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THE PROSPECTS OF CULTIVATION AND USE OF THE SPECIES PEARL MILLET, *Pennisetum glaucum*, IN MOLDOVA

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Abstract

The goal of this research was to evaluate the quality of phytomass of the non-native species pearl millet, Pennisetum glaucum, cultivated in the experimental plot of the National Botanical Garden (Institute), Chişinău, Republic of Moldova. It has been found that the green mass contained 116 g/kg CP, 361 g/kg CF, 370 g/kg ADF, 606 g/kg NDF, 33 g/kg ADL, 166 g/kg TSS, 236 g/kg HC, 337 g/kg Cel, with 9.75 MJ/kg ME and 5.58 MJ/kg NEl, the prepared silage was characterized by pleasant smell, pH = 3.78, 18.0 g/kg DM lactic acid and 1.8 g/kg DM acetic acid. The pearl millet grain contained 132.8 g/kg CP, 58.5 g/kg EE, 21 g/kg CF, 764.1 g/kg NFE, 304.6 g/kg starch, 10.9 g/kg ash, 0.6 g/kg Ca, 0.7 g/kg P, 1.09 nutritive units and 11.78 MJ/kg ME, but pearl millet straw 57 g/kg CP, 487 g/kg CF, 530 g/kg ADF, 823 g/kg NDF, 74 g/kg ADL, 293 g/kg HC, 456 g/kg Cel, with 7.92 MJ/kg ME and 3.95 MJ/kg NEl. The pearl millet substrates for anaerobic digestion have C/N = 26-54 with biochemical methane potential 282-375 l/kg. The theoretical ethanol potential from structural carbohydrates of the pearl millet straw averaged 544.4l/t, Pearl millet, Pennisetum glaucum, can be used in many ways: as multi-purpose feed for livestock and as feedstock in the production of renewable energy.

Key words: *biochemical composition, energy biomass, forage value, pearl millet Pennisetum glaucum, phytomass.*

INTRODUCTION

The most important task for the sustainable development of modern agriculture is to increase the biological diversity of cultivated crops. In recent years, due to global climate change, the possibilities of using more thermophilic crops in new agro-ecological zones have expanded. In this regard, *Poaceae* species with C_4 photosynthesis type are of great interest among non-traditional plant species, due to their high resilience to climate change effects: high temperature, water insufficiency and salinity stress. The cultivation of this plant species will provide an opportunity to expand the range of non-traditional crops and will be a promising renewable source of valuable plant raw materials, which will find application in various fields of circular economy: in agriculture, in the food industries and renewable energy production, as well as in ornamental gardening. The possibility of increasing the biological diversity of *Poaceae* crops largely depends on the introduction of non-traditional plant species, simultaneously assessing the initial material for its potential implementation in economically useful purposes and the creation of varieties adapted to local conditions.

Millets are gaining popularity especially due to their high resilience to climate change effects and acceptable productivity and nutritional value (Jukanti et al., 2016). Pearl millet, *Pennisetum glaucum* [L.] R.Br. (syn. *Pennisetum americanum, Pennisetum typhoides, Pennisetum typhoideum, Pennisetum spicatum, Setaria glauca*) is one such multi-purpose C_4 photosynthesis type crop, cultivated in the Indian subcontinent and African semiarid regions since prehistoric times. Currently, pearl millet is the sixth most important cereal crop after rice, wheat, maize, barley and sorghum in the world, being grown on over 33 million hectares, accounting for approximately 50% of the total world production of millets, besides, it is a crop of major importance in arid and semi-arid regions. *Pennisetum glaucum* is a robust, strongly tillering, annual, herbaceous, grass plant, usually 1-4 m tall, with basal and nodal tillering, producing an extensive and dense root system, which may reach a depth of 1.2-1.6 m, sometimes even of 3.5 m; sometimes the nodes near ground level produce thick, strong prop roots. The stem is slender, 1-3 cm in diameter, solid, often densely villous below the panicle, with prominent nodes. The leaf sheath is open and often hairy; the ligule is short, membranous, with a fringe of hairs; the leaf blade is linear to linear-lanceolate, up to 1.5 m × 5-8 cm, and has margins with small teeth, scaberulous and often pubescent. The inflorescence is cylindrical or ellipsoidal, contracted, with a stiff and compact panicle, similar to a spike, 15-200 cm long. The spikelet is 3-7 mm long, consisting of 2 glumes and usually 2 florets. The caryopsis is globose, subcylindrical or conical, 2.5-6.5 mm long, the colour varies from white, pearl, or yellow to grey-blueish and brown, occasionally purple; the weight of 1000 seeds ranges from 2.5 to 14 g, with a mean of 8 g. The size of the pearl millet kernel is about one-third that of sorghum. The relative proportion of germ to endosperm is higher than in sorghum (Oyen & Andrews, 1996; Marsalis et al., 2012).

Pearl millet is drought- and heat-tolerant and has a considerable ability to grow and yield in poor, sandy and saline soils under arid, hot and dry climates; this is an advantage over other popular forage grasses in the region, such as fodder maize. It is also a hydrocyanic and prussic acid-free crop, which gives it nutritional superiority over sorghum and Sudan grass (Jukanti et al., 2016; Hassan et al., 2014; Toderich et al., 2016).

