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# BIOCHEMICAL COMPOSITION OF PLANT RAW MATERIAL OF SWEET SORGHUM (*SORGHUM SACCHARATUM* (L.) MOENCH) GENOTYPES

***Objective*** *— to investigate biochemical properties of plant raw material of cultivars and varieties of Sorghum saccharatum (L.) Moench in conditions of M.M. Gryshko National Botanical Garden of the NAS of Ukraine.*

***Material and methods.*** *Investigated plants were cultivars and varieties of Sorghum saccharatum collected in experimental collection of Cultural Flora Department of National Botanical Garden of the NAS of Ukraine: S. saccharatum (SS), S. saccharatum, cv. Botanichnyi (SSB), S. saccharatum, cv. Energodar (SSE), S. saccharatum, cv. Medove (SSM), S. saccharatum, cv. Yantar (SSY), S. saccharatum, f. AMBR-1 (India) (SSA-1), S. saccharatum, f. AMBR-2 (Kazakhstan) (SSA-2), S. saccharatum, f. AMBR-5 (Kazakhstan) (SSA-5).*

*The content of dry matter was determined according to A.I. Yermakov et al. (1972), the total content of sugars and ascorbic acid concentration — according to V.P. Krishchenko (1983), the content of carotene — according to B.P. Pleshkov (1985), the content of ash — according to Z.M. Hrycaenko et al. (2003), the content of calcium and phosphorus — according to H.N. Pochinok (1976). Energetic value of dry plant raw material determined on calorimeter. Content of photosynthetic pigments in leaves detected according to M.M. Musienko et al. (2001).*

***Results.*** *In the period of milky-wax seed ripening the plant raw material of Sorghum saccharatum accumulated dry matter from 21.11 % (SSA-1) to 46.41 % (SSB), total content of sugars — from 8.64 % (SSE) to 28.65 % (SSA-1), ascorbic acid — from 11.39 mg% (SSA) to 35.96 mg% (SSA-2), carotene — from 0.16 mg% (SSE) to 0.92 mg% (SSA-2), ash — from 2.32 % (SSY) to 4.02 % (SSB), calcium — from 0.503 % (SSA-5) to 1.127 % (SS), phosphorus — from 0.037 % (SSY) to 0.148 % (SSM). Energetic value of dry raw was from 2928.77 Cal/g (SSE) to 4075.62 Cal/ g (SSA-5). Ratio of photosynthetic pigments content was 1.26 (SSM) — 6.20 (SSB).*

***Conclusions.*** *Obtained data demonstrated that in conditions of M.M. Gryshko National Botanical Garden of the NAS of Ukraine cultivars and varieties of Sorghum saccharatum are the valuable source of nutrients and biofuel in the period of milky-wax seed ripening. Among investigated genotypes SSB characterized by the most content of dry matter and ash, SSA-1 — total content of sugars, SSA-2 — vitamins, SSA-5 — energetic value.*

**Key words:** *Sorghum saccharatum*, plant raw material, biochemical properties, energy valuation.

Sweet sorghum (*Sorghum saccharatum* (L.) Moench) is a subspecies of sorghum (*Sorghum bicolor* (L.) Moench) developed for its high stalk sugar content rather than for grain production [29]. This warm season tropical grass is reported to be the most widely adapted species among cereal grasses that perform favorably in dry environments [18]. Sorghum is important food crop in many areas of Asia, Africa, and Latin America. In the United States and Argentina sorghum is used primarily as animal feed [25]. Last time numerous reviews about different species of *Sorghum* Moench resulted about active selection work [21; 22; 26]. Sweet sorghum has been identified as a possible ethanol feedstock because of its biomass yield and high concentration of readily fermentable sugars [8; 11; 13; 19; 33]. Feasibility of ethanol production from sweet sorghum juice and bagasse for second generation ethanol production has already been presented in many studies [7; 16; 24; 27; 28].

Kumar et al. (2010) were resulted that *Sorghum saccharatum* (L.) Moench. can be recommended for harvesting at both physiological maturity or post physiological maturity due to high level of sugars [10]. Physiological study on *S. saccharatum*

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showed that these plants can be used as bioindicator of presence of soil residues of herbicides [23]. As reported Rooney (1978), fatty acid composition of sorghum grains its free fatty acids (70—90 %), where palmitic acid was prevalent [25]. Methanol extracts of different species of *Sorghum* showed an antiradical scavenging activity of 31.13—86.48 % [32].

Objective — to evaluate plant raw material of *S. saccharatum* (L.) Moench cultivars and varieties by biochemical characteristics.

## Material and methods

Plant material was collected from the experimental collection of Department of Cultural Flora in M.M. Gryshko National Botanical Garden of the NAS of Ukraine in the milky-wax seed ripening stage: *S. saccharatum* (SS), *S. saccharatum,* cv. Botanichnyi (SSB), *S. saccharatum,* cv. Energodar (SSE), *S. saccharatum,* cv. Medove (SSM), *S. saccharatum,* cv. Yantar (SSY), *S. saccharatum,* f. AMBR-1 (India) (SSA-1), *S. saccharatum,* f. AMBR-2 (Kazakhstan) (SSA-2), *S. saccharatum,* f. AMBR-5 (Kazakhstan) (SSA-5).

All biochemical analyses were conducted using above-ground part of plants in the milky-wax ripening period. The determination of absolutely dry matter was done by drying to constant weight at 100—105 °C according to A.I. Yermakov et al. [3]. The total content of sugars was investigated by Bertrand method in water extracts. The concentration of ascorbic acid (AA) of the acid extracts was 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 [2]. 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 [5]. 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. [1]. 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. These analyses were done according to H.N. Pochinok [6]. Procedure of detection of energetic value was measured on calorimeter IKA-200. I this case, dry plant raw material was burned in oxygen bomb. Measurement of every sample was 15 minutes approximately and expressed in Cal/g. Photosynthetic pigments identified in acetone extracts at 662 nm (chlorophyll *a*), 644 nm (chlorophyll *b*) and 440 nm (carotenoids) using spectrophotometer Unico UV 2800 according to M.M. Musienko [4].

Experimental data were evaluated by using Excel 2010. Mean values of three replicates and standard deviation are given in Tables 1—3.

## Results and discussions

Knowledge of genetic diversity has an important impact on the improvement of crop productivity. Plants from *Poaceae* Barnhart. family well adapted to low input conditions as well as to biotic and abiotic stress factors [14]. Last time carry out investigations of *S. saccharatum* concerning biochemical composition due to ecological properties of these plants. It is relates with drought resistance of plants [30]. We investigated before biochemical composition of some *Poaceae* plants and found that the most content of dry matter and total content of sugars were detected in seed ripening stage [9; 17; 31]. Also, we detected that these plants are potential source of antioxidants [32].

Content of dry matter among investigated plants was in range from 21.11 % (SSA-1) to 46.41 % (SSB) (Tabl. 1).

The knowledge on sugar components at different phenological stages of crop growth and identification of appropriate stage of harvesting is critical for sweet sorghum commercialization and value chain sustenance. Variations in sugar content at different growth stages revealed that the sugar yield was high at physiological maturity, but highest at post-physiological maturity [10]. Compared to other sorghums, sweet sorghum produces less grain but contains a large amount of readily fermentable sugars in the stem. Sweet sorghum stem juice can be used for sugar, syrup, and ethanol production [18].

Accumulation of sugars in plant raw material of *S. saccharatum* plants was in range from 8.64 % (SSE) to 28.65 % (SSA-1). According to Kozłowski et al. (2009), content of sugars in different part of *S. saccharatum* plants was of 37.86 — 142.61 g/kg [12].

Concentration of ascorbic acid was from 11.39 mg% (SSA-5) to 35.96 mg% (SSA-2) and carotene — from 0.16 mg% (SSE) to 0.92 mg% (SSA-2).

As shown in Table 2 the content of ash in plant raw material was from 2.32 % (SSY) to 4.02 % (SSB) (Tabl. 2). Content of calcium was in range from 0.503 % (SSA-5) to 1.127 % (SS), phosphorus —

*Table 1.* **The content of dry matter, total content of sugars and vitamins in above-ground parts of plants of *Sorghum saccharatum* (L.) Moench depending on cultivars and varieties**

| Sample | Dry matter, % | Total content of sugars, % | Ascorbic acid, mg% | Carotene, mg% |
|---|---|---|---|---|
| SS | 30.75 ± 0.07 | 18.31 ± 0.57 | 27.49 ± 1.01 | 0.39 ± 0.01 |
| SSB | 46.41 ± 0.70 | 9.58 ± 0.49 | 18.21 ± 0.21 | 0.45 ± 0.01 |
| SSE | 42.70 ± 0.59 | 8.64 ± 0.58 | 19.96 ± 0.65 | 0.16 ± 0.01 |
| SSM | 30.05 ± 0.18 | 22.45 ± 1.37 | 22.98 ± 1.08 | 0.26 ± 0.02 |
| SSY | 25.54 ± 0.56 | 20.58 ± 1.98 | 13.46 ± 1.55 | 0.20 ± 0.01 |
| SSA-1 | 21.11 ± 0.05 | 28.65 ± 1.44 | 26.05 ± 0.38 | 0.42 ± 0.02 |
| SSA-2 | 29.06 ± 0.46 | 14.05 ± 1.37 | 35.96 ± 1.90 | 0.92 ± 0.02 |
| SSA-5 | 30.77 ± 0.02 | 18.78 ± 1.80 | 11.39 ± 1.31 | 0.26 ± 0.01 |

*Table 2.* **The content of ash, lipids and macroelements in above-ground parts of plants of *Sorghum saccharatum* (L.) Moench depending on cultivars and varieties**

| Sample | Ash, % | Calcium, % | Phosphorus, % | Energetic value, Cal/g |
|---|---|---|---|---|
| SS | 3.78 ± 0.59 | 1.127 ± 0.125 | 0.140 ± 0.007 | 3949.53 ± 55.60 |
| SSB | 4.02 ± 0.30 | 0.733 ± 0.006 | 0.040 ± 0.003 | 3865.88 ± 97.67 |
| SSE | 2.99 ± 0.13 | 0.610 ± 0.020 | 0.090 ± 0.001 | 2928.77 ± 85.70 |
| SSM | 2.50 ± 0.06 | 0.927 ± 0.066 | 0.148 ± 0.003 | 4001.22 ± 88.91 |
| SSY | 2.32 ± 0.09 | 0.727 ± 0.033 | 0.037 ± 0.004 | 3881.14 ± 96.21 |
| SSA-1 | 2.68 ± 0.03 | 0.780 ± 0.017 | 0.095 ± 0.001 | 4039.93 ± 33.80 |
| SSA-2 | 3.42 ± 0.11 | 1.027 ± 0.045 | 0.053 ± 0.004 | 3350.73 ± 79.81 |
| SSA-5 | 2.82 ± 0.23 | 0.503 ± 0.065 | 0.116 ± 0.001 | 4075.62 ± 110.20 |

*Table 3.* **The content of photosynthetic pigments in leaves of plants of *Sorghum saccharatum* (L.) Moench depending on cultivars and varieties, mg/g (fresh weight)**

| Sample | Chlorophyll *a* | Chlorophyll *b* | Carotenoids | Chlorophyll *a*/chlorophyll *b* |
|---|---|---|---|---|
| SS | 0.141 ± 0.002 | 0.025 ± 0.004 | 0.166 ± 0.001 | 5.67 |
| SSB | 0.247 ± 0.034 | 0.040 ± 0.005 | 0.287 ± 0.039 | 6.20 |
| SSE | 0.120 ± 0.008 | 0.053 ± 0.008 | 0.173 ± 0.016 | 2.28 |
| SSM | 0.206 ± 0.004 | 0.163 ± 0.006 | 0.369 ± 0.011 | 1.26 |
| SSY | 0.245 ± 0.002 | 0.061 ± 0.002 | 0.305 ± 0.001 | 4.02 |
| SSA-1 | 0.302 ± 0.004 | 0.104 ± 0.008 | 0.406 ± 0.011 | 2.92 |
| SSA-2 | 0.193 ± 0.003 | 0.036 ± 0.002 | 0.229 ± 0.003 | 5.37 |
| SSA-5 | 0.194 ± 0.005 | 0.054 ± 0.009 | 0.247 ± 0.015 | 3.69 |

from 0.037 % (SSY) to 0.148 % (SSM). Energetic value of dry plant raw material was from 2928.77 Cal/g (SSE) to 4075.62 Cal/g (SSA-5).

As resulted Kozłowski et al. (2009), content of calcium in different organs of *S. saccharatum* was of 3.04—12.05 g/kg, and phosphorus was of 1.16—2.45 g/kg [12]. According to Kozłowski et al. (2007), energetic value of different organs of these plants was 16.63—18.10 MJ [20].

As resulted Faheed et al. (2005), the pigment contents of plants of *S. bicolor* subjected to salt stress via a gradual increase in NaCl concentration, were higher than plants in normal conditions [15].

We determined that ratio of chlorophylls accumulation was in range from 1.26 (SSM) to 6.20 (SSB) (Tabl. 3). These results showed that the less resistance to stress factors of environment can exhibit SS, SSB and SSA-2 plants, where chlorophyll *b* accumulated less than in other plants.

Concentration of chlorophyll *a* was from 0.120 mg/g (SSE) to 0.302 mg/g (SSA-1) and chlorophyll *b* — from 0.025 mg/g (SS) to 0.163 mg/g (SSM). Carotenoids in leaves accumulated in range from 0.166 mg/g (SS) to 0.406 mg/g (SSA-1).

## Conclusions

Based on obtained data, it can be concluded that in conditions of M.M. Gryshko National Botanical Garden of the NAS of Ukraine plants of *S. saccharatum* accumulated nutrients in the stage of milky-wax seed ripening such as dry matter, vitamins, macroelements etc. Maximal content of dry matter and ash was detected in plant raw material of SSB, total content of sugars — in SSA-1, ascorbic acid and carotene — in SSA-2, calcium — in SS, phosphorus — in SSM, energetic value — in SSA-5. Minimal content of dry matter accumulated in plant raw material of SSA-1, total content of sugars, carotene and level of energetic value — in SSE, ascorbic acid — in SSA, ash and phosphorus — in SSY, calcium — in SSA-5. Variable level of sugars (8.64—28.65 %) and calorific value (2928.77—4075.62 Cal/g) allow concluding that selection work with more productive forms should continue.

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## БІОХІМІЧНИЙ СКЛАД РОСЛИННОЇ СИРОВИНИ ГЕНОТИПІВ СОРГО ЦУКРОВОГО (*SORGHUM SACCHARATUM* (L.) MOENCH)

**Мета** — дослідити біохімічні особливості сировини *Sorghum saccharatum* (L.) Moench в умовах Національного ботанічного саду імені М.М. Гришка НАН України.

**Матеріал та методи.** Досліджені рослини — сорти та форми *Sorghum saccharatum*, зібрані на експериментальних ділянках колекції відділу культурної флори Національного ботанічного саду імені М.М. Гришка НАН України: *S. saccharatum* (SS), *S. saccharatum,* cv. Botanichnyi (SSB), *S. saccharatum,* cv. Energodar (SSE), *S. saccharatum,* cv. Medove (SSM), *S. saccharatum,* cv. Yantar (SSY), *S. saccharatum,* f. AMBR-1 (India) (SSA-1), *S. saccharatum,* f. AMBR-2 (Kazakhstan) (SSA-2), *S. saccharatum,* f. AMBR-5 (Kazakhstan) (SSA-5). Вміст сухої речовини у рослин сорго визначали за А.І. Єрмаковим та ін. (1972), загальний вміст цукрів та аскорбінової кислоти — за В.П. Крищенком (1983), вміст каротину — за Б.П. Плешковим (1985), вміст золи — за З.М. Грицаєнко та ін. (2003), вміст кальцію та фосфору — за Х.Н. Починком (1976). Енергетичну цінність рослинної сировини визначали на калориметрі IKA C 200. Вміст фотосинтетичних пігментів у листках — за методикою М.М. Мусієнка та ін. (2001).

**Результати.** В період молочно-воскової стиглості насіння в рослинній сировині *Sorghum saccharatum* накопичувалося сухої речовини від 21,11 % (SSA-1) до 46,41 % (SSB), цукрів — від 8,64 % (SSE) до 28,65 % (SSA-1), аскорбінової кислоти — від 11,39 мг% (SSA) до 35,96 мг% (SSA-2), каротину — від 0,16 мг% (SSE) до 0,92 мг% (SSA-2), золи — від 2,32 % (SSY) до 4,02 % (SSB), кальцію — від 0,503 % (SSA-5) до 1,127 % (SS), фосфору — від 0,037 % (SSY) до 0,148 % (SSM). Енергетична цінність сухої сировини становила від 2928,77 кал/г (SSE) до 4075,62 кал/г (SSA-5). Співвідношення фотосинтетичних пігментів —1,26 (SSM) — 6,20 (SSB).

**Висновки.** Отримані результати свідчать про те, що в умовах Національного ботанічного саду імені М.М. Гришка НАН України досліджувані сорти та форми *Sorghum saccharatum* є цінним джерелом поживних речовин та біопалива в період молочно-воскової стиглості насіння. Серед досліджених генотипів SSB характеризувався найбільшим вмістом сухої речовини та золи, SSA-1 — найбільшим загальним вмістом цукрів, SSA-2 — найбільшим вмістом вітамінів, SSA-5 — найбільшою енергетичною цінністю.

**Ключові слова:** *Sorghum saccharatum*, рослинна сировина, біохімічні особливості, енергетична цінність.

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## БИОХИМИЧЕСКИЙ СОСТАВ РАСТИТЕЛЬНОГО СЫРЬЯ ГЕНОТИПОВ СОРГО САХАРНОГО (*SORGHUM SACCHARATUM* (L.) MOENCH)

**Цель** — исследовать биохимические особенности сырья *Sorghum saccharatum* (L.) Moench в условиях

Национального ботанического сада имени Н.Н. Гришко НАН Украины.

**Материал и методы.** Исследованные растения — сорта и формы *Sorghum saccharatum*, собранные на экспериментальных участках коллекции отдела культурной флоры Национального ботанического сада имени Н.Н. Гришко НАН Украины: *S. saccharatum* (SS), *S. saccharatum,* cv. Botanichnyi (SSB), *S. saccharatum,* cv. Energodar (SSE), *S. saccharatum,* cv. Medove (SSM), *S. saccharatum,* cv. Yantar (SSY), *S. saccharatum,* f. AMBR-1 (India) (SSA-1), *S. saccharatum,* f. AMBR-2 (Kazakhstan) (SSA-2), *S. saccharatum,* f. AMBR-5 (Kazakhstan) (SSA-5). Содержание сухого вещества у растений определяли по А.И. Ермакову и др. (1972), общее содержание сахаров и аскорбиновой кислоты — по В.П. Крищенко (1983), содержание каротина — по Б.П. Плешкову (1985), содержание золы — по З.М. Грицаенко и др. (2003), содержание кальция и фосфора — по Х.Н. Починку (1976). Энергетическую ценность растительного сырья определяли на калориметре. Содержание фотосинтетических пигментов в листьях — по методике Н.Н. Мусиенко (2001).

**Результаты.** В период молочно-восковой спелости семян в растительном сырье *Sorghum saccharatum* накапливалось сухого вещества от 21,11 % (SSA-1) до 46,41 % (SSB), сахаров — от 8,64 % (SSE) до 28,65 % (SSA-1), аскорбиновой кислоты — от 11,39 мг% (SSA) до 35,96 мг% (SSA-2), каротина — от 0,16 мг% (SSE) до 0,92 мг% (SSA-2), золы — от 2,32 % (SSY) до 4,02 % (SSB), кальция — от 0,503 % (SSA-5) до 1,127 % (SS), фосфора — от 0,037 % (SSY) до 0,148 % (SSM). Энергетическая ценность сухого сырья составляла от 2928,77 кал/г (SSE) до 4075,62 кал/г (SSA-5). Соотношение фотосинтетических пигментов — 1,26 (SSM) — 6,20 (SSB).

**Выводы.** Полученные данные свидетельствуют о том, что в условиях Национального ботанического сада имени Н.Н. Гришко НАН Украины сорта и формы *Sorghum saccharatum* являются ценным источником питательных веществ и биотоплива в период молочно-восковой спелости семян. Среди исследованных генотипов SSB характеризовался наибольшим содержанием сухого вещества и золы, SSA-1 — наибольшим общим содержанием сахаров, SSA-2 — наибольшим содержанием витаминов, SSA-5 — наибольшей энергетической ценностью.

**Ключевые слова:** *Sorghum saccharatum*, растительное сырье, биохимические особенности, энергетическая ценность.