Scientific Papers. Series A. Agronomy, Vol. LXVIII, No. 1, 2025
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

SOME AGROBIOLOGICAL FEATURES AND QUALITY INDICES OF THE BIOMASS OF *Panicum virgatum* and *Panicum miliaceum* GROWN UNDER THE CONDITIONS OF THE REPUBLIC OF MOLDOVA

Victor ȚÎȚEI

"Alexandru Ciubotaru" National Botanical Garden (Institute) of Moldova State University, 18 Padurii Street, MD 2002, Chisinau, Republic of Moldova

Corresponding author email: vic.titei@gmail.com

Abstract

This research was conducted to determine the productivity of switchgrass - Panicum virgatum and common millet - Panicum miliaceum, grown in monoculture in the experimental plot of the NBGI Chişinău. It was determined that the dry matter yield and its biochemical composition varied among the Panicum species: 8.2-14.1 kg/m² with 61-132/kg CP, 352- 419 g/kg CF, 82-101 g/kg ash, 372-433 g/kg ADF, 608-692 g/kg NDF, 39-59 g/kg ADL, 124-127 g/kg TSS, 333-381 g/kg Cel, 236-259 g/kg HC and the nutritive and energy values of the fresh mass fodder reached 55.2-59.9 % DDM, 9.04-9.73 MJ/kg ME and 5.05-5.75 MJ/kg NEl. The hay prepared from the studied Panicum species contained 56-132 g/kg CP, 79-104 g/kg ash, 348-384 g/kg Cel, 243-272 g/kg HC with 54.5-58.8 % DDM, 8.94-9.57 MJ/kg ME and 4.96-5.59 MJ/kg NEl. The prepared silages had pH index = 4.06-4.14, 30.6-32.5 g/kg organic acids with 88.0-93.5% lactic acid. We found that the biochemical methane potential of the studied substrates varied from 302 to 364 l/kg ODM. Panicum virgatum and Panicum miliaceum may be used as forages for livestock and as feedstock for renewable energy production in Moldova.

Key words*: agrobiological features, biomass, biochemical composition, forages, methane potential, Panicum miliaceum, Panicum virgatum.*

INTRODUCTION

Panicum L. is a genus in the family Poaceae, with nearly 450 species of annual or perennial grasses, occurring in areas with tropical and warm temperate climate. Many representatives of this genus are popular agricultural and horticultural crops, due to their economic significance.

Common millet or proso millet, *Panicum miliaceum* L. is one of the world's oldest cultivated plants as grains and forage crops, which has also been cultivated in our region. *Panicum miliaceum* is a summer annual plant, the stems are light green, erect, sometimes branched at the base, growing about 0.5-1.5 m tall, with bright green leaves, compact panicle, the grains are round, about 3 mm long and 2 mm wide, enclosed in a smooth hull, which is typically white or creamy-white, yellow, or red, but also may be gray, brown or black. Plants have shallow, fibrous root systems and produce few tillers. It is a short growing, summer season crop (60 to 100 days) with unique agronomic properties such as high tolerance to heat and drought conditions. *Panicum miliaceum* could be a viable alternative to main summer forages in areas where cultivation of corn or Sudan grass is restricted because of a longer growing season or poor agricultural conditions. The *Panicum miliaceum* have recently been subjects of research around the world (Jahansouz et al., 2014; Habiyaremye et al., 2017; Bhat et al., 2019; Ventura et al., 2020; Wei et al., 2021; Turkestani et al., 2023; Wimalasiri et al., 2023; Petcu et al., 2024).

