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THE ACCUMULATION OF NUTRIENTS IN UNDER-GROUND PARTS OF PLANTS OF THE GENUS *CRAMBE* L. SPP.

Objective *— to study the accumulation of biochemical compounds in the under-ground part of the plants of the genus Crambe L. in the period of early spring in the conditions of M.M. Gryshko National Botanical Garden of the NAS of Ukraine.*

Material and methods. *Plant material of this investigation — Crambe species (Brassicaceae Burnett): C. cordifolia Steven (CCR), C. grandiflora DC. (CGR), C. juncea M.Bieb. (CJR), C. koktebelica (Junge) N. Busch (CKR), C. maritima L. (CMR), C. steveniana Rupr. (CSR), C. tataria Sebeok (CTR). As control were selected plants of Armoracia rusticana P. Gaerth., B. Mey & Scherb (ARR). All biochemical analyses were conducted using the under-ground part of plants in the period of early spring.*

The determination of absolutely dry matter was done according to A.I. Yermakov, total content of sugars, ascorbic acid, content of organic acids, tannins — according to V.P. Krishchenko, level of total ash — according to Z.M. Hrycajenko et al., concentration of calcium and phosphorus — according to H.N. Pochinok, antiradical activity of ethanol and water extracts — according to W. Brandt-Williams et al.

Results. *Obtained data showed that content of dry matter ranged from 16.00 % (CMR) to 22.48 % (CCR), total content of sugar ranged from 11.03 % (CJR) to 46.48 % (CSR), content of ascorbic acid ranged from 192.85 mg% (CSR) to 483.45 mg% (CTR), level of tannins in range from 1.64 % (CGR) to 5.12 % (CJR), content of organic acids ranged from 2.28 % (CSR) to 3.64 % (CJR), content of ash in range from 9.24 % (CSR) to 14.67 % (CJR), level of calcium ranged from 0.76 % (CTR) to 1.37 % (CKR),content of phosphorus varied from 0.57 % (CCR) to 1.33 % (CTR). Antioxidant activity of ethanol extracts was in range from 6.84 % (CGR) to 11.65 % (CTR) and water extracts — from 0.76 % (CGR) to 2.52 % (CCR).*

Conclusions. *It can be concluded that under-ground part of plants of the genus Crambe is rich source of nutrients in the period of early spring. Some investigated species showed higher biological activity in comparison with ARR plants. Comparative analyze of phytochemical content of raw matter demonstrated that under-ground part of investigated plants can be competed with other food plants such as Armoracia rusticana by content of ascorbic acid, total content of sugars, organic acids, ash, macroelements etc. Total antioxidant activity of ethanol extracts of investigated plants demonstrated higher results than water extracts.*

Key words: *Crambe*, dry matter, ascorbic acid, tannins, ash, macroelements, antioxidant activity.

10,000-year-old traces of cultivation give evidence that plants in the family *Brassicaceae* Burnett are among the oldest cultivated plants known. These plants grow under various climatic conditions and accumulate different bioactive compounds that are important for human health, food and animal feed [10, 19, 25]. Cruciferous vegetables (e.g., Chinese cabbage, broccoli, and mustard) are a major food crop contributing to the diet of millions of people and are of significant importance for agricultural economies worldwide. They have been independently domesticated for consumption, industrial products, and medicine in Europe, the Middle East and Asia [16].

One of the most interesting plants of *Brassicaceae* are the genus *Crambe* L. species, that indicate the need for their widespread introduction and investigation due to promising properties such as food, decorative, medicinal etc. [21]. Nowadays has carried out the study with *Crambe* seeds for biodiesel production, mainly due to the high content of oil in it [24]. As reported Wazilewski et al. (2013) the crambe biodiesel is more stable than the soybean biodiesel [26]. Raw material of these plants has an antioxidant activity due to content of phenolic compounds and flavonoids [15]. Plants of the genus *Crambe*, as other species of *Brassicaceae*, contain glucosinolates [20]. Also, Goncalves et al. (2013) identified that the crambe (*Crambe abissinica* Hochst) can be effective in the treat-

ment of wastewater containing toxic metals by being a low cost option and a byproduct that requires no previous treatment [29]. On the other hand, some species of *Crambe* genus is threatened and they require conservation measures [14, 16].

