UDC 577.19:582.661.21

Biologically Active Substances of Amaranth (*Amaranthus* L.) from the Collection of the Institute of Cytology and Genetics of the SB RAS (Novosibirsk)

G. I. VYSOCHINA[1], T. A. KUKUSHKINA[1], N. B. ZHELEZNOVA[2] and A. V. ZHELEZNOV[2]

[1]*Central Siberian Botanical Garden, Siberian Branch of the Russian Academy of Sciences, Ul. Zolotodolinskaya 101, Novosibirsk 630090 (Russia)*

E-mail: vysochina_galina@mail.ru

[2]*Institute of Cytology and Genetics, Siberian Branch of the Russian Academy of Sciences, Pr. Akademika Lavrentyeva 10, Novosibirsk 630090 (Russia)*

(Received April 14, 2012; revised April 24, 2012)

Abstract

The content of biologically active substances (flavonols, catechins, tannins, carotenoids) was studied for 45 samples of amaranth (*Amaranthus* L.) of different geographical origin, grown at the experimental plot of the Institute of Cytology and Genetics of the SB RAS (Novosibirsk). Amaranth leaves contain up to 3.2 % of flavonols, 0.33 % of catechins, 10.7 % of tannins, 101.4 mg% of carotenoids, whereas the flowers contain up to 3.1, 0.19, 11.3 %, and 32.3 mg %, respectively. A significant variation in the characteristics under testing has been revealed, which allows one to carry out the selection for increasing the content of either substance, and to use available species as feedstock sources.

Key words: flavonols, catechins, tannins, carotenoids, amaranth *Amaranthus* L.

INTRODUCTION

Amaranth (genus *Amaranthus* L., family Amaranthaceae) contains about 75 species, occurring in warm temperate zones of the world [1]. In South America, the home of amaranth, there is the greatest number of species, varieties and forms of this plant. A plenty of representatives of the genus is dwelling in North America, India and China. Amaranth represents a valuable cereal, vegetable, fodder, ornamental and technical culture with thousand-year history, known since the ancient Incas, Aztecs and Mayans. In Europe, amaranth was grown as an ornamental plant, and only since the beginning of the XVIII century agrarians began to cultivate grain. In Asia, amaranth became popular as a cereal and vegetable culture among the hill tribes of India, Pakistan, Nepal, and China [2].

Amaranth is a new multi-use culture for Siberia. The grain thereof could be used for obtaining flour, starch, bran, oil. It is used in the food and pharmaceutical industries, since it contains a complex of biologically active compounds. The grain of amaranth contains 18 % of protein and 5–7 % of fat. More than a half of the protein is presented by albumin and globulins with a balanced amino acid composition. The fat basically consists of unsaturated fatty acids, the lipid fraction involves up to 10 % hydrocarbon squalene [3, 4]. Some species of amaranth are promising as fodder crop [5]. Amaranth is rich in substances of secondary origin those determine its medicinal properties. Numerous pharmacological studies demonstrated that different types of amaranth exhibit hepatoprotective [6], radioprotective [7, 8], anti-inflammatory, antipyretic, antihepatotoxic [9, 10], antidiabetic, antihyperlipidemic, sper-

matogonia [11, 12], antiproliferative, antifungal [13, 14] and other actions. The leaves of amaranth contain flavonoids quercetin, trefolin and rutin (3 %) [15]. As far as the aerial part is concerned, the content of pectins therein amounts up to 10 %; pectins within grain are presented in the form of insoluble protopectin [16].

Of great value is amaranth oil, capable of adjusting the level of unsaturated fatty acids in the blood [17], of inhibiting tumour growth, of positive effect exerted on atherosclerosis, heart diseases and hypertension [18, 19]. Amaranth oil is patented as an immunostimulatory agent for the correction of immunodeficiency states [20]. Owing to a high content of fatty acid esters (6 %) and polyphenols (6.5 %) therein those exhibit antioxidant activity, amaranth is recommended for use as an antioxidant in the dairy and bakery industries [21], as well as for the preparing of specialty products for people suffering from diabetes, allergies, celiac disease [22–24].