Switchgrass, *Panicum virgatum* L. is native to North America and is the most abundant in the Great Plains and eastern states of US. It is a warm-season perennial and rhizomatous plant, sometimes forming a knotty crown. Stems are green or purplish, erect or decumbent, 40-300 cm tall and 3-5 mm thick, forming dense clumps. The ligules are 2-6 mm; the blades 30-60 cm long and 2-15 mm wide, flat, erect; the adaxial surfaces sometimes densely pubescent; the margins scabrous, with a prominent midrib. The inflorescences are open panicles, 10-55 cm long and 4-20 cm wide, the primary branches thin and straight; the spikelets are 2.5-8 mm long and 1.2-2.5 mm wide, narrowly lanceoloid, turgid to slightly laterally compressed, glabrous, acuminate. The seeds are 3-6 mm long and 1.2 to 1.5 mm wide and are developed from a single-flowered spikelet. Switchgrass generally produces seeds abundantly, the seed yield in cultivated stands is on average 500-700 kg/ha. Switchgrass reproduces both by seeds and rhizomes. The rhizomes are responsible for the vegetative expansion, and some rhizomes of sod-forming ecotypes may extend to lengths of 0.3-0.6 m, the roots may reach soil depths of 3 m or more. This perennial grass grows on a wide variety of soil types and textures, land conditions, pH from 4.5 to 7.6. It is tolerant of moderate soil salinity and acidity, used for a variety of revegetation and erosion control purposes. Switchgrass is suitable for growth on marginal land and requires relatively modest amounts of chemical fertilizers. The method of establishing switchgrass stands is planting seeds in a properly prepared soil, after the soil has warmed well during the spring, using highly germinable seeds and planting 0.6-1.2 cm deep, or up to 2 cm deep in sandy soils, packing or firming the soil both before and after seeding. Switchgrass in North American an important livestock forage, used primarily for warm-season pasture and hay (Griffin & Jung, 1983; Guretzky et al., 2011; Belanger et al., 2012; Jefferson & McCaughey, 2012; Davis et al., 2018). It has also been introduced as a forages plants to other parts of the world (Ferri et al., 2000; Pilat et al., 2007; Eliş & Özyazıcı, 2019). *Panicum virgatum* has received much attention in recent years and has been a focus of bioenergy research for over a decade, in several countries (Massé et al., 2010; 2011; Rakhmetov et al., 2014a.; 2014 b; Niu et al., 2015; Seepaul et al., 2016; Baute et al., 2018; Kieffer et al., 2023; Happs et al., 2024).

This research was conducted to determine the quality indices of the green mass, prepared silage and hay from *Panicum miliaceum* and *Panicum virgatum* as forages for livestock, as well as feedstock in biogas reactors for the production of biomethane as renewable energy.

MATERIALS AND METHODS

The common millet - *Panicum miliaceum* cultivar 'Soiuz' created at the at the "Selectia" Research Institute of Field Crops Bălți, Republic of Moldova, and the introduced taxa of switchgrass - *Panicum virgatum* grown in the experimental plot of the National Botanical Garden (Institute) "Alexandru Ciubotaru", Chişinău, served as subjects of the research.

The *Panicum miliaceum* plant samples were collected in the flowering stage, while the *Panicum virgatum* plants were mown in middle flowering stage, in the second year of life. The harvested plants were chopped into 1.5-2.0 cm small pieces, with a laboratory forage chopper, the dry matter content was detected by drying samples up to constant weight at 105°C. The silage was prepared from chopped green mass, compressed in well-sealed glass containers, stored at ambient temperature (18-20°C). After 45 days, the containers were opened, and the sensorial and fermentation indices of the conserved forage were determined according to standard laboratory procedures - the Moldavian standard SM 108*. The prepared hay was dried directly in the field. For biochemical analysis, the plant 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 and some assessments of the main biochemical parameters: crude protein (CP), ash, acid detergent fibre (ADF), neutral detergent fibre (NDF), acid detergent lignin (ADL), total soluble sugars (TSS), digestible dry matter (DDM), digestible organic matter (DOM) have been determined by near infrared spectroscopy (NIRS) technique PERTEN DA 7200. The concentration of hemicellulose (HC), cellulose (Cel), digestible energy (DE), metabolizable energy (ME), net energy for lactation (NEl) and 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 the equations of Dandikas et al. (2015).

RESULTS AND DISCUSSIONS

Analysing some agrobiological peculiarities of the studied *Panicum* species (Table 1), we would like to mention that in the flowering stage *Panicum miliaceum* plants reach 84 cm in height, but *Panicum virgatum* - 127 cm. The biomass productivity of *Panicum miliaceum* was 3.59 kg/m^2 fresh mass or 0.82 kg/m^2 dry matter, while - of *Panicum virgatum* 3.85 kg/m^2 fresh mass or 1.41 kg/m^2 dry matter. The content of leaves and panicles in *Panicum miliaceum* fodder was much higher, but the dry matter content lower than in *Panicum virgatum.*