Pearl millet is also nutritionally superior and rich in micronutrients such as iron and zinc and can mitigate malnutrition and hidden hunger. Inclusion of minimum standards for micronutrients-grain iron and zinc content in the cultivar release policy-is the first of its kind step taken in pearl millet anywhere in the world, which can lead toward enhanced food and nutritional security. Nutrients of pearl millet play a role in the prevention of diabetes, cancer, cardiovascular and neurodegenerative diseases. It has been reported that Pearl millet has many nutritional and medical functions, such as hypoglycaemic, cardio protective, colon cancer anticipatory and prebiotic actions. Pearl millet grain is used in different forms at a global level, for example, to make unleavened bread (roti or chapatti), porridge, gruel, desserts etc. Its flour can substitute (10-20%) wheat flour in "whole-grain" breads, pretzels, crackers, tortillas and dry and creamed cereals (Satyavathi et al., 2021)

The goal of this research was to evaluate the quality of phytomass of the non-native species pearl millet, *Pennisetum glaucum* and the prospects of its use as fodder for farm animals or as substrates for renewable energy production.

MATERIALS AND METHODS

The non-native species pearl millet, *Pennisetum glaucum*, which was cultivated 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, and the common oat *Avena sativa* and tall fescue *Festuca arundinacea* were used as control variants. *Pennisetum glaucum* was sown at a rate of 130 seeds per 1 m^2. The green mass was harvested manually in the flowering period: *Festuca arundinacea* - on May 20, *Avena sativa* - on June 15 and *Pennisetum glaucum* - on July 24.

The leaf/stem ratio was determined by separating leaves and flowers from the stem, weighing them separately and establishing the ratios for these quantities. For this purpose, samples of 1.0 kg harvested plants were taken.

The harvested green mass was chopped with a stationary forage chopping unit. The fractional composition of the chopped green mass was determined using a vibrating screen device. We used 200 mm diameter sieves, where sieves with round pores were placed one on another (in the order from the top sieve): with the diameter of 31.5 mm, 16 mm, 8 mm, 3.15 mm and 1 mm.

The dry matter content was detected by drying samples up to constant weight at 105°C. For chemical analyses, the samples were dried at 65°C.

For ensiling, the green mass (pearl millet, tall fescue) and wilted mass (oat) was chopped into 1.5-2.0 cm pieces by using a forage chopping unit, and then it was shredded and compressed in well-sealed glass containers. After 45 days, the containers were opened, and the sensorial and fermentation indices of the conserved forage were determined in accordance with standard laboratory procedures - the Moldavian standard SM 108 for forage quality analysis. Some assessments of the main biochemical parameters: crude protein (CP), crude fibre (CF), ash, acid detergent fibre (ADF), neutral detergent fibre (NDF), acid detergent lignin (ADL), total soluble sugars (TSS) have been evaluated using the near infrared spectroscopy (NIRS) technique PERTEN DA 7200 of the Research-Development Institute for Grassland Brasov, Romania. The concentration of hemicelluloses (HC) and celluloses (Cel), digestible dry matter (DDM), relative feed value (RFV), digestible energy (DE), metabolizable energy (ME), net energy for lactation (NEl)) were calculated according to standard procedures. The content of crude protein (CP), crude fats (EE), crude cellulose (CF), nitrogen free extract (NFE), soluble sugars (TSS), starch, ash, calcium (Ca), phosphorus (P) in seeds - in accordance with standard laboratory procedures at the Institute of Biotechnology in Animal Husbandry and Veterinary Medicine, Maximovca. The carbon content of the substrates was obtained from data on volatile solids, using an empirical equation reported by Badger et al., 1979. The biochemical methane potential was calculated according to the equations of Dandikas et al., 2015. The Theoretical Ethanol Potential (TEP) was calculated according to the equations of Goff et al. (2010) based on conversion of cellulose and hemicellulose into hexose (H) and pentose (P) sugars.

RESULTS AND DISCUSSIONS

Under the weather conditions of the spring of 2020 in the Republic of Moldova, which was characterized by amounts of precipitation below the average and very high temperatures, *Pennisetum glaucum* seeds were sown on May 5, when the soil temperature in the germinative layer was over 16°C. The seedlings emerged in the period 11-14 of May, and by the end of that month the plants developed by 3-5 leaves. In June, the growth and development rates were moderate. In the first days of July, the formation of the inflorescences was observed, and after 20 days - the full flowering of *Pennisetum glaucum* plants. At the harvest time, the plants were 132-135 cm tall and the weight of a shoot was on average 162 g, consisting of 74.6% leaves and panicle. The productivity of *Pennisetum glaucum* plants achieved 5.49 kg/m^2 green mass or 1.03 kg/m^2 dry matter, but the forage yield of *Festuca arundinacea* (first cut) was 3.78 kg/m^2 green mass or 0.89 kg/m^2 dry matter and *Avena sativa* - 2.99 kg/m^2 green mass or 0.94 kg/m^2 dry matter.