The aim of the present work consisted in assessing the species and lines of amaranth presented in the collection of the Institute of Cytology and Genetics of the SB RAS with respect to the content of biologically active substances (flavonols, catechins, tannins, carotenoids).

MATERIALS AND METHODS

As the objects for investigation we chose 11 species of amaranth, 10 samples of indeterminate species and 11 lines of *A. hypochondriacus*, grown annually at the experimental plot of the Institute of Cytology and Genetics of the SB RAS near Novosibirsk (Akademgorodok). Samples for biochemical studies (leaves and inflorescences) were harvested at the flowering stage of the plants in 2009 and 2010.

The quantification of flavonols was performed by means of a technique based on approach [25] with the use of a complexation reaction between aluminum chloride and flavonols. Catechins were determined by means of spectrophotometric method [26], tannins (tanning agent) were analyzed by titrimetric method [27]. The sum of carotenoids was determined spectrophotometrically in an acetone-ethanol extract at the wavelengths of 450 and 550 nm [28].

All the biochemical parameters were calculated for the mass of oven-dry raw material. The results represent the mean of three replicates for each parameter.

RESULTS AND DISCUSSION

The content of flavonols, catechins, tannins and carotenoids in the leaves and inflorescences of plants was studied for the following species: *Amaranthus caudatus* L., *A. mangostanus* L., *A. cruentus* L. (Syn. *A. paniculatus* L.), *A. bouchjnii* Thell., *A . edulis* L., *A. aureus* L., *A. deflexus* L., *A. gangeticus* l., *A. powellis* L., *A. mantegazzianus* Passerini, *A. hybridus* L. The level of knowledge concerning these species is different. Researchers paid more attention to such species as *A. caudatus*, *A. cruentus*, *A. gangeticus*, *A. hybridus*; other species are poorly understood.

A. caudatus is widely distributed in the mountains of Argentina, Peru and Bolivia, wherefrom it was brought to North America, India, China and other countries. It is cultivated for grain, and therefore it is called «wheat of Incas» [2]. The aboveground part and roots of *A. caudatus* are rich in biologically active substances. In the course of studying the leaves, roots, stems, inflorescences there were compounds detected belonging to four classes such as carbohydrates, polyprenols, sterols, and triterpenols [29]. Methanol extract of leaves served as a base for isolation seven triterpene saponins [30]. In plants *A. caudatus*, *A. paniculatus* and *A. hypochondriacus* cultivated in Slovakia there were flavonoids found (0.29–0.75 %, for dry solid matter), carotenoids, tannins and saponins [31]. From the flowers of *A. caudatus* one isolated two new flavonoids such as 3,5,7-trihydroxy-6-methyl-4′-metoxydihydroflavonol and 5,7-dihydroxy-8-methyl-4′-metoxyflavanone, as well as well-known substances 5,7-dihydroxy-8-methyl-4′-methoxyisoflavone and kaempferide [32].

Leaves can serve as a source of red pigment amarantin, a valuable food dye [33]. The presence of biologically active substances in different plant organs of *A. caudatus* is associated with a high antioxidant activity thereof [34–36]. According to our data, the leaves and inflorescences of *A. caudatus* contain 0.6–1.7 %

and 0.2–1.8 % of flavonols, respectively, and for the most of samples the content in leaves is higher than the content in flowers (Table 1). As far as the content of flavonols is concerned, the best sample is *A. caudatus* 110079 with a bright red, almost crimson inflorescence (about 2.0 % of flavonols in the leaves and flowers). The content of catechins in the leaves and in flowers is equal to 0.08–0.27 % and 0.04–0.12 %, respectively. In all the samples, the leaves accumulate them almost twice as much as the inflorescences. A higher content of catechins was found in samples Nos. 11015, 11023, 11033 and 11048. The content of tannins in the leaves and in the inflorescences ranges within 3.2–9.1 and 3.6–7.5 %, respectively. The amount of tannins is greater in samples Nos. 11047, 11048, 11033, 11015 and 11078. The ranges of varying the content of carotenoids in the leaves and in the inflorescences of *A. caudatus* of different origin amount to 8.0–54.0 and 3.7–10.9 %, respectively. The highest content of carotenoids is observed in the samples Nos. 11020 and 11078.