It was interesting to conduct biochemical comparative analyze of these plants with well-known food and medical plants of *Armoracia rusticana* P. Gaerth., B. Mey & Scherb (Horseradish) due to similar pungent smell of roots. Previous data resulted, that horseradish plants contain compounds that can act as natural antioxidants and anti-cancer component [12, 23]. The main aim of this study was to compare the accumulation of biochemical compounds in the under-ground part of the genus *Crambe* L. species and plants of *A. rusticana* in the period of early spring in the conditions of M.M. Gryshko National Botanical Garden of the NAS of Ukraine.

Material and methods

Plant material was collected in M.M. Gryshko National Botanical Garden of the NAS of Ukraine. It was used to investigate plants of *Crambe cordifolia* Steven (CCR), *C. grandiflora* DC. (CGR), *C. juncea* M.Bieb. (CJR), *C. koktebelica* (Junge) N. Busch (CKR), *C. maritima* L. (CMR), *C. steveniana* Rupr. (CSR), *C. tataria* Sebeok (CTR) [3], as control — plants of *Armoracia rusticana* P. Gaerth., B. Mey & Scherb (ARR).

All biochemical analyses were conducted using the under-ground part of plants in the period of early spring (the end of March) to screen accumulation of some nutrients.

The determination of absolutely dry matter was done by drying to constant weight at 100—105 °C according to A.I. Yermakov [5]. 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. Total content of organic acids was identified by titrimetric method with phenolphthalein. Content of tannins was determined by titrimetric method with reaction of indigo carmine discoloration. All these analyses carried out according to V.P. Krischenko [4]. 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. [2]. 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 were done according to H.N. Pochinok [6].

Antioxidant capacity of the ethanolic and aqueous extracts was determined according to W. Brand-Williams et al. (1995) against DPPH radical (2,2-diphenyl-1-picrylhydrazyl) [13]. This method based on reaction of radical discoloration. The procedure of determination of optical density measured with 2800 UV/VIS Spectrophotometer, UNICO at wavelength 515 nm. Optical density of the solution was measured after adding sample immediately and after 10 min of incubation in the dark. Obtained results were calculated in percentage by using formula: $((A_0—A_{10})/A_0) \cdot 100$

(A_0 — absorbance of the control solution (containing only DPPH•); A_{10} — absorbance in the presence of the plant extract in DPPH• solution.

Mean values of three replicates and standard deviations are given in Table 1, 2 and Fig. 1.

Experimental data were evaluated by using Excel 2010.

Results and discussions

In the department of Cultural Flora of National Botanical Garden of the NAS of Ukraine the biochemical research of different *Brassicaceae* representatives have conducted [1, 2, 28]. In this work we compare the biochemical properties of *Armoracia rusticana* (horseradish) and *Crambe* species.

Horseradish has been known since ancient times as a folk medicinal herb and as a plant of nutritional value and culinary interest. The traditions to use horseradish plant for medicinal purpose are still applied in many countries. *A. rusticana* is a rich source of a number of bioactive compounds such as glucosinolates, their breakdown products, phenolic compounds [8, 30]. Also, some studies demonstrated antimicrobial, antifungal, anti-inflammatory and antioxidant activity

of horseradish extracts [8, 9, 31]. Likewise, Cirimbei et al. (2013) reported that horseradish root is rich in vitamin C, B_1, minerals (iron, potassium, calcium, magnesium) [27]. According to Ciska et al. (2017), glucoraphanin, glucoraphenin and napoleiferin were noted for the first time in the tissues of horseradish [18].

As shown in Table 1 dry matter of investigated plants of the genus *Crambe* was in range from 16.00 % (CMR) to 22.48 % (CCR). Control sample of ARR showed significant difference in the content of dry matter if compare with the genus *Crambe* species by 14.49—20.97 %. Content of dry matter in under-ground part increased in the following order: CMR > CSR > CKR > CJR > CGR > CTR > CCR > ARR. Total content of sugar was in range from 11.03 % (CJR) to 46.48 % (CSR) and plants of ARR showed accumulation of sugars 20.29 %. Under-ground part of ARR has accumulated total content of sugar on 26.19, 24.12, 13.47 and 1.72 % less than samples CSR, CMR, CTR and CGR respectively. Total content of sugars in under-ground part increased in following order: CJR > CCR > ARR > CKR > CGR > CTR > CMR > CSR.

It should be noted that the content of ascorbic acid was ranged from 192.85 mg% (CSR) to 483.45 mg% (CTR). Obtained result for ARR plants was 316.51 mg%. Level of ascorbic acid in samples CTR, CMR, CCR was more than in control sample and difference was 166.94, 99.83 and 36.47 mg% respectively. Accumulation of ascorbic acid was increased in following order: CSR > CKR > CGR > CJR > ARR > CCR > CMR > CTR.

It was observed that level of tannins was in range from 1.64 % (CGR) to 5.12 % (CJR) while under-ground parts of ARR plants accumulated the smallest amount of tannins (0.42 %) among investigated plants. Level of tannins was identified in following order from minimal to maximum: ARR > CGR > CCR > CTR > CKR > > CSR > CMR > CJR.

Table 1. **The content of dry matter, vitamins, tannins and total content of sugar in under-ground parts of plants of the genus *Crambe* L.**

Sample	Dry matter, %	Total content of sugar, %	Ascorbic acid, mg%	Total content of tannins, %
CCR	22.48 ± 1.72	17.92 ± 1.80	352.98 ± 6.93	2.48 ± 0.29
CGR	21.34 ± 1.11	22.01 ± 1.14	220.87 ± 7.61	1.64 ± 0.31
CJR	19.71 ± 0.51	11.03 ± 0.54	305.08 ± 8.25	5.12 ± 0.52
CKR	19.54 ± 0.63	20.50 ± 1.84	207.85 ± 8.32	4.76 ± 0.34
CMR	16.00 ± 0.72	44.41 ± 2.04	416.34 ± 10.16	5.09 ± 0.42
CSR	16.52 ± 0.19	46.48 ± 0.45	192.85 ± 3.94	4.93 ± 0.41
CTR	22.05 ± 0.43	33.76 ± 0.48	483.45 ± 2.95	3.52 ± 0.31
ARR	36.97 ± 0.18	20.29 ± 0.67	316.51 ± 8.79	0.42 ± 0.18

Table 2. **The content of ash, macroelements and total content of organic acids in under-ground parts of plants of the genus *Crambe* L., %**

Sample	Total content of organic acids	Ash	Calcium	Phosphorus
CCR	3.32 ± 0.27	10.53 ± 0.54	1.09 ± 0.11	0.56 ± 0.01
CGR	3.61 ± 0.12	11.52 ± 1.10	0.89 ± 0.04	1.63 ± 0.02
CJR	3.64 ± 0.15	14.67 ± 1.31	1.18 ± 0.07	1.61 ± 0.07
CKR	3.19 ± 0.27	14.44 ± 1.68	1.37 ± 0.08	0.64 ± 0.03
CMR	4.00 ± 0.13	11.47 ± 0.83	1.36 ± 0.06	0.63 ± 0.04
CSR	2.28 ± 0.28	9.24 ± 0.59	0.92 ± 0.07	0.92 ± 0.02
CTR	3.59 ± 0.05	9.64 ± 0.03	0.76 ± 0.04	1.33 ± 0.04
ARR	2.50 ± 0.07	5.86 ± 0.37	0.74 ± 0.05	0.98 ± 0.02

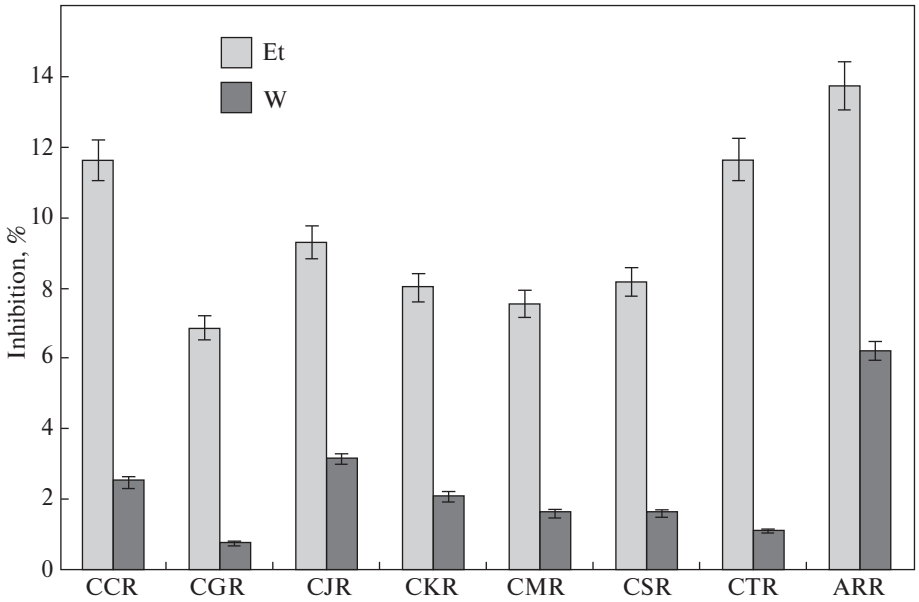

Fig. 1. Antioxidant activity of ethanol and water extracts of plants of the genus *Crambe* L. (%): Et — etanol extracts; W — water extracts

Total content of organic acids was ranged from 2.28 % (CSR) to 3.64 % (CJR) while ARR plants had similar sign to CSR plants (2.50 %) (Table 2). Samples of CTR, CMR, CKR, CJR, CGR, CCR contained more organic acids than control sample. Concentration of total organic acids increased in investigated plants in following order: CSR > ARR > CKR > CCR > CTR > CGR > CJR > > CMR.

Content of ash was in the range from 9.24 % (CSR) to 14.67 % (CJR) and increased in following order: ARR > CSR > CTR > CCR > CMR > CGR > CKR > CJR. Level of calcium was ranged from 0.76 % (CTR) to 1.37 % (CKR) and increased in following order: ARR > CTR > CGR > CSR > > CCR > CJR > CMR > CKR. Content of ash and calcium in control plants was less relatively investigated plants of *Crambe*. Content of phosphorus varied from 0.56 % (CCR) to 1.33 % (CTR). Plants of CGR, CJR and CTR contained more phosphorus than plants of ARR. Concentration of phosphorus in investigated plants increased in following order: CCR > CMR > CKR > CSR > ARR > CTR > > CJR > CGR.

We were interested to measure the antiradical capacity of different extracts of investigated plants (Fig. 1). It was chosen ethanol and aqueous extracts for experiment only. In classic investigation of antioxidant activity, it is customary to determine inhibition of DPPH radical in the methanol extracts also [13]. We proceeded from the fact that plants *A. rusticana* are used as food plants with numerous properties for human healthy [12]. Previous data on antioxidant capacity of extracts of leaves and under-ground parts of horseradish showed strong activity [22]. The purpose of this study was to compare biochemical capacity of plants of *Crambe* and *A. rusticana* to recommend it for possible use.

Figure 1 demonstrates antioxidant activity of plant extracts of *Crambe* species and ARR. Generally, ethanol extracts of investigated plants showed inhibition of DPPH radical solution more than water extracts. Antioxidant activity of ethanol extracts was ranged of 6.84 % (CGR) to 11.65 % (CTR) whereas ethanol extracts of ARR plants showed inhibition by 13.75 %. Antioxidant capacity of water extracts for plants of the genus *Crambe* was ranged from 0.76 % (CGR) to 2.52 % (CCR). This result was less than for ARR control plants. Minimal results were obtained for CGR plant extracts, and inhibition index of ethanol extract was

9 times more than water extracts. The highest index was marked for CTR plants (ethanol extracts) and CCR plants (water extracts). Difference between maximal indexes of different extracts was in 4.6 times more for ethanol solutions. According to Tomsone et al. (2012) the scavenging activity of DPPH radical of root extracts of *A. rusticana* ranged from 1.16 to 20.56 % depending from variety [23]. Analyzed water extract of AAR showed DPPH free radical scavenging activity of 46.22 % as reported Istrati et al. (2013) [17].

Conclusions

This is the study providing results on biochemical properties of under-ground parts of plants of the genus *Crambe* L. Study showed that plant raw material of investigated plants are valuable source of nutrients such as dry matter, vitamin C, tannins, macroelements, ash, organic acid in early spring. Comparative analysis between investigated plants and plants of *Armoracia rusticana* demonstrated that in under-ground part of *A. rusticana* content of dry matter was the highest. Plants of *Crambe* prevailed in content of ash and calcium. Summarizing obtained data, it can be noted that investigated plants even after winter period are able to accumulate nutrients such as vitamins, macroelements, soluble sugars, tannins etc.

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НАКОПИЧЕННЯ ПОЖИВНИХ РЕЧОВИН У ПІДЗЕМНІЙ ЧАСТИНІ РОСЛИН ВИДІВ РОДУ *CRAMBE* L.

Мета — дослідити накопичення біохімічних речовин у підземній частині видів роду *Crambe* L. у ранньовесняний період в умовах Національного ботанічного саду імені М.М. Гришка НАН України.

Матеріал та методи. Рослинний матеріал цього дослідження — види роду *Crambe* L. (*Brassicaceae* Burnett.): *C. cordifolia* Steven (CCR), *C. grandiflora* DC. (CGR), *C. juncea* M.Bieb. (CJR), *C. koktebelica* (Junge) N. Busch (CKR), *C. maritima* L. (CMR), *C. steveniana* Rupr. (CSR), *C. tataria* Sebeok (CTR). Рослини *Armoracia rusticana* P. Gaerth., B. Mey & Scherb (ARR) слугували контролем. Для всіх біохімічних аналізів використовували підземну частину рослин у ранньовесняний період. Абсолютно суху масу визначали за А.І. Єрмаковим, загальний вміст цукрів, рівень аскорбінової кислоти, органічних кислот, дубильних речовин — за В.П. Крищенком, загальний вміст золи — за З.М. Грицаєнко, вміст кальцію та фосфору — за Х.Н. Починком, антирадикальну активність етанольних та водних екстрактів — за W. Brandt-Williams et al.

Результати. Встановлено, що вміст сухої речовини становив від 16,00 % (CMR) до 22,48 % (CCR), загальний вміст цукрів — від 11,03 % (CJR) до 46,48 % (CSR), вміст аскорбінової кислоти — від 192,85 мг% (CSR) до 483,45 мг% (CTR), дубильних речовин — від 1,64 % (CGR) до 5,12 % (CJR), органічних кислот — від 2,28 % (CSR) до 3,64 % (CJR), золи — від 9,24 % (CSR) до 14,67 % (CJR), кальцію — від 0,76 % (CTR) до 1,37 % (CKR), фосфору — від 0,57 % (CCR) до 1,33 % (CTR). Антиоксиданта активність етанольних екстрактів становила від 6,84 % (CGR) до 11,65 % (CTR), водних — від 0,76 % (CGR) до 2,52 % (CCR).

Висновки. Підземна частина рослин видів роду *Crambe* L. — цінне джерело поживних речовин у ранньовесняний період. Деякі з досліджуваних рослин виявили вищу біологічну активність порівняно з рослинами *Armoracia rusticana*. Порівняльний аналіз фітохімічного складу сировини показав, що досліджувані рослини можуть конкурувати з іншими харчовими рослинами, наприклад, з *Armoracia rusticana*, за загальним вмістом аскорбінової кислоти, цукрів, органічних кислот, золи, мікроелементів тощо. Загальна антиоксидантна активність етанольних екстрактів досліджуваних рослин була вищою, ніж водних.

Ключові слова: *Crambe*, суха речовина, аскорбінова кислота, дубильні речовини, зола, макроелементи, антиоксидантна активність.

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НАКОПЛЕНИЕ ПИТАТЕЛЬНЫХ ВЕЩЕСТВ В ПОДЗЕМНОЙ ЧАСТИ РАСТЕНИЙ ВИДОВ РОДА *CRAMBE* L.

Цель — исследовать накопление биохимических веществ в подземной части видов рода *Crambe* L. в ранневесенний период в условиях Национального ботанического сада имени Н.Н. Гришко НАН Украины.

Материал и методы. Растительный материал данного исследования — виды рода *Crambe (Brassicaceae* Burnett.*): C. cordifolia* Steven (CCR), *C. grandiflora* DC. (CGR), *C. juncea* M.Bieb. (CJR), *C. koktebelica* (Junge) N. Busch (CKR), *C. maritima* L. (CMR), *C. steveniana* Rupr. (CSR), *C. tataria* Sebeok (CTR). Растения *Armoracia rusticana* P. Gaerth., B. Mey & Scherb (ARR) служили контролем. Для всех биохимических анализов использовали подземную часть растений в ранневесенний период. Абсолютно сухую массу определяли по А.И. Ермакову, общее содержание сахаров, уровень аскорбиновой кислоты, органических кислот, дубильных веществ — по В.П. Крищенко, общее содержание золы — по З.М. Грицаенко, содержание кальция и фосфора — по Х.Н. Починку, антиради-

кальную активность этанольных и водных экстрактов — по W. Brandt-Williams et al.

Результаты. Установлено, что содержание сухого вещества составило от 16,00 % (CMR) до 22,48 % (CCR), общее содержание сахаров — от 11,03 % (CJR) до 46,48 % (CSR), содержание аскорбиновой кислоты — от 192,85 мг% (CSR) до 483,45 мг% (CTR), дубильных веществ — от 1,64 % (CGR) до 5,12 % (CJR), органических кислот — от 2,28 % (CSR) до 3,64 % (CJR), золы — от 9,24 % (CSR) до 14,67 % (CJR), кальция — от 0,76 % (CTR) до 1,37 % (CKR), фосфора — от 0,57 % (CCR) до 1,33 % (CTR). Антиоксидантая активность этанольных екстрактов составляла от 6,84 % (CGR) до 11,65 % (CTR), водных — от 0,76 % (CGR) до 2,52 % (CCR).

Выводы. Подземная часть растений видов рода *Crambe* — ценный источник питательных веществ в ранневесенний период. Некоторые из исследованных растений продемонстрировали более высокую биологическую активность по сравнению с растениями *Armoracia rusticana*. Сравнительный анализ фитохимического состава сырья показал, что исследованные растения могут конкурировать с другими пищевыми растениями, например, с *Armoracia rusticana*, по общему содержанию сахара, аскорбиновой кислоты, органических кислот, золы, макроелементов и т.д. Общая антиоксидантная активность этанольных экстрактов исследуемых растений была выше, чем водных.

Ключевые слова: *Crambe*, сухое вещество, аскорбиновая кислота, дубильные вещества, зола, макроелементы, антиоксидантная активность.