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BIOCHEMICAL COMPOSITION OF THE GENUS *MISCANTHUS* ANDERSS. PLANT RAW MATERIAL IN CONDITIONS OF INTRODUCTION

Objective — to investigate biochemical properties of raw material of the genus *Miscanthus* Anderss. plants in conditions of M.M. Gryshko National Botanical Garden of the NAS of Ukraine.

Material and methods. Investigated plants were cultivars and varieties of the genus *Miscanthus* species: *M. sinensis* Anderss. f. *ESBMK-1* (MSEK-1), *M. sinensis* f. *ESBMK-6* (MSEK-6), *M. sinensis* cv. *Veleten* (MSV), *M. sacchariflorus* (Maxim.) Benth. f. *ESBMTS-1* (MSES-1), *M. sacchariflorus* f. *ESBMTS-5* (MSES-5), *M. sacchariflorus* cv. *Snihopad* (MSS), *M. × giganteus* J.M. Greef & Deuter ex Hodk & Ronvoize cv. *Huliver* (MGH). The content of dry matter and lipids were determined according to A.I. Yermakov, the total content of sugars and ascorbic acid concentration — according to V.P. Krishchenko, the content of carotene — according to B.P. Pleshkov, the content of ash — according to Z.M. Hrycaenko, the content of calcium and phosphorus — according to H.M. Pochinok.

Results. During vegetation, the plant raw material of the genus *Miscanthus* species and their varieties and cultivars accumulated dry matter in range from 26.16 % (MSEK-1) to 57.80 % (MSS), the total content of sugars — from 1.27 % (MSES-5) to 5.13 % (MGH), ascorbic acid — from 11.42 mg% (MSES-5) to 43.61 mg% (MSEK-6), carotene — from 0.197 mg% (MSS) to 1.113 mg% (MSV), ash — from 2.06 % (MSS) to 6.11 % (MSEK-6), calcium — from 0.203 % (MSES-5) to 1.070 % (MSEK-1), phosphorus — from 0.023 % (MGH) to 0.121 % (MSV), lipids — from 0.933 % (MSS) to 3.780 % (MSEK-6).

Conclusions. Obtained data showed that in conditions of M.M. Gryshko National Botanical Garden of the NAS of Ukraine the genus *Miscanthus* plants is a valuable source of nutrients the most content of which observed in the tillering period. Due to this fact these plants can be recommended as nutritional supplements for animal feed. In addition to the aforementioned content of dry matter, total content of sugars of investigated plants of the genus *Miscanthus* increased from tillering to seed ripening stage. It is found that content of carotene, ascorbic acid, calcium decreased from tillering to seed ripening stage. The total content of ash decreased to seed ripening phase but not significantly. The level of phosphorus varied during vegetation in investigated plants.

Key words: *Miscanthus*, plant raw material, biochemical properties.

Plants of the genus *Miscanthus* Anderss. — one of the most popular and promising fast-growing crops for biofuels and chemical production. *Miscanthus* was introduced from Japan and cultivated in Europe in the 1930s [19, 21, 22, 24, 28]. It is a herbaceous perennial and tall plant, composing stable community. The main components of the plant cell wall are cellulose, hemicellulose, lignin [23, 29]. As a C₄-perennial plant characterized with high biomass yield and relatively low nitrogen and water requirement, *Miscanthus* is considered to be

one of the top candidates of second-generation energy crops [18, 20, 25, 30].

It is known that some countries successfully operate biotechnological production of bioethanol the basic raw material of which are crop cultures such as *Miscanthus* spp. The saccharification technology of biomass of these plants is possible with commercial fermentation [1, 13, 15, 26]. Most of investigations on *Miscanthus* merely evaluated pre-treatment effects on its enzymatic hydrolysis, with only a few on ethanol production [16].

But the most existing data connected with investigation of the genus *Miscanthus* plants as a raw material for bioethanol production only. Previous

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medical study showed that plant raw material exhibits the antioxidant properties and inhibition of mutagenic process [27]. According to Poberezhnaya (2011) *M. sinensis* is effective plant-accumulator of metals. Because of this fact these plants can be recommended for phytoremediation of contaminated soils [9]. Our research was directed on biochemical investigation of above-ground part of these plants.