A. cruentus (Syn. *A. paniculatus*) originates from the mountainous regions of Mexico. It is cultivated in Central America, China, India, Burma, and other Asian countries. This species is characterized by beautiful bright red or dark cherry-coloured inflorescences.

In the above-ground parts of plants of this species found phenolic compounds [37], two coumarins such as umbelliferone and scopoletin, chromone derivative piliostigmin three flavonoids such as 8-di-C-methylquercetin-3-Meester, eucalyptin and gnaphalin [38], four new triterpenoid glycosides [39]. Betacyanines contained in bright inflorescences could be used as naturally occurring colorants in the production of jelly, ice cream, beverages with high pH value [40]. The authors of [41] evaluated the content of the protein fraction, oil and squalene in seeds. Basing on a high content of carotenoids, proteins, minerals, vitamin C, amino acids lysine and methionine the authors of [8, 42, 43] determined the antioxidant, radioprotection and radical-binding activity of the extract made of the aerial parts of *A. cruentus*.

In the leaves of plants *A. cruentus* there were earlier found: protein (17.9–20.0 %), ascorbic acid (38.0–40.1 mg %), carotene (ACB) (2.4–4.5 mg %), sugars in the aerial part (1.0–2.9 %) [2]. According to our data, in leaves and flowers contain 0.8–1.0 % of flavonols, whereas the leaves contain 0.21–0.33 % of catechins, *i. e.*, two times more than it does in the flowers. The tannin content in the leaves and in the inflorescences ranges from 6.5 to 8.4 % and from 7.5 to 7.8 %, respectively. According to the amount of carotenoids in leaves the two samples of *A. cruentus* under investigated differ to a considerable extent: sample No. 11045 contains nearly five times more carotenoids than sample No. 11014, whereas the carotenoid content in the flowers is almost identical (see Table 1).

A. hybridus is widely distributed in South America. The local population uses it as an ornamental and vegetable plant. It is naturally occurring in the Caucasus, in the Crimea, in the Baltic States. The chemical composition of plants *A. hybridus* growing in Africa was investigated in detail by the authors of [44]. They found that the leaves contain nutrients, minerals, vitamins, amino acids in significant amounts. The content of secondary metabolites was as it follows (mg/100 g): alkaloids 3.54, flavonoids 0.83, saponins 1.68, tannins 0.49, phenols 0.35, hydrocyanic acid 16.22, phytic acid 1.32. In the grains of *A. hybridus* there were caffeic, ferulic, *p*-coumaric, *p*-hydroxybenzoic and protocatechuic acids revealed [45]. In the leaves of *A. hybridus* (sample No. 11083), we have found a great amount of carotenoids (59.2 mg%), as well as flavonols. catechins and tannins have been revealed (see Table 1).

A. tricolor (Syn. *A. gangeticus*) is annual plant. It grows mainly in Southeast Asia, Africa, China, and India. It is often used as an ornamental and food plant. In the regions of Central Asia it grows as a weed. In connection with the possibility of using *A. tricolor* in the diet, researchers pay attention to the chemical composition of its leaves. They revealed that in the leaves there is a high content of carotene (46.55 mg/g), vitamin C (151.2 mg/100 g), polyphenols, which determines a significant antioxidant activity and radioprotective effect thereof [7, 46, 47]. According to our data, the leaves contain a lot of carotene (48.1 mg%), 0.6 % of flavonols, 0.13 % of catechins and 6.5 % of tannins. The inflorescences have these substances is smaller amounts than the leaves.