Several literature sources have described the productivity of *Pennisetum glaucum* plants. According to Medvedev & Smetannikova (1981), in the Kuban region of Russia, the green mass productivity of *Pennisetum glaucum* var. *aristatum* was 40.5-51.0 t/ha, but *Pennisetum glaucum* var, *inermis* yielded 34.0-43.0 t/ha. Shashikala et al. (2013) found that pearl millet yield recorded was 81.1 t/ha green fodder, 27.7 t/ha dry matter and 30.4 t/ha protein. Toderich et al. (2016) reported that, in some marginal lands of Central Asia, the productivity of pearl millet ranged from 42.23 to 45.12 t/ha green mass at the first cut and 27.18-31.23 t/ha green mass at the second cut, respectively, the total annual aboveground dry matter varied from 27.18 to 31.23 t/ha. As a result of a research conducted by Gurinovich et al. (2020) in the Oryol region of Russia, it has been revealed that the three years' period average yield of pearl millet Gurso variety was 65.4 t/ha green mass and Sogur variety - 62.4 t/ha green mass.

Particle size distribution of harvested chopped whole plants influences the cost of transport and particle size reduction has been an important goal in preparing livestock feed, in the process of ensiling and storage, also of different substrate pretreatments of lignocellulosic energy biomass. The results, Table 1, show that a higher amount of particles (60.2%) with a size < 8 mm was found in *Pennisetum glaucum* chopped mass, but in *Zea mays* green mass forage, on average 66.8% of the particles were larger than 8 mm.

Table 1. Particle size distribution of chopped green mass from the *Poaceae* species, %

Particle size	*Pennisetum glaucum*	*Zea mays*
3.15 mm	13.4	5.5
3.15-8.00 mm	46.8	27.2
8.00-16.00 mm	28.5	48.4
16.00-31.50 mm	11.3	18.4

The comparative analysis whole plant nutrient composition of studied *Poaceae* species, Table 2, showed that pearl millet fodder was characterized by a significantly higher content of proteins (11.6%), as compared with common oat (9.5%), but reduced as compared with tall fescue forage (12.4%). The concentration of minerals in the pearl millet is at the same level as in tall fescue forage, but higher than in oat green mass. The pearl millet green mass is richer in soluble sugar. The level of cell wall fractions were low as compared with the control, which had a positive effect on the digestibility, nutritional value and energy supply of the feed.

Different results regarding the biochemical composition and the nutritive value of the green mass from pearl millet, *Pennisetum glaucum*, whole plants are given in the specialized literature. According to Sheta et al. (2010), the forage of pearl millet contained 8.08-11.95% CP, 71.38-77.49% NDF, 40.07-45.45% ADF. Heuze et al. (2015; 2016) mentioned that the average feed value of fresh pearl millet was: 194 g/kg DM, 12.4% CP, 2.0% EE, 29.2% CF, 64.8% NDF, 34.5% ADF, 4.2% lignin, 2.7% WSC, 12.3% ash, 63.8% DOM, 17.6 MJ/kg GE, 10.8 MJ/kg DE and 8.7 MJ/kg ME, but oat fresh forage - 263 g/kg DM, 10.5% CP, 3.4% EE, 30.2% CF, 54.2% NDF, 31.0% ADF, 4.5% lignin, 7.1% WSC, 10.1% ash, 67.0% DOM, 18.0 MJ/kg GE, 11.5 MJ/kg DE and 9.3 MJ/kg ME, respectively. Anjum & Cheema (2016) remarked that the harvested fresh millet forage contained 32.15% DM, 7.12% CP, 21.82% CF, 69.81% NDF, 42.93% ADF and 52.55% TDN. Görgen et al. (2016) revealed that under the irrigation conditions during dry season in Brasil, the pearl millet fodder harvested on the 47th-67th days after seedling emergence was characterized by 12.7-17.2% DM, 20.2-24.2% CP, 10.6-12.1% ash, 52.1-55.1% NDF and 25.1-27.5% ADF. Jahansouz, et al. (2016) found that the concentrations of nutrients and the nutritive value of pearl millet dry matter were 11.85% CP, 60.47% NDF, 39.77% ADF, 9.78% WSC, 50.0% TDN, 57.91% DDM, RFV=89.1 and 1.25 Mcal/kg NEl. Freitas et al. (2017) revealed that *Pennisetum glaucum* green mass contained 280 g/kg dry matter with 10.86% CP, 2.1 % EE, 63.62% NDF, 34.47% ADF, 9.04% ash, 4.16% lignin, 30.61% Cel, 32.29% HC, 14.38% NFC, 69.9% IVDMD. Animasaun et al. (2018) evaluating of the forage quality of *Pennisetum* species collected at 10 weeks after planting, reported that *Pennisetum glaucum* dry matter yield was 4.18-6.28 t/ha with 7.51-10.35% CP, 27.30-30.12% ADF, 40.25-43.70% NDF, 8.86-9.60% ash; *Pennisetum purpureum* contained 8.67-11.67t/ha, 9.01-9.31% CP, 32.15-35.42% ADF, 51.65-53.60% NDF, 8.93-9.90% ash. Costa et al. (2018) reported that the nutritive value of pearl millet was 314 g/kg DM, 149 g/kg CP, 545 g/kg NDF, 308 g/kg ADF, 48 g/kg EE, 20 g/kg ash with 695 g/kg TDN and 692 g/kg IVDMD. Machicek et al. (2019) found that "pearl millet produced 6.29- 9.87 t/ha DM with 4.3-5.1% CP, 58.9-64.5% NDF, 38.0-39.3% ADF, 58.6-59.9% TDN, RFV 85.5-90.8. Salama et al. (2020) mentioned that pearl millet fodder contained 6.50-11.33% CP, 30.52-35.89% ADF, 61.60-68.78% NDF, 44.31 - 54.38% NFE, 2.94-6.74% ADL, 30.40-46.31% OMD, 32.31-42.70% TDN, 4.81-5.44 MJ/kg ME, 2.24-2.79 MJ/kg NEl.

Table 2. The biochemical composition and the economic value of the green mass from the studied *Poaceae* species

Indices	*Pennisetum glaucum*	*Avena sativa*	*Festuca arundinacea*
Crude protein, g/kg DM	116	95	124
Crude fibre, g/kg DM	361	356	368
Minerals, g/kg DM	75	65	76
Acid detergent fibre, g/kg DM	370	374	398
Neutral detergent fibre, g/kg DM	606	627	665
Acid detergent lignin, g/kg DM	33	46	35
Total soluble sugars, g/kg DM	166	167	107
Cellulose, g/kg DM	337	328	363
Hemicellulose, g/kg DM	236	258	267
Digestible dry matter, g/kg DM	600	598	570
Relative feed value	92	89	80
Digestible energy, MJ/ kg DM	11.88	11.94	11.34
Metabolizable energy, MJ/ kg DM	9.75	9.72	9.31
Net energy for lactation, MJ/ kg DM	5.58	5.53	5.46
Ratio carbon/nitrogen	28	34	26
Biomethane potential, L/kg VS	353	329	353

Table 3. The biochemical composition and the economic value of the silage from the studied *Poaceae* species

Indices	*Pennisetum glaucum*	*Avena sativa*	*Festuca arundinacea*
pH index	3.78	4.10	4.16
Content of organic acids, g/kg DM	20.1	46.7	32.5
Free acetic acid, g/kg DM	0.9	2.5	4.2
Free butyric acid, g/kg DM	0.1	0	0
Free lactic acid, g/kg DM	6.8	10.7	4.8
Fixed acetic acid, g/kg DM	0.9	3.4	5.1
Fixed butyric acid, g/kg DM	0.2	0	0
Fixed lactic acid, g/kg DM	11.2	28.1	18.4
Total acetic acid, g/kg DM	1.8	5.9	9.3
Total butyric acid, g/kg DM	0.3	0	0
Total lactic acid, g/kg DM	18.0	38.8	23.2
Acetic acid, % of organic acids	8.96	13.20	28.66
Butyric acid, % of organic acids	1.49	0	0
Lactic acid, % of organic acids	89.55	86.80	71.38
Crude protein, g/kg DM	120	102	123
Crude fibre, g/kg DM	390	393	350
Minerals, g/kg DM	93	78	99
Acid detergent fibre, g/kg DM	391	413	365
Neutral detergent fibre, g/kg DM	668	699	608
Acid detergent lignin, g/kg DM	21	40	23
Total soluble sugars, g/kg DM	99	26	81
Cellulose, g/kg DM	370	373	342
Hemicellulose, g/kg DM	277	281	243
Digestible dry matter, g/kg DM	584	567	597
Relative feed value	81	76	91
Digestible energy, MJ/ kg DM	11.58	11.28	11.81
Metabolizable energy, MJ/ kg DM	9.51	9.26	9.70
Net energy for lactation, MJ/ kg DM	5.53	5.29	5.83
Ratio carbon/nitrogen	26	31	25
Biomethane potential, L/kg VS	375	341	372

Table 4. The biochemical composition of the grains of the studied *Poaceae* species

Indices	*Pennisetum glaucum*	*Avena sativa*
Crude protein, % DM	13.28	10.30
Crude fats, % DM	5.85	4.46
Crude cellulose, % DM	2.10	13.76
Nitrogen free extract, % DM	76.41	62.69
Soluble sugars, % DM	2.61	-
Starch, % DM	30.46	-
Ash, % DM	2.36	3.74
Nutritive units/ kg DM	1.09	1.00
Metabolizable energy, MJ/kg DM	11.78	10.76
Calcium, % DM	0.06	-
Phosphorus, % DM	0.07	-

Table 5. The biochemical composition and the economic value of the straw from studied *Poaceae* species

Indices	*Pennisetum glaucum*	*Avena sativa*	*Festuca arundinacea*
Crude protein, g/kg DM	57	62	68
Crude fibre, g/kg DM	487	467	471
Minerals, g/kg DM	113	82	96
Acid detergent fibre, g/kg DM	530	499	518
Neutral detergent fibre, g/kg DM	823	800	754
Acid detergent lignin, g/kg DM	74	56	75
Cellulose, g/kg DM	456	443	443
Hemicellulose, g/kg DM	293	301	236
Digestible dry matter, g/kg DM	476	500	485
Digestible energy, MJ/ kg	9.65	10.09	9.82
Metabolizable energy, MJ/ kg	7.92	8.28	8.07
Net energy for lactation, MJ/ kg	3.95	4.30	4.08
Ratio carbon/nitrogen	54	51	46
Biomethane potential, L/kg VS	282	308	275
Hexose sugars, g/kg	82.35	80.20	79.41
Pentose sugars, g/kg	48.20	49.51	38.82
Theoretical ethanol potential, L/t	544.4	540.9	493.0

Fodder conservation is necessary in most parts of Earth to maintain feed supply during winter. Silage and haylage are the main conserved green succulent roughage fodder for domestic herbivores, their quality is key to good animal performance, reducing winter feed costs and increasing profitability during the housing period. During the sensorial assessment, it was found that, in terms of colour, the silage from pearl millet had specific dark green leaves and pink-maroon stems and panicles, with pleasant smell, specific to pickled apples, while the silage made from tall fescue- yellow stems with olive leaves, with pleasant smell, like pickled cucumbers; the oat haylage was of homogeneous olive colour with dark green hues and pleasant smell, specific to pickled vegetables. The results regarding the quality of the ensiled forage are shown in Table 3. It has been determined that the pH values and content of organic acids of the ensiled forage depended on the species, thus, *Pennisetum glaucum* silage had lower pH value and amount of organic acids. In pearl millet silage, butyric acid was detected in very small quantities (0.3 g/kg), but the level of acetic acid was very low in comparison with tall fescue silage and oat haylage. It was found that during the process of ensiling, the concentrations of crude protein did not modify essentially, minerals increased, lignin and soluble sugars decreased in comparison with initial green mass. As compared with the initial fresh mass, the silage from pearl millet had high concentration of NDF, ADF, cellulose and hemicellulose which had a negative impact on digestibility, relative feed value and energy concentrations. In pearl millet silage, the amount of crude protein, digestible dry matter and energy concentrations was high as compared with ensiled oat, but lower nutritive value as compared with tall fescue silage.

Several studies have evaluated the potential of pearl millet as silage for ruminants. According to Hernández et al. (2013), the chemical composition of silage was: 10.26-10.98% CP, 8.68-9.31% DP, 57.80-61.87% NDF, 35.05-37.12% ADF, 5.24-6.01% EE, 12.82-13.04% ash, 0.48% Ca, 0.17-0.18% P. Anjum & Cheema (2016) mentioned that the silage was characterized by 31.97% DM, pH 4.12, 6.18% lactic acid, 7.02% CP, 22.15% CF, 71.82% NDF, 44.15% ADF and 55.18% TDN. Costa et al. (2018) found that the pearl millet silage was characterized by pH 3.75, 47.3 g/kg lactic acid, 6.7 g/kg acetic acid, 0.1 g g/kg butyric acid, 148.1 g/kg CP, 573.2 g/kg NDF, 337.1 g/kg ADF, 47.3 g/kg EE, 16.7 g/kg ash, 689 g/kg TDN with 683.5 g/kg IVDMD. Alix et al. (2019) remarked that the pearl millet silage had pH 3.8, 55-60 g/kg lactic acid, 10-12 g/kg acetic acid, 0.33-0.46 g/kg propionic acid, 7-16 g/kg N, 100-145 g/kg WSC, 9-62 g/kg starch and 429-474 g/kg TDN.

On the basis of our observations, *Pennisetum glaucum*, under the pedoclimatic conditions of the Central region of the Republic of Moldova, achieved full seed maturity in late August - middle September. The biochemical composition of the grains of the studied *Poaceae* species has been shown in Table 4. It has been found that pearl millet grain contained higher amount of protein, fats, nitrogen free extract, starch and low concentration of crude cellulose and ash than oat grain. The esteemed nutritive value of pearl millet grains reached 1.09 nutritive units/ kg and 11.78 MJ/kg ME, while the control oat grains - 1.00 nutritive units/kg and 10.76 MJ/kg ME, respectively.

Davis et al. (2003) mentioned that the evaluated pearl millet grains had 3300-3448 kcal/kg ME and 12-14% protein, higher content than corn grains. Wu et al. (2006) stated that pearl millet grains contained 9.72-13.68% CP, 6.27-6.80% EE, 1.10-1.87% CF, 65.30-70.39% starch, 1.53-1.96% ash, but corn grains - 8.35% CP, 4.05% EE, 1.97% CF, 73.00% starch, 1.54% ash. Mustafa (2010) found that the biochemical composition of pearl millet grains used was 2.0% ash, 6.7% EE, 13.9% CP, 63.4% starch, 18.3% NDF and 4.4 % ADF, the respective values for corn grains were: 1.3% ash, 3.9%EE, 9.1% CP, 72.2% starch, 15.3% NDF and 8.2% ADF. Pearl millet grains contained 13.8% CP, 4.34% EE, 2.8% CF, 17.6% NDF, 3.42% ADF, 77.95% NFE, 64.93% starch, 1.91% ash, 4480 kcal/kg GE, 81.25% DDM, 11.77% DP, 3361 kcal/kg DE, they can completely substitute corn in diets for growing rabbits (Catelan et al., 2012).