Objective — to investigate biochemical properties of raw material of the genus *Miscanthus* plants in conditions of M.M. Gryshko National Botanical Garden of the NAS of Ukraine.

Material and methods

Plant material was collected in the experimental collection of Department of Cultural Flora of M.M. Gryshko National Botanical Garden of the NAS of Ukraine. In this study we used to investigate varieties and cultivars of plants of three species of *Miscanthus* such as *M. sinensis* Anderss. f. ESBMK-1 (MSEK-1), *M. sinensis* f. ESBMK-6 (MSEK-6), *M. sinensis* cv. Veleten (MSV), *M. sacchariflorus* (Maxim.) Benth. f. ESBMTS-1 (MSES-1), *M. sacchariflorus* f. ESBMTS-5 (MSES-5), *M. sacchariflorus* cv. Snihopad (MSS), *M. × giganteus* J.M. Greef & Deuter ex Hodk & Ronvoize cv. Huliver (MGH). Names of cultivars and varieties used according to D.B. Rakhmetov et al. (2015) [5].

All biochemical analyses were conducted using above-ground part of plants during vegetation. The determination of absolute dry matter done by drying to constant weight at 100–105 °C according to A.I. Yermakov [7]. The total content of sugars was investigated by Bertrand method in water extracts. The concentration of ascorbic acid (AA) of the acid extracts determined by a 2,6-dichlorophenol-indophenol method that based on the reduction properties of AA. Both analyses carried out according to V.P. Krishchenko [6]. The concentration of total carotene determined according to B.P. Pleshkov. The procedure carried out in petrol extracts by spectrophotometric method using 2800 UV/VIS Spectrophotometer, Unico. Mixtures were left in a shaker for 2 hours and their absorbance was measured at the wavelength of 440 nm [8]. The level of total ash was determined

using the method of combustion in muffle-oven (SNOL 7.2-1100, Termolab) at 300–800 °C until the samples turned into white ash to constant weight according to Z.M. Hrycajenko et al. [4]. The concentration of calcium was determined by titration method of acid extracts with Trilon B. Phosphorus content in plants was identified in acid extracts using molybdenum solution. Both these analyses done according to H.N. Pochinok [10]. The procedure of the determination of total oil level was performed using Soxhlet extractor with petroleum ether according to A.I. Yermakov [7]. Experimental data were evaluated by using Excel 2010. Mean values of three replicates and standard deviation are given in Tables 1–6.

Results and discussions

Different investigations of the genus *Miscanthus* have conducted in the M.M. Gryshko National Botanical Garden (Department of Cultural flora) for many years. One of the most priority branches of study is energetic capacity of these plants, their high productivity and relation to the different ecological factors. It was main reason for mobilization and evaluation of collection of the different species, cultivars and varieties of this genus [11, 14].

Previous data of *M. sinensis*, *M. sacchariflorus* and *M. × giganteus* showed the content of dry matter 30.47–43.96 %, the total content of sugars — 3.27–6.79 %, the ascorbic acid — 12.51–25.06 mg%, the carotene — 0.04–0.80 mg%, the lignin — 5.23–15.11 % during vegetation. Maximal signs of investigated parameters were noted in plants in the start of vegetation [12]. Also, the previous study showed that carbohydrates in *M. giganteus* constituted approximately 75 % of its dry matter content [25].

In the Table 1 and 2 represented results of accumulation certain compounds in stage of tillering. Content of dry matter in this period was from 26.16 % (MSEK-1) to 38.26% (MSES-1), total content of sugars — from 1.27 % (MSES-5) to 3.36 % (MSES-1), ascorbic acid — from 17.76 mg% (MSS) to 43.61 mg% (MSEK-6) and carotene — from 0.311 mg% (MSS) to 1.113 mg% (MSV).

As shown in Table 2 the content of ash in plant raw material was from 2.35 % (MSES-1) to 6.11 %

(MSEK-6), calcium — from 0.557 % (MSS) to 1.070 % (MSEK-1), phosphorus — from 0.023 % (MGH) to 0.081 (MSEK-6), lipids — from 1.44 % (MSEK-1) to 3.78 % (MSEK-6).

In the flowering stage the dry matter of plants was from 35.57 % (MSEK-6) to 57.25 % (MSS), total content of sugars — from 1.31 % (MSV) to 4.77 % (MSEK-1), ascorbic acid — from 13.93 mg% (MSS) to 33.21 mg% (MGH), carotene — from 0.576 mg% (MSS) to 0.879 mg% (MSEK-6) (Table 3).

In the period of flowering (Table 4) a minimal content of ash was 2.07 % (MSS) and maximal — 4.08 % (MSV). The level of calcium varied from 0.263 % (MSEK-6) to 0.690 % (MSES-1), phosphorus — from 0.032 % (MSEK-1) to 0.121 % (MSV) and lipids — from 1.310 % (MSEK-6) to 3.043 % (MSES-5). As reported Rakhmetov et al. (2015) in the flowering stage for MSS, MGH and MSV the content of dry matter was 43.96, 37.72 and 36.90 %, content of sugars — 5.04, 6.30 and 6.15 %, content of ascorbic acid — 12.51, 25.06

Table 1. The content of dry matter, total content of sugars and vitamins in above-ground parts of the genus *Miscanthus* plants in the stage of tillering depending on cultivars

Cultivar, form	Dry matter, %	Total content of sugars, %	Ascorbic acid, mg%	Carotene, mg%
MSEK-1	26.16 ± 1.41	1.64 ± 0.08	36.44 ± 1.93	0.606 ± 0.040
MSEK-6	28.90 ± 0.03	1.98 ± 0.09	43.61 ± 2.08	0.366 ± 0.014
MSV	26.51 ± 0.06	1.34 ± 0.10	23.76 ± 2.26	1.113 ± 0.028
MSES-1	38.26 ± 0.34	3.36 ± 0.07	20.38 ± 0.79	0.384 ± 0.024
MSES-5	30.26 ± 0.84	1.27 ± 0.10	27.37 ± 2.49	0.375 ± 0.031
MSS	36.96 ± 0.62	2.91 ± 0.07	17.76 ± 0.86	0.311 ± 0.024
MGH	28.22 ± 0.35	2.90 ± 0.24	25.52 ± 2.13	0.518 ± 0.015

Table 2. The content of ash, lipids and macroelements in above-ground parts of the genus *Miscanthus* plants in the stage of tillering depending on cultivars

Cultivar, form	Ash, %	Calcium, %	Phosphorus, %	Lipids, m%
MSEK-1	4.54 ± 0.81	1.070 ± 0.010	0.036 ± 0.002	1.441 ± 0.072
MSEK-6	6.11 ± 0.10	0.597 ± 0.021	0.081 ± 0.009	3.780 ± 0.114
MSV	4.43 ± 0.18	0.670 ± 0.010	0.074 ± 0.002	2.634 ± 0.092
MSES-1	2.35 ± 0.09	0.683 ± 0.006	0.066 ± 0.002	3.573 ± 0.391
MSES-5	3.33 ± 0.73	0.737 ± 0.025	0.055 ± 0.001	3.740 ± 0.137
MSS	3.70 ± 0.28	0.557 ± 0.025	0.029 ± 0.002	2.408 ± 0.032
MGH	3.36 ± 0.20	0.700 ± 0.030	0.023 ± 0.002	2.059 ± 0.140

Table 3. The content of dry matter, total content of sugars and vitamins in above-ground parts of the genus *Miscanthus* plants in the stage of flowering depending on cultivars

Cultivar, form	Dry matter, %	Total content of sugars, %	Ascorbic acid, mg%	Carotene, mg%
MSEK-1	35.67 ± 0.26	4.77 ± 0.06	26.21 ± 1.55	0.617 ± 0.023
MSEK-6	35.57 ± 0.37	1.75 ± 0.08	30.93 ± 1.55	0.879 ± 0.017
MSV	37.97 ± 0.29	1.31 ± 0.13	17.39 ± 0.73	0.583 ± 0.013
MSES-1	39.57 ± 0.10	4.45 ± 0.10	20.85 ± 1.39	0.648 ± 0.015
MSES-5	42.53 ± 0.17	4.26 ± 0.05	23.87 ± 0.65	0.688 ± 0.015
MSS	57.25 ± 0.62	2.74 ± 0.06	13.93 ± 1.44	0.576 ± 0.028
MGH	41.41 ± 0.50	2.08 ± 0.13	33.21 ± 1.33	0.763 ± 0.023

and 24.59 mg%, content of carotene — 0.06, 0.04 and 0.09 respectively [12]. These results have some difference comparing with our results that depend on condition of year evidently, especially regarding content of carotene.