Analysing the results of the fresh mass quality of the studied *Panicum* species (Table 2), we found that the dry matter of the harvested whole plants contained 61-132 g/kg CP, 352-419 g/kg CF, 82-101 g/kg ash, 372-433 g/kg ADF, 608-692 g/kg NDF, 39-59 g/kg ADL,124-127 g/kg TSS, 333-381 g/kg Cel, 236-259 g/kg HC. The *Panicum virgatum* green fodder is characterized by higher cell wall content and lower concentration of crude protein and minerals than the fodders from *Panicum miliaceum*. The concentration of total soluble sugars is very high and does not differ particularly between the fodders from the studied *Panicum* species. The nutritive and energy values of the fresh mass from the studied *Panicum* species reached 55.2-59.9% DDM, 11.01-11.86 MJ/kg DE, 9.04-9.73 MJ/kg ME and 5.05-5.75 MJ/kg NEl. The high amount of cell wall content in switchgrass plants contributed to the reduction of the dry matter digestibility, relative feed value, metabolizable energy and net energy for lactation. The green forage from *Panicum miliaceum* plants had optimal concentration of crude protein, fibres, acid detergent lignin digestibility and energy concentration.

Table 1. Some agrobiological peculiarities of the studied *Panicum* species

Species	Plant height, cm	Stem, g		Leaf + panicle, g		Total weight of a shoot, g		Yield, kg/m^2		Content of leaves and panicles in fodder, %
		fresh mass	dry matter	fresh mass	dry matter	fresh mass	dry matter	fresh mass	dry matter	
Panicum miliaceum	84	14.7	3.2	14.6	3.5	29.3	6.7	3.59	0.82	52.2
Panicum virgatum	127	4.1	1.5	3.0	1.1	7.1	2.6	3.85	1.41	42.0

Table 2. The biochemical composition and the nutritive value of the green mass harvested from *Panicum* species

Indices	*Panicum virgatum*	*Panicum miliaceum*
Crude protein, g/kg DM	61	132
Crude fibre, g/kg DM	419	352
Minerals, g/kg DM	82	101
Acid detergent fibre, g/kg DM	433	372
Neutral detergent fibre, g/kg DM	692	608
Acid detergent lignin, g/kg DM	52	39
Cellulose, g/kg DM	381	333
Hemicellulose, g/kg DM	259	236
Total soluble sugars	127	124
Digestible dry matter, g/kg DM	552	599
Relative feed value	74	92
Digestible energy, MJ/ kg DM	11.01	11.86
Metabolizable energy, MJ/ kg DM	9.04	9.73
Net energy for lactation, MJ/ kg DM	5.05	5.75