Cereal crop residues are important feed resources for ruminants and other herbivores animals, also as feedstock for biorefineries. The biochemical composition and the economic value of the straw from the studied *Poaceae* species are presented in Table 5. The pearl millet straw as fodder is characterized by low content of crude protein and high ash and cell wall concentration which had a negative effect on feed value and energy concentration as compared with control variants. According to Bidinger & Blummel (2007) the pearl millet stover quality was 32% leaf, 0.83% nitrogen, 3.35% soluble sugars and 5.53 MJ/kg ME. Blümmel et al. (2010) found that pearl millet stover yields range from 3760 to 4930 kg/ha, stover nitrogen content from 0.62 to 1.10%, *in vitro* digestibility of dry matter from 37.6 to 46.7% and metabolizable energy from 5.26 to 6.88 MJ/kg. Hamed & Elimam (2014) reported that pearl millet straw contained 96.87% DM with 5.21% CP, 0.50 % EE, 39.99% CF, 10.0% ash, 43.50% NFE, 79.00% NDF, but sorghum stover: 97.53% DM, with 4.52% CP, 1.27% EE, 40.00% CF, 7.84% ash, 41.0.5% NFE, 67.50% NDF. Packiam et al. (2018) revealed that pearl millet biomass contained 41.60% Cel, 21.81 % HC, 21.32% lighin, 6.27% ash. Vijayanand (2016) found that pearl millet straw contained 93% DM, with 29.6% HC, 37.7% Cel, 18.8% lighin, 2.5% ash, 86.0% volatile matter, 11.5% fixed carbon, 16.4 MJ/kg caloric value, 2171.4 MJ/m^3 energy density. Elzaki et al (2020) reported that the chemical characteristics of *Pennisetum glaucum* whole stalks were as follows: 5.6% ash, 3.6% total silica, 47.4% Kurschner-Hoffer cellulose, 42.2% alfa-cellulose, 64.3% holocellulose, 17.0% pentosans, 21.1% lignin, 8.1% total extractives, thus representing a promising feedstock in pulp and paper manufacturing.

Substituting fossil fuels with biofuels has been identified as one of the most feasible steps to reduce the agricultural greenhouse gas footprint. Conversion technologies used to produce renewable energy from biomass include combustion, anaerobic digestion (AD) and thermochemical methods (Hall and Gifford, 2007). Anaerobic digestion of organic waste has gained improved consideration to produce methane as energy source and to address environmental challenges including effective waste disposal, besides, mineral nutrients and undigested carbon compounds can be recycled back to the land as digestate, thereby largely eliminating the need for external nutrient inputs.

The results regarding the quality of the substrates for anaerobic digestion from studied *Poaceae* species and the potential for obtaining biomethane are shown in Tables 2, 3 and 5. We would like to mention that carbon to nitrogen ratio (C/N), which constitutes a basic factor governing the correct course of methane fermentation, ranged from 25 to 54. In the tested *Pennisetum glaucum* substrates, the carbon to nitrogen ratio was C/N = 28 in green mass substrate, C/N = 26 in silage substrate and C/N = 54 in straw substrate. Essential differences were also observed between the lignin contents. The tested substrates contained acceptable amounts of hemicellulose. The biochemical methane potential of *Pennisetum glaucum* tested substrates varied from 282 l/kg VS to 375 l/kg VS, but in substrates made from the control crops - from 275 l/kg VS to 372 l/kg VS. The best methane potential was achieved in silage substrates, the lowest - in straw substrates.

Several literature sources describe the composition of cell walls in pearl millet straw and energy potential. Paritosh et al. (2019) remarked that the contents of cellulose, hemicellulose and lignin in pearl millet straw were about 36.42%, 25.31% and 15.63%, respectively. C/H = 48.87 124.1-162.4 L/kg VS methane yield.

The possibility of converting lignocellulosic biomass in bioethanol fuel is currently an area of great research interest around the world. The bioethanol yields are influenced by tissue composition, ratios of cellulose, hemicellulose and lignin. Analyzing the cell wall composition of straw substrates (Table 5), we could mention that the concentration of structural carbohydrates in *Pennisetum glaucum* straw substrate was 823 g/kg, including 456 g/kg cellulose, 293 g/kg hemicellulose and 74 g/kg lignin, but *Avena sativa* and *Festuca arundinacea* substrates: 754-800 g/kg, 443 g/kg, 236-301 g/kg and 56-75 g/kg, respectively. The theoretical ethanol yield from fermentable sugars averaged 544.4 L/t in pearl millet straw substrates, compared to 493 L/t in tall fescue straw substrates and 540.9 L/t in oat straw substrates.

CONCLUSIONS

The introduced ecotype of pearl millet, *Pennisetum glaucum*, under the climatic conditions of the Republic of Moldova, was characterized by optimal growth rates and productivity.

The green mass and silage prepared from pearl millet contain a lot of nutrients, which make them suitable to be used as a part of diverse livestock diets.

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REFERENCES

Alix, H., Tremblay, G.F., Chantigny, M.H., Bélanger, G., Seguin, P., Fuller Keith, D., Bittman, S., Hunt, D., Larney, F.J., Acharya, S.N., Vanasse A. (2019). Forage yield, nutritive value, and ensilability of sweet pearl millet and sweet sorghum in five Canadian ecozones. *Canadian Journal of Plant Science, 99*(5), 701–714.

Animasaun, D., Rathod, H.P., Krishnamurthy, R. (2018). Analysis of forage yield and nutritional contents of *Pennisetum glaucum* (pearl millet) and *Pennisetum purpureum* (Napier grass) accessions. *Cuban Journal of Agricultural Science*, *52*(4), 447–455.

Anjum, M.I., Cheema, A.U. (2016). Feeding value of millet harvested as silage or hay fed to buffalo calves supplemented with concentrate on growth performance and nutrient digestibility, *Pakistan Journal of Zoology, 48*(1), 101–105.

Bidinger, F.R., Blummel, M. (2007). Determinants of ruminant nutritional quality of pearl millet [*Pennisetum glaucum* (L.) R. Br.] stover. I. Effects of

management alternatives on stover quality and productivity. *Field Crops Research, 103*.119–128.
Blessie, J. P., Kennady, Z. J., Karthikeyan, S., Ramesh, D. (2021). Pearl millet (*Pennisetum glaucum*) as a sustainable feedstock for bioethanol production by catalytic downflow liquid contact reactor. *Crop Research*, *56*(5), 270–275.
Blümmel, M., Khan, A.A., Vadez, V., Hash, C.T. and Rai, K.N. (2010). Variability in stover quality traits in commercial hybrids of pearl millet (*Pennisetum glaucum* (L.) R. Br.) and grain - stover trait relationships. *Animal Nutrition and Feed Technology*, *10*, 29–38.
Catelan, F., Scapinello, C., Figueira, J.L., Oliveira, A.F.G., Motta, A.C.M. (2012). Evaluation of milled pearl millet in the feeding of growing rabbits. *Revista Brasileira de Zootecnia*, *41*(8), 1866–1871.
Chen, C., Sharma-Shivappa, R., Chen, Y., Wichman, D., Johnson, D. (2007). Potential of annual cereal crops to serve as fuel ethanol feedstock and livestock feed. *Issues in New Crops and New Uses. Proc. 6th National Symposium Creating Markets for Economic Development of New crops and New Uses. ASHS Press. Alexandria, VA* (pp. 47–55).
Costa, R.R.G.F., Costa K.A.P., Souza, W.F., Epifanio P. S., Santos, C.B., Silva J.T., Oliveira, S.S. (2018). Production and quality of silages pearl millet and paiaguas palisadegrass in monocropping and intercropping in different forage systems. *Bioscience Journal, 34*(2), 357–367.
Dhabhai, R., Jain, A., Chaurasia, S. P. (2012). Production of fermentable sugars by dilute acid pretreatment and enzymatic saccharification of three different lignocellulosic materials. *International Journal of Chemtech Research*, *4*(4), 1497–1502.
Davis, A. J., Dale, N. M., Ferreira, F. J. (2003). Pearl millet as an alternative feed ingredient in broiler diets. *Journal of Applied Poultry Research*, *12*(2), 137–144.
Elzaki, O., Khider, T., Omer, S., Mohieldin, S., Shomeina, S. (2020). Suitability of sudanese pearl millet stalks *Pennisetum glaucum* (L.) for alkaline pulping with additives. *Songklanakarin Journal of Science and Technology*, *42*(1), 117–122.
Freitas, P., Carvalho, G., Santos, E., Araújo, O., Pires, A., Maranhão, C., Rodrigues, T., Pinto, L. (2017). Qualitative parameters of pearl millet silage ammoniated with urea, at different compaction densities. *Pesquisa Agropecuária Brasileira*, *52*. 679–689. 10.1590/s0100-204x2017000800014.
Görgen, A.V., Filho, S.L.S., Leite, G., Spehar, C., Diogo, J.M.S., Ferreira, D.B. (2016). Productivity and forage quality of buckwheat ("*Fagopyrum esculentum*" moench) and pearl millet ("*Pennisetum glaucum*" (L.) R.BR). *Revista Brasileira de Saude e Producao Animal, 17*(4), 599–607.
Gurinovich, S.O., Zotikov, V.I., Sidorenko. V.S. (2020). Pearl millet (*Pennisetum glaucum* (L.) R.BR) - new culture in agriculture of Central Russia. https://journal.vniizbk.ru/jurnals/34/j_vniizbk_2020_2-064-070.pdf [in Russian].
Jahansouz, M.R, Afshar, R.K., Heidari, H., Hashemi, M. (2014) Evaluation of yield and quality of sorghum and millet as alternative forage crops to corn under normal and deficit irrigation regimes. *Jordan Journal of Agricultural Sciences, 10*(4), 699–715.
Hamed, A. H., Elimam, M. E. (2014). Proximate analysis of fibres of grain sorghum, pearl millet and sesame residues and their fractions in Gadarif State, Sudan. *Gezira Journal of Agricultural Science*, *12*(1), 19–32.
Hassan, M.U., Zamir, S.I., Haq, I., Khalid, F., Rasool, T., Hussain, A. (2014). Growth, yield and quality performance of pearl millet (*Pennisetum americanum* L.) varieties under Faisalabad conditions, Pakistan. *American Journal of Plant Science*s, *5*(15), 2215.
Hernández, A.A., Urrutia, M.J., Cervantes, B.J.F., Hernández, G.F.J. (2013). *Producción, conservación y aprovechamiento del forraje de mijo perla en San Luis Potosí.* 60p. http://www.inifapcirne.gob.mx/Biblioteca/Publicaciones/975.pdf
Heuzé V., Tran G., Boudon A., Lebas F. (2016). Oat forage. https://www.feedipedia.org/node/500
Heuzé, V., Tran, G., Hassoun, P., Sauvant, D. (2015). Pearl millet (*Pennisetum glaucum*), forage. *https://www.feedipedia.org/node/399.*
Jahansouz, M.R, Afshar, R.K., Heidari, H., Hashemi, M. (2014) Evaluation of yield and quality of sorghum and millet as alternative forage crops to corn under normal and deficit irrigation regimes. *Jordan Journal of Agricultural Sciences, 10*(4), 699–715.
Jukanti, A.K., Gowda, C.L., Rai, K.N., Manga, V.K., Bhatt, R.K. (2016). Crops that feed the world 11. Pearl Millet (*Pennisetum glaucum* L.): an important source of food security, nutrition and health in the arid and semi-arid tropics. *Food Security*, *8*. 307–329.
Machicek, J.A., Blaser, B.C., Darapuneni, M., Rhoades, M.B. (2019). Harvesting regimes affect brown sorghum-Sudan grass and brown midrib pearl millet forage production and quality. *Agronomy. Multidisciplinary Digital Publishing Institut, 9*(8), 416. doi:10.3390/agronomy9080416.
Marsalis, M.A., Lauriault, L.M., Trostle, C. (2012). Millets for forage and grain in New Mexico and West Texas. College of Agricultural, Consumer and Environmental Sciences. New Mexico State University. http://aces.nmsu.edu/pubs/_a/A417/welcome.html.
Medvedev, P.F., Smetannikova, A.I. (1981). *The forage crops of European part of the USSR.* Leningrad, Kolos. [in Russian].
Mustafa, A. F. (2010). Performance of lactating dairy cows fed pearl millet grain. *Journal of Dairy Science*, *93*(2), 733–736. diss.pdf
Oyen, L.P.A., Andrews, D.J. (1996). *Pennisetum glaucum*. *Plant Resources of South-East Asia* No. 10. Cereals. Springer. Backhuys Publishers. Leiden: 119–123.
Packiam, M., Karthikeyan, S., Ramesh, D., Uthandi, S., Subramanian, M., Kamaraj, S. (2018). Suitability of

