with *Poa pratensis* – 433 to 998 m^3/ha, while with *Festuca valesiaca* – 409 to 941 m^3/ha, respectively. Brandhorst et al. (2024) mentioned that cumulated area-related methane yields of the orchard meadows ranged from 818 m^3/ha to 1036 m^3 /ha.

CONCLUSIONS

In Orhei National Park the hay productivity of grassland with *Arrhenatheretum elatioris* varied from 4.13 to 5.63 t/ha with 107-142 g/kg CP, 343-373 g/kg CF, 93-106 g/kg ash, 43-44 g/kg ADL,57-85 g/kg TSS, 330-351 g/kg Cel, 22 g/kg HC, 58.1-61.9% DMD, RFV=83-97, 9.47-10.03 MJ/kg ME, 5.74- 5.49 MJ/kg NEl.

The economic potential of collected hays from first cut are 400-700 kg/ha/year of crude protein or 240-421kg/ha/year of digestible protein, 35.3-49.5 GJ/ha/year of metabolizable energy, and 20.5-28.4 GJ/ha/year of net energy for lactation.

The biomethane yield potential from hays substrates 1130-1512 m^3/ha/year.

The hay collected from the studied *Arrhenatheretum elatioris* grasslands can be used as fodder for livestock, also as energy biomass for biomethane production.

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