Different results regarding the nutrient content of the harvested mass from *Panicum* species are given in the specialized literature. According to Griffin & Jung (1983), the forage quality of leaf mass of *Panicum virgatum* harvested in early heading stage was 8.5% CP, 67.1% NDF, 4.7% lignin and 58.8% IVDMD, while stem mass - 3.8% CP, 77.7% NDF, 8.3% lignin and 47.2% IVDMD. Burlacu et al. (2002) mentioned that the *Panicum miliaceum* green mass contained 230 g/kg DM with 8.7% ash, 14.0% CP, 4.7% EE, 27.1% CF, 45.5% NFE and 18.5 MJ/kg GE. Dien et al. (2006) reported that switchgrass plant material harvested in pre-boot stage had 6.5% CP, 1.0% EE, 8.9% ash, 66.9% NDF, 1.2% ADL, 33.7% Cel, 31.8% HC and 18.22 MJ/kg GE, while plant harvested in anthesis stage 3.2% CP, 1.0% EE, 5.7% ash, 66.9% NDF, 2.3% ADL, 34.0% Cel, 30.1% HC and 18.61 MJ/kg GE. Pilat et al. (2007) reported that the green forage dry matter from switch grass contained 274.9 g/kg DM with 92.84% OM, 10.46% CP, 1.48% CT, 32.60% CF, 72.33% NDF, 39.23% ADF, 33.1% HC and 48.3 % NFE. Svirskis (2009) found that, under the climatic conditions of Lithuania, the dry matter of the studied *Panicum miliaceum* cultivars contained 12.6-19.6% CP, 28.0-35.6% CF, 56.6-65.3% NDF, 25.3-33.1% ADF, 4.56-11.39% WSC and 48.4-65.3% DMD. Guretzky et al. (2011) remarked that switch grass had 8.5-10.5 N g/kg, 261-381 g/kg CF, 426-455 g/kg ADF, 740-752 g/kg NDF, 411-492 g/kg IVDMD. Belanger et al. (2012) remarked that *Panicum virgatum* biomass harvested on four different dates contained 40.2-117.7 g/kg TSS, 297-415 g/kg ADF, 551-705 g/kg NDF, 582-843 g/kg IVTD. Jefferson & McCaughey (2012) mentioned that the forage dry matter from *Panicum virgatum* cultivars had 53.7-64.7% NDF, 28.2-33.0% Cel, 26.2-30.2% HC, with 44.3-61.2% OMD. Zhang et al. (2010) mentioned that, in northern China, dry biomass from proso millet contained 12.8% CP, 73.3% NDF, 40.2% ADF, from Sudan grass - 12.0% CP, 62.7% NDF, 38.4% ADF and maize fodder dry matter - 10.8% CP, 66.1% NDF and 42.8% ADF. Avetisyan (2013) reported that the quality indices of the green mass from proso millet were 200 g/kg dry matter with 9.8% CP, 38.9% CF, 6.2% sugar, 9.7 MJ/kg ME. Mohajer et al. (2013) mentioned that the dry matter of the studied common millet cultivars contained 9.15-10.78% CP, 43.45-44.84% CF, 5.58-7.16% WSC, 28.17-29.50% ADF and 64.74-65.90% DMD. Jahansouz et al. (2014) reported that the quality indices of green mass from *Panicum miliaceum* were 10.91% CP, 76.34% NDF, 50.82% ADF, 6.29% WSC, 49.31% DMD, 0.98 Mcal/kg NEl and RFV = 60.1. Seepaul et al. (2016) remarked that switchgrass whole plant harvested in the June-July period had 3.5-4.6% CP, 6.5-7.7% ash, 73.9-80.5% NDF, 40.4-45.9% ADF, 4.6-7.9% ADL, 33.5-35.1% Cel, 32.9-40.9% HC, 553-589 g/kg IVDMD. Tran (2016) remarked that proso millet forage was characterized by the following quality indices 7.9% ash, 10.1% CP, 73.7% NDF, 36.0% ADF, 4.5% lignin, 3.6 g/kg Ca, 1.6 g/kg P, 58.5% DOM. Wei et al. (2021) reported that proso millet green mass had 303.4 g/kg dry matter with 6.31% CP, 32.6% ADF, 607.2% NDF and 649.5 g/kg IVDMD. Park et al. (2022) stated that *Panicum miliaceum* forage had 5.7-10.4% CP, 63.1-65.4% NDF, 36.3-37.0% ADF, 59.7-60.2% TDN and RFV = 86-89, but from *Panicum coloratum* 12.0-12.4% CP, 57.8-62.2% NDF, 30.3-31.7% ADF, 63.9-64.9% TDN and RFV = 95-105, respectively. Van Die & Entz (2022) reported that the proso millet green forage dry matter had 8.0-10.0% CP and 64.8% TDN. Kieffer et al. (2023) remarked that *Panicum virgatum* biomass was characterized by the following quality indices: 3.65% ash, 6.72% CP, 74.60% NDF, 42.88% ADF, 4.06% lignin, 38.97% Cel, 31.73% HC, RFV=69.84, 3.76 g/kg Ca, 1.75 g/kg P. In our previous studies (Țîței, 2023) we found that nutrient content and forage value of proso millet plants was 12.3% CP, 8.4% ash, 38.0.6% ADF, 63.0% NDF, 3.9% ADL, 12.1% TSS, 34.1% Cel, 25.0% HC, 593 g/kg DDM, RFV= 88, 11.75 MJ/kg DE, 9.65 MJ/kg ME and 5.65 MJ/kg NEl.

Table 3. The biochemical composition and the nutritive value of the hay from *Panicum* species

Indices	*Panicum virgatum*	*Panicum miliaceum*
Crude protein, g/kg DM	56	132
Crude fibre, g/kg DM	420	368
Minerals, g/kg DM	79	104
Acid detergent fibre, g/kg DM	441	386
Neutral detergent fibre, g/kg DM	713	629
Acid detergent lignin, g/kg DM	57	38
Cellulose, g/kg DM	384	348
Hemicellulose, g/kg DM	272	243
Total soluble sugars	109	93
Digestible dry matter, g/kg DM	545	588
Relative feed value	71	87
Digestible energy, MJ/ kg DM	10.89	11.66
Metabolizable energy, MJ/ kg DM	8.94	9.57
Net energy for lactation, MJ/ kg DM	4.96	5.59

Hay is the most commonly used forage for ruminant animals, horses, rabbits etc. The quality indices of the hay prepared from the studied *Panicum* species are shown in Table 3. We found that the hay prepared from the studied *Panicum* species contained 56-132 g/kg CP, 79-104 g/kg ash, 348-384 g/kg Cel, 243-272 g/kg HC. The nutritive and energy value of the prepared hays were 54.5-58.8% DDM, 8.94-9.57 MJ/kg ME and 4.96-5.59 MJ/kg NEl. During the hay making process, the concentration of structural carbohydrates increased and the total soluble sugar content decreased. As compared with the *Panicum miliaceum* hay, the *Panicum virgatum* hay is characterized by lower amount of crude protein, minerals, but had high concentration of cell wall fractions (NDF, ADF, ADL) and total soluble sugars, which resulted in the reduction of digestibility, relative feed value and energy concentration.

Several literature sources described the quality indices of the hay prepared from *Panicum* species. According to Ferri et al. (2000) mentioned that *Panicum virgatum* hay contained 749 g/kg DM with 1.3% CP, 5.3% ash, 85.9% NDF, 54.3% ADF, 5.6% Klason lignin and 33.6% *in vivo* dry matter apparent digestibility. Burlacu et al. (2002) mentioned that *Panicum miliaceum* hay had 850 g/kg dry matter with 12.5% ash, 5.8% CP, 2.1% EE, 33.5% CF, 51.2% NFE and 17.9 MJ/kg GE. Tan et al. (2016) mentioned that *Panicum miliaceum* hay, without nitrogen fertilization, had 12.39% CP, 58.40% NDF, 36.05% ADF, but in the variants when nitrogen fertilizers were applied: 13.16-14.24% CP, 58.09-60.02% NDF, 35.73-36.10% ADF, respectively. Tran (2017) reported that the concentration of nutrients and energy in proso millet hay were 7.9% ash, 12.5% CP, 2.5% EE, 33.9% CF, 72.3% NDF, 39.9% ADF, 5.9% lignin, 6.6% ash, 59.3% DOM, 18.9 MJ/kg GE, 10.7 MJ/kg DE, 8.6 MJ/kg ME. Davis et al. (2018) reported that the hay prepared from *Panicum virgatum* cultivars, harvested at different stages of maturity, had 901-912 g/kg DM with 4.8-13.5% CP, 57.1-65.1% NDF, 29.2-36.7% ADF, 51.50-72.6% apparent DMD. Dağtekin et al. (2020) found that the hays from 11 genotypes of proso millet contained 16.3-20.5% CP, 28.7-36.3% ADF, 60.0-70.6% NDF, 0.373-0.434% P, 0.58 - 0.824% Ca, 0.270-0.393% Mg, 3.17-3.96% K. Stybayev et al. (2023) reported that the chemical composition of the proso millet hay in the variant without cover crop was 9.07% CP, 2.76% EE, 30.32% CF, 3.32% sugar, 9.25% ash, 1.11% Ca, 0.23% P, but in the variant with cover crop, the proso millet hay contained 9.62% CP, 3.74% EE, 31.32% CF, 10.20% sugar, 4.23% ash, 2.1% Ca, 0.33% P, respectively. As a result of our previous studies (Țîței, 2024) we found that the nutrient content of *Panicum miliaceum* hay was: 13.40% CP, 2.37% EE, 32.22% CF, 42.29% NFE, 9.72% ash, 0.32% Ca and 0.27% P, 18.02 MJ/kg GE. Forage conservation provides a more uniform level of high quality forage for ruminant livestock throughout the year. Silage fodder is a key element for good farm animal feeding. When opening the glass containers with ensiled mass from the studied *Panicum* species, there was no gas or juice leakage from the preserved mass. As for the organoleptic properties, the prepared silage from *Panicum miliaceum* had yellowish-green stems and leaves with pleasant smell like pickled apples, while silage from *Panicum virgatum* had had homogeneous agreeable olive colour with pleasant smell specific to grass silage. The texture of the ensiled mass from *Panicum* species was preserved well, without mold and mucus. The fermentation profile, the biochemical composition and nutritional value of silage from the studied *Panicum* plants is shown in Table 4. The prepared silages were characterized by pH = 4.06-4.14, 30.6-32.5 g/kg organic acids, 28.5-28.6 g/kg lactic acid, 2.0-3.6 g/kg acetic acid, 0.1-0.3 g/kg butyric acid, the most organic acids were in fixed form, lactic acids constituted 88.0-93.1% of total organic acids. The obtained silages met the standard SM 108 for the 1-st class quality. In the *Panicum virgatum* silage, the concentration of acetic and butyric acids was lower as compared with the silage prepared from *Panicum miliaceum*. The quality indices of silage dry matter were: 6.2-11.6% CP, 8.2-10.3% ash, 34.7-41.4% CF, 36.0-42.3% ADF, 62.0-6.57% NDF, 2.6-4.3 % ADL, 33.4-38.0% Cel, 23.4-26.0% HC, 559-609 g/kg DDM, RFV = 79-91, 11.14-12.03 MJ/kg DE, 9.15-9.87 MJ/kg ME and 5.17-5.89 MJ/kg NEl. It was found that, during the process of ensiling, the concentrations of acid detergent lignin and total soluble sugars decreased. In comparison with the initial green mass, in common millet silage the level of crude protein, crude fibre, acid detergent fibre decreased, the cellulose content did not change and the concentration of hemicellulose increased substantially, which had a positive impact on the digestibility and energy value. In the switch grass silage crude protein, the cellulose and ash content did not change essentially, the hemicellulose content decreased, the dry matter digestibility and energy concentration differed considerably as compared with the initial green mass.

Table 4. The quality indices of the silage from *Panicum* species

Indices	*Panicum virgatum*	*Panicum miliaceum*
pH index	4.14	4.06
Organic acids, g/kg DM	30.6	32.5
Free acetic acid, g/kg DM	0.2	2.0
Free butyric acid, g/kg DM	0.1	0
Free lactic acid, g/kg DM	4.1	10.6
Fixed acetic acid, g/kg DM	1.8	1.6
Fixed butyric acid, g/kg DM	0	0.3
Fixed lactic acid, g/kg DM	24.4	18.0
Total acetic acid, g/kg DM	2.0	3.6
Total butyric acid, g/kg DM	0.1	0.3
Total lactic acid, g/kg DM	28.5	28.6
Acetic acid, % of organic acids	6.53	11.09
Butyric acid, % of organic acids	0.33	0.91
Lactic acid, % of organic acids	93.14	88.00
Crude protein, g/kg DM	62	116
Crude fibre, g/kg DM	414	347
Minerals, g/kg DM	82	103
Acid detergent fibre, g/kg DM	423	360
Neutral detergent fibre, g/kg DM	657	620
Acid detergent lignin, g/kg DM	43	26
Cellulose, g/kg DM	380	334
Hemicellulose, g/kg DM	234	260
Total soluble sugars	21	121
Digestible dry matter, g/kg DM	559	609
Relative feed value	79	91
Digestible energy, MJ/ kg DM	11.14	12.03
Metabolizable energy, MJ/ kg DM	9.15	9.87
Net energy for lactation, MJ/ kg DM	5.17	5.89

Some authors mentioned various findings about the quality of the silage prepared from *Panicum* species. Pilat et al. (2007) reported that silage forage matter from switch grass had pH = 4.57, 1.19% lactic acid, 0.71% acetic acid, 0.08% butyric acid, contained 240.4 g/kg DM with 91.61% OM, 11.84 % CP, 2.99% CT, 33.91% CF, 74.57% NDF, 43.22% ADF, 31.35%HC, 42.87%NFE. Belanger et al. (2012) mentioned that the prepared silages from *Panicum virgatum* were characterized by: pH = 4.0-4.3, 3.99-5.80% lactic acid, 0.26-0.77% acetic acid, 0.79-1.81% N. Maksimova et al. (2019) found that the quality indices of proso millet silage were pH = 5.0, 0.55 feed units/kg dry matter, 39.0 g/kg digestible protein, and 8.21 MJ/kg exchange energy and 72.5 g digestible proteins/ feeding unit. Eliş & Özyazıcı (2019) stated that the silage obtained from switchgrass cultivars have pH = 3.84-4.73, 390-510 g/kg dry matter with 1.78-2.35% lactic acid, 0.35-1.55% acetic acid, 0.05-0.33% butyric acid, 3.76-5.33% CP, 70.96-75.41% NDF, 39.30-41.73% ADF, 18.75% TSS, 35.13% HC, 10.44% ash. Nematpour et al. (2020) mentioned that the proso millet silage had pH = 4.68, 1.68% acetic acid, 265 g/kg dry matter with 8.14% ash. 16.1% CP, 55.4% NDF, 27.3% ADF, 65.2% DDM, RFV=114 and 1.58 Mcal/kg NEl. Wei et al. (2021) found that the chemical composition and nutritive value of proso millet was pH = 4.35, 4.01% lactic acid, 1.41% acetic acid, 0.23% butyric acid, 266 g/kg dry matter with 5.66% CP, 35.8% ADF, 62.4% NDF, 58.0% IVDMD, 605.5 g/kg TDN and RFV = 91; corn silage pH = 3.86, 6.15% lactic acid, 4.86% acetic acid, 263 g/kg dry matter, 5.20% CP, 26.52% ADF, 46.51% NDF, 68.46% IVDMD, 692.8 g/kg TDN and RFV = 137; but sorghum-Sudan grass silage had pH = 4.07, 7.67% lactic acid, 4.52% acetic acid, 175.4 g/kg dry matter, 4.69% CP, 42.80% ADF, 65.48% NDF, 54.76% IVDMD, 547.6 g/kg TDN and RFV = 78, respectively. In our previous research (Ţîţei, 2023; 2024), the quality indices of common millet silages were as follows: 11.0-13.3% CP, 4.0% EE 36.7-37.0% CF, 37.1% ADF, 63.0% NDF, 2.0% ADL, 6.8% TSS, 35.1% Cel, 23.7% HC, 9.7-11.5% ash, 0.31% Ca, 0.27% P, 600 g/kg DDM, RFV=92, 18.38 MJ/kg GE, 11.87 MJ/kg DE, 9.75 MJ/kg ME, 5.76 MJ/kg NEl. Turkestani et al. (2023) mentioned that proso millet silages had pH = 4.5-4.8 and contained 343-395 g/kg dry matter with 9.0-12.1% CP, 28.8% ADF, 47.4-50.5% NDF, 3.38-3.56% ADL, 593-633 g/kg DMD.

Increasing biomass usage leads to the reduction of greenhouse gas emissions, as compared with the use of fossil fuels. In recent years, the considerations for the use of *Poaceae* species for bioenergy have increased considerably, it can be used as biomass feedstock for the production solid fuel, lignocellulosic bioethanol, synthetic natural gas or synthetic biofuels and, in particular, for biogas production. The C_4 grasses are considered as a potential feedstock for biogas production, due to their low water consumption as compared with other crops, and the fact that they can be cultivated in non-arable lands, avoiding the direct competition with food crops. Biogas is a product of anaerobic fermentation of organic products. Anaerobic fermentation is a labile process whose normal course depends on many factors, including the content of lignin in the substrate. Among the fuels from plant biomass, biogas is of great importance and can successfully replace fossil fuels to obtain electric power and heat. The quantities of biogas and the methane content depend mainly on carbohydrates, fats and proteins, the biodegradability and ratio of carbon and nitrogen (C/N) from the substrates. The results of the determination of the quality indices of prepared substrates from the studied *Panicum* species and its biochemical biomethane production potential are presented in Table 5.

Table 5. The biochemical biomethane production potential of the investigated substrates from *Panicum* species

Indices	*Panicum virgatum*			*Panicum miliaceum*		
	green mass	silage	hay	green mass	silage	hay
Crude protein, g/kg DM	61.00	62.00	56.00	132.00	116.00	132.00
Nitrogen, g/kg DM	9.76	9.92	8.96	21.12	18.56	21.12
Ash, g/kg DM	82.00	82.00	79.00	101.00	103.00	104.00
Carbon, g/kg DM	510.00	510.00	511.67	499.44	498.33	497.78
Ratio carbon/nitrogen	52.25	51.14	57.11	23.67	26.85	23.57
Acid detergent lignin, g/kg DM	52.00	43.00	57.00	39.00	26.00	38.00
Hemicellulose, g/kg DM	259.00	234.00	272.00	236.00	260.00	243.00
Biomethane potential, L/kg VS	311	326	302	346	365	348
Biomethane potential, L/kg DM	285	299	278	311	327	312

It is a commonly known fact that methanogenic bacteria need a suitable ratio of carbon to nitrogen for their metabolic processes, ratios higher than 30:1 were found to be unsuitable for optimal digestion, and ratios lower than 10:1 were found to be inhibitory, because of low pH, poor buffering capacity and high concentrations of ammonia in the substrate. The C/N ratio is favorable in *Panicum miliaceum* green mass, silage and hay substrates. In *Panicum virgatum* substrates there is a very high carbon to nitrogen ratio - C/N = 52-57, which may have a negative impact on the methanogenesis processes, that is why it is necessary to use mixed substrates with other plants. As previously mentioned, in the studied substrates the hemicellulose content varies from 234 to 272 g/kg, and the acid detergent lignin content - from 26 g/kg to 57 g/kg. The lowest content of acid detergent lignin was detected in *Panicum miliaceum* substrates. The biochemical methane potential varied from 302 to 365 L/kg VS. The highest biomethane potential was achieved in *Panicum miliaceum* silage substrate. There are different results reported in research studies conducted by other authors. Ahn et al. (2010) studied the effect of co-fermentation of manure with switchgrass silage noted that switchgrass silage with swine manure had 373 L/kg methane, in mixtures of switchgrass silage and dairy manure 28 L/kg methane, while in mixtures of switchgrass silage and poultry manure 2 L/kg methane. Massé et al. (2011) reported that correlation of nitrogen rates and harvest dates and the methane yield of switchgrass silage substrate varied from 184 to 252 L/kg VS, while in reed canary grass silage substrate, it varied from 5 to 253 L/kg VS. Frigon et al. (2012) found that, in the switchgrass harvested at the end of August, the concentrations carbohydrates were 2.4 g/kg arabinan, 18.5 g/kg xylan, 0.5 g/kg mannan, 1.34 g/kg galactan and 39.4 g/kg glucan, C/N ratio of 25:1, and the final methane production after 134 days of incubation in dependence of biomass pre-treatments varied from 157.0 to 297.7 L/kg VS. Niu et al. (2015) reported that in batch anaerobic digestion process of switchgrass biogas production was 268.80 L/kg VS and methane potential 135.31 L/kg VS, the conversion efficiencies of the material and energy from switchgrass to biogas were 36.1% and 30.1%. As a result of the analysis of the biogas produced from switchgrass by anaerobic digestion, Baute et al. (2018) found that the methane potential of *Panicum virgatum* varied from 160.1 to 186.5 L/kg VS, while *Miscanthus giganteus* substrate - from 167.5 to 229.8 L/kg VS, respectively. Barbanti et al. (2014) shows that switchgrass biomass had production methane potential of 217 L/kg, but maize substrate 316 L/kg VS. Battista et al. (2019) found the methane yield of *Panicum miliaceum* substrate was 253 L/kg, but *Zea mays* substrate - 289 L/kg, *Triticum aestivum* substrate - 351L/kg, *Hordeum distichon* substrate - 290 L/kg and *Sorghum* spp. substrate - 313 L/kg. Holder et al. (2022) found that the biochemical methane potential of the substrate from guinea grass, *Panicum maximum*, was 250 l/kg DM. Kupryś-Caruk et al. (2023) remarked that the methane yield of *Panicum virgatum* pure silages was 310 L/kg ODM, while the methane yields of inoculated silage reached 380 L/kg ODM.

CONCLUSIONS

The common millet, *Panicum miliaceum* and the introduced taxa of switchgrass *Panicum virgatum* are suitable for cultivated under the conditions of the Republic of Moldova and the harvested biomass may be used as fodders for livestock, also as substrates for biomethane production as a source of renewable energy.

ACKNOWLEDGEMENTS

This study has been supported by the subprogram no. 01.01.02 "*Identification of valuable forms of plant resources with multiple uses for the circular economy*".

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