pearl millet as an alternate lignocellulosic feedstock for biofuel production in India. *Journal of Applied & Environmental Microbiology,* 6(2), 51–58. 10.12691/jaem-6-2-4.

Paritosh, K., Balan, V., Vijay, V.V, Vivekanand, V. (2019). Simultaneous alkaline treatment of pearl millet straw for enhanced solid state anaerobic digestion: Experimental investigation and energy analysis. *Journal of Cleaner Production*. 252. 119798. 10.1016/j.jclepro.2019.119798.

Salama, H.S.A., Shaalan, A.M., Nasser, M.E.A. (2020). Forage performance of pearl millet (*Pennisetum glaucum* [L.] R. Br.) in arid regions: Yield and quality assessment of new genotypes on different sowing dates. *Chilean Journal of Agricultural Research,* *80*(4), 572–584. http://dx.doi.org/10.4067/S0718-58392020000400572

Sheta, B.T., Kalyanasundaram, N.K., Patel, K.C. (2010). Quality parameters and plant nutrient ratios of forage pearl millet as influences by nitrogen, potassium and sulphur levels in loamy sand soils of Anand. *An Asian Journal of Soil Science*, *5*(1), 116–121.

SM 108: 1995(1996). Siloz din plante verzi. Condiţii tehnice. Moldovastandart. 10.

Satyavathi CT, Ambawat S, Khandelwal V and Srivastava RK (2021) Pearl Millet: a climate-resilient nutricereal for mitigating hidden hunger and provide nutritional security. *Frontiers in Plant Science, 12.* 659938. doi: 10.3389/fpls.2021.659938

Toderich, K., Massino I., Popova, V., Boboev, F., Kalashnikov, A., Zhapaev, R., Baizakova, A., Kalashnikov, P., Zheksembekova, M. (2016). *Practical recommendations for the cultivation of Pearl millet in the marginal lands of Central Asia*. Uzbekistan, Tashkent: IKBA-TsAZ, 11 p.[in Russian].

Wu, X., Wang, D., Bean, S. R., Wilson, J.P. (2006). Ethanol production from pearl millet using *Saccharomyces cerevisiae. Cereal Chemistry*, *83*(2), 127–131.

Vijayanand, C. (2016). Characterization of indigenous biomass. *International Journal of Agriculture Sciences,8*(50)*,* 2124–2127.

Wu, X., Wang, D., Bean, S. R., Wilson, J.P. (2006). Ethanol production from pearl millet using *Saccharomyces cerevisiae. Cereal Chemistry*, *83*(2), 127–131.