TABLE 1

Content of biologically active substances in the amaranth plants of different species and inbred lines grown at the collection plot of the ICG of the SB RAS

Sample, seed origin	Organ	Flavonols, %	Catechins, %	Tannins, %	Carotenoids, mg%
A. caudatus	Leaves	0.6	0.16	8.33	8.0
11003 Russia	Inflorescences	0.3	0.09	5.11	10.9
A. caudatus	Leaves	0.8	0.27	8.2	28.5
11015 Gana	Inflorescences	1.0	0.11	7.5	7.1
A. caudatus	Leaves	0.8	0.13	4.5	46.9
11020 Mali	Inflorescences	0.7	0.06	3.6	n/d
A. caudatus	Leaves	0.7	0.26	9.1	20.2
11033 Belgium	Inflorescences	0.4	0.12	4.2	7.8
A. caudatus	Leaves	1.2	0.27	9.0	13.1
11048 Russia	Inflorescences	0.4	0.11	5.7	8.3
A. caudatus	Leaves	1.3	0.11	3.2	24.6
11064 Hungary	Inflorescences	0.3	0.04	5.6	n/d
A. caudatus	Leaves	1.7	0.15	7.7	54.0
11078 Russia	Inflorescences	1.8	0.07	6.6	n/d
A. caudatus	Leaves	0.6	0.08	6.3	28.6
11079 Russia	Inflorescences	0.3	0.05	2.1	n/d
A. caudatus	Leaves	0.9	0.22	9.1	15.6
11047 Ukraine	Inflorescences	0.2	0.08	4.3	4.4
A. caudatus	Leaves	0.6	0.26	6.7	27.5
11023 Poland	Inflorescences	0.2	0.11	4.8	3.7
A. cruentus	Leaves	0.8	0.21	6.5	7.6
11014 Kazakhsta	Inflorescences	0.8	0.09	7.8	8.0
A. cruentus	Leaves	0.8	0.33	8.4	39.1
11045 India	Inflorescences	1.0	0.16	7.5	9.4
A. gangeticus	Leaves	0.6	0.13	6.5	48.1
11061 India	Inflorescences	0.4	0.06	5.0	H. o.
A. deflexus	Leaves	0.5	0.09	6.6	46.4
11057 Germany	Inflorescences	n/d	n/d	n/d	n/d
A. bouchoni	Leaves	1.5	0.32	7.2	52.7
11027Germany	Inflorescences	0.4	0.09	7.6	4.1
A. edulis	Leaves	3.2	0.11	6.1	26.8
11072 Russia	Inflorescences	0.6	0.03	4.0	n/d
A. edulis	Leaves	1.2	0.27	5.9	52.4
11030 Ghana	Inflorescences	1.5	0.19	10.0	10.4
A. edulis	Leaves	3.2	0.10	6.0	28.4
11070 Argentina	Inflorescences	0.4	0.02	4.0	n/d
A. powellis	Leaves	1.4	0.13	5.8	14.4
11065 Greece	Inflorescences	0.9	0.06	6.0	n/d
A. powellis	Leaves	1.1	0.08	6.6	48.9
11066 Czech	Inflorescences	0,8	0.05	5.8	n/d
A. angostanus	Leaves	1.0	0.17	6.7	14.4
11009 China	Inflorescences	1.0	0.12	6.3	13.3
A. aureus	Leaves	0.7	0.30	5.4	31.1

TABLE 1 (END)