Dry matter in the seed ripening period (Table 5) was in range from 35.42 % (MSEK-1) to 57.80 % (MSS), total content of sugars — from 2.08 % (MSS) to 5.13 % (MGH), ascorbic acid — from 6.66 mg% (MSS) to 29.89 mg% (MGH), carotene — from 0.162 mg% (MSEK-1) to 0.516 mg% (MSEK-6).

Rakhmetov et al. (2015) obtained data that for MSS, MSV and MGH content of lipids during vegetation was 1.40—6.84, 3.59—5.81 and 2.58—5.92 % respectively [12].

In the stage of seed ripening (Table 6) content of ash in the investigated plants was in range from 2.06 % (MSS) to 4.56 % (MSEK-1), calcium — from 0.203 % (MSES-5) to 0.570 % (MSES-1), phosphorus — from 0.063 % (MSES-5) to 0.106 % (MSEK-1) and lipids — from 0.933 % (MSS) to 2.047 % (MSES-1).

Table 4. The content of ash, lipids and macroelements in above-ground parts of the genus *Miscanthus* plants in the stage of flowering depending on cultivars

Cultivar, form	Ash, %	Calcium, %	Phosphorus, %	Lipids, m%
MSEK-1	3.13 ± 0.06	0.483 ± 0.021	0.032 ± 0.002	1.650 ± 0.078
MSEK-6	3.87 ± 0.20	0.263 ± 0.021	0.041 ± 0.006	1.310 ± 0.070
MSV	4.08 ± 0.02	0.568 ± 0.031	0.121 ± 0.002	2.320 ± 0.020
MSES-1	2.44 ± 0.02	0.690 ± 0.020	0.085 ± 0.008	2.600 ± 0.130
MSES-5	2.64 ± 0.15	0.343 ± 0.015	0.045 ± 0.003	3.043 ± 0.105
MSS	2.07 ± 0.24	0.327 ± 0.025	0.044 ± 0.003	2.003 ± 0.245
MGH	3.80 ± 0.50	0.497 ± 0.035	0.042 ± 0.001	1.830 ± 0.170

Table 5. The content of dry matter, total content of sugars and vitamins in above-ground parts the genus *Miscanthus* plants in stage of seed ripening depending on cultivars

Cultivar, form	Dry matter, %	Total content of sugars, %	Ascorbic acid, mg%	Carotene, mg%
MSEK-1	35.42 ± 0.11	3.24 ± 0.15	13.97 ± 1.56	0.162 ± 0.028
MSEK-6	46.83 ± 1.14	4.55 ± 0.22	20.57 ± 1.18	0.516 ± 0.025
MSV	45.61 ± 0.04	5.09 ± 0.11	17.49 ± 0.61	0.227 ± 0.037
MSES-1	50.33 ± 0.39	4.07 ± 0.13	12.93 ± 0.84	0.293 ± 0.024
MSES-5	48.96 ± 0.06	3.15 ± 0.13	11.42 ± 0.86	0.213 ± 0.016
MSS	57.80 ± 0.32	2.08 ± 0.10	6.66 ± 0.95	0.197 ± 0.026
MGH	49.38 ± 0.15	5.13 ± 0.11	29.89 ± 3.07	0.438 ± 0.023

Table 6. The content of ash, lipids and macroelements in above-ground parts of the genus *Miscanthus* plants in the stage of seed ripening depending on cultivars

Cultivar, form	Ash, %	Calcium, %	Phosphorus, %	Lipids, m%
MSEK-1	4.56 ± 0.14	0.390 ± 0.020	0.106 ± 0.002	1.073 ± 0.070
MSEK-6	2.99 ± 0.39	0.287 ± 0.025	0.067 ± 0.002	1.010 ± 0.090
MSV	3.36 ± 0.48	0.343 ± 0.015	0.068 ± 0.001	1.140 ± 0.040
MSES-1	2.85 ± 0.23	0.570 ± .030	0.096 ± 0.002	2.047 ± 0.135
MSES-5	3.78 ± 0.48	0.203 ± 0.025	0.063 ± 0.002	1.577 ± 0.485
MSS	2.06 ± 0.14	0.360 ± 0.030	0.104 ± 0.003	0.933 ± 0.095
MGH	3.28 ± 0.25	0.430 ± 0.010	0.072 ± 0.002	1.523 ± 0.040

As reported Jurisic et al. (2015) content of ash of *M. sacchariflorus* was 5 % per dry mass [17]. Gismatulina (2016) investigated that in the period 2011—2015 the content of ash in various organs of *M. sinensis* was variable [3]. All plants characterized by content of ash in range 3.57—6.30 %, leaves — 6.66—11.50 %, and shoots — 2.09—2.96 %. Also, Gismatulina (2015) reported that middle signs of ash were noted for all plant and maximal signs — for leaves [2]. It should be noted that for using plants for biofuel production the best is minimal content of ash in plant raw material. Brosse et al. (2012) reported that in the end of vegetation content of ash for *M. × giganteus* was 2.67—2.74 %, for *M. sacchariflorus* — 2.16—2.29 %, for *M. sinensis* — 3.04—3.19 % [22].

Conclusions

Taking into account the obtained data it should be noted that in conditions of M.M. Gryshko National Botanical Garden of the NAS of Ukraine content of dry matter, total content of sugars of investigated plants of the genus *Miscanthus* increased from tillering stage to seed ripening stage. It is found that content of carotene, ascorbic acid, calcium decreased from tillering to seed ripening stage. The total content of ash decreased to seed ripening phase but not significantly. The level of phosphorus varied during vegetation in investigated plants. Among experimental plants should be noted plants of MSEK-6 with maximal content of ascorbic acid (43.61 mg%), ash (6.11 %), lipids (3.78 %) in the period of tillering. The most content of dry matter was found for plants of MSS (57.80 %) in seed ripening stage, total content of sugars — for MGH (5.13 %) in the same stage, carotene (1.113 mg%) and phosphorus (0.121 %) — for MSV in the tillering and flowering period respectively, calcium — for MSEK-1 (1.070 %) in the tillering period.

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БИОХИМИЧНИЙ СКЛАД СИРОВИНИ РОСЛИН *MISCANTHUS* ANDERSS. В УМОВАХ ІНТРОДУКЦІЇ

Мета — дослідити біохімічні особливості сировини рослин роду *Miscanthus* Anderss. в умовах Національного ботанічного саду імені М.М. Гришка НАН України.

Матеріал та методи. Об'єктами дослідження були сорти та форми видів роду *Miscanthus* Anderss.: *M. sinensis* Anderss. f. ESBMK-1 (MSEK-1), *M. sinensis* f. ESBMK-6 (MSEK-6), *M. sinensis* cv. Veleten (MSV), *M. sacchariflorus* (Maxim.) Benth. f. ESBMTS-1 (MSES-1), *M. sacchariflorus* f. ESBMTS-5 (MSES-5), *M. sacchariflorus* cv. Snihopad (MSS), *M. × giganteus* J.M. Greef & Deuter ex Hodk & Ronvoize cv. Huliver (MGH). Вміст сухої речовини та ліпідів визначали за А.І. Єрмаковим, загальний вміст цукрів та аскорбінової кислоти — за В.П. Крищенком, каротину — за Б.П. Плешковим, золи — за З.М. Грицаєнко, кальцію та фосфору — за Х.М. Починком.

Результати. Протягом вегетації у рослинній сировині видів роду *Miscanthus*, їх сортів та форм накопичувалося сухої речовини від 26,16 % (MSEK-1) до 57,80 % (MSS), цукрів — від 1,27 % (MSES-5) до 5,13 % (MGH), аскорбінової кислоти — від 11,42 mg% (MSES-5) до 43,61 mg% (MSEK-6), каротину — від 0,197 mg% (MSS) до 1,113 mg% (MSV), золи — від 2,06 % (MSS) до 6,11 % (MSEK-6), кальцію — від 0,203 % (MSES-5) до 1,070 % (MSEK-1), фосфору — від 0,023 % (MGH) до 0,121 % (MSV), ліпідів — від 0,933 % (MSS) до 3,780 % (MSEK-6).

Висновки. В умовах Національного ботанічного саду імені М.М. Гришка НАН України рослини роду *Miscanthus* — цінне джерело поживних речовин, найбільший вміст яких спостерігався в період кушіння. Ці рослини можна рекомендувати як поживні компоненти кормів. Вміст сухої речовини та загальний вміст цукрів у досліджуваних рослин роду *Miscanthus* збільшувалися від фази кушіння до фази дозрівання насіння, каротину, аскорбінової кислоти і кальцію — зменшувалися. Загальний вміст золи зменшувався до фази дозрівання насіння незначно. Рівень фосфору змінювався протягом вегетації в усіх досліджуваних рослин.

Ключові слова: *Miscanthus*, рослинна сировина, біохімічні особливості.

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БИОХИМИЧЕСКИЙ СОСТАВ СЫРЬЯ РАСТЕНИЙ *MISCANTHUS* ANDERSS. В УСЛОВИЯХ ИНТРОДУКЦИИ

Цель — исследовать биохимические особенности сырья растений рода *Miscanthus* Anderss. в условиях Национального ботанического сада имени Н.Н. Гришко НАН Украины.

Материал и методы. Объектами исследования были сорта и формы видов рода *Miscanthus*: *M. sinensis* Anderss. f. ESBMK-1 (MSEK-1), *M. sinensis* f. ESBMK-6 (MSEK-6), *M. sinensis* cv. Veleten (MSV), *M. sacchariflorus* (Maxim.) Benth. f. ESBMTS-1 (MSES-1), *M. sacchariflorus* f. ESBMTS-5 (MSES-5), *M. sacchariflorus* cv. Snihopad (MSS), *M. × giganteus* J.M. Greef & Deuter ex Hodk & Ronvoize cv. Huliver (MGH). Содержание сухого вещества и липидов определяли по А.И. Ермакову, общее содержание сахаров и аскорбиновой кислоты — по В.П. Крищенко, содержание каротина — по Б.П. Плешкову, золи — по З.М. Грицаенко, кальция и фосфора — по Х.М. Починку.

Результаты. В течение вегетации в растительном сырье видов рода *Miscanthus*, их сортов и форм накапливалось сухого вещества от 26,16 % (MSEK-1) до 57,80 % (MSS), сахаров — от 1,27 % (MSES-5) до 5,13 % (MGH), аскорбиновой кислоты — от 11,42 mg% (MSES-5) до 43,61 mg% (MSEK-6), каротина — от 0,197 mg% (MSS) до 1,113 mg% (MSV), золи — от 2,06 % (MSS) до 6,11 % (MSEK-6), кальция — от 0,203 % (MSES-5) до 1,070 % (MSEK-1), фосфора — от 0,023 % (MGH) до 0,121 % (MSV), липидов — от 0,933 % (MSS) до 3,780 % (MSEK-6).

Выводы. В условиях Национального ботанического сада имени Н.Н. Гришко НАН Украины растения рода *Miscanthus* — ценный источник питательных веществ, наибольшее содержание которых наблюдали в период кушения. Эти растения можно рекомендовать как питательные компоненты кормов. Содержание сухого вещества и общее содержание сахаров у исследуемых растений рода *Miscanthus* увеличивались с фазы кушения до фазы созревания семян, каротина, аскорбиновой кислоты и кальция — уменьшались. Общее содержание золи уменьшалось до фазы созревания семян незначительно. Уровень фосфора изменялся на протяжении вегетации у всех исследуемых растений.

Ключові слова: *Miscanthus*, растительное сырье, биохимические особенности.