Sample, seed origin	Organ	Flavonols, %	Catechins, %	Tannins, %	Carotenoids, mg%
11093 Moldova	Inflorescences	1.5	0.11	5.9	13.0
11011*	Leaves	1.7	0.22	6.6	7.6
Canada	Inflorescences	0.9	0.07	4.2	9.0
11029*	Leaves	1.8	0.31	9.0	63.7
Italy	Inflorescences	0.9	0.18	7.0	21.8
11035*	Leaves	1.4	0.23	5.7	22.0
Ghana	Inflorescences	1.5	0.19	8.2	9.2
11044	Leaves	2.4	0.28	10.7	26.3
India	Inflorescences	0.2	0.13	3.6	7.9
11046*	Leaves	1.8	0.28	6.4	22.9
India	Inflorescences	1.5	0.15	5.9	9.5
11051*	Leaves	1.3	0.03	7.1	28.3
Tanzania	Inflorescences	1.0	0.14	7.8	7.3
11053*	Leaves	2.3	0.26	6.4	101.4
Guinea	Inflorescences	1.0	012	6.0	9.8
11054*	Leaves	0.7	0.24	8.9	60.5
India	Inflorescences	0.6	0.13	7.7	32.3
11076*	Leaves	2.1	0.11	9.3	64.2
India	Inflorescences	1.7	0.07	7.4	n/d
11077*	Leaves	1.5	0.17	6.3	49.5
India	Inflorescences	3.1	0.10	11.3	n/d
11040*	Leaves	0.7	0.10	4.7	19.1
the Netherlands	Inflorescences	1.1	0.06	4.2	n/d
11083*	Leaves	1.0	0.14	4.3	59.2
Germany	Inflorescences	0.9	0.07	5.5	n/d
A. hypochondriacus,	Leaves	0.9	0.15	4.7	74.0
Line 787	Inflorescences	1.5	0.10	6.0	n/d
the same, line 788	Leaves	2.7	0.24	6.4	24.4
	Inflorescences	1.8	0.09	4.8	n/d
the same, line 800	Leaves	2.6	0.17	7.6	68.3
	Inflorescences	1.6	0.09	4.7	n/d
the same, line 801	Leaves	2.0	0.24	10.1	60.3
	Inflorescences	1.3	0.11	3.1	n/d
the same, line 802	Leaves	2.1	0.15	5.2	59.5
	Inflorescences	1.9	0.06	5.6	n/d
the same, line 803	Leaves	1.4	0.11	6.2	75.7
	Inflorescences	1.9	0.10	4.2	n/d
the same, line 805	Leaves	1.0	0.18	4.6	59.2
	Inflorescences	1.6	0.08	6.3	n/d
the same, line 806	Leaves	1.3	0.16	4.3	71.0
	Inflorescences	1.8	0.10	6.6	n/d
the same, line 807	Leaves	1.6	0.18	5.2	31.9
	Inflorescences	2.1	0.09	6.2	n/d
the same, line 808	Leaves	1.1	0.17	2.6	44.3
	Inflorescences	1.4	0.08	3.0	n/d
the same, line 798	Leaves	1.9	0.16	7.1	78.9
	Inflorescences	1.8	0.06	3.4	n/d

Note. n/d – not determined.
* Species is not defined.

Not all the amaranth species are well studied. The collection of the ICG of the SB RAS presents a number of amaranth species *A. aureus*, *A. bouchjnii*, *A. deflexus*, *A. edulis*, *A. mangostanus*, *A. mantegazzianus*, *A. powellis*, with almost no biochemical information available. The only exception is presented by paper [2], whose authors revealed that in the leaves and aerial parts of the plants of the mentioned species contain 15.4–25.9 % of protein, 1.0–9.4 % of sugar, 25–63 mg% ascorbic acid, 1.4–8.2 mg% carotene (ABC). According to our data, the leaves of these species contain 0.5–3.2 % of flavonols, 0.08–0.32 % of catechins, 5.4–7.2 % of tannins and 14.4–52.7 % mg of carotenoids; in florescences 0.4–1.5 % flavonols, 0.02–0.19 % catechins, 4.0–10.0 % tannins, 4.1–13.3 mg % of carotenoids, *i. e.*, the leaves contain biologically active substances twice as much as the inflorescences. According to the content of flavonols we indicate *A. edulis* and *A. mantegazzianus*, the content of catechins – *A. bouchjnii*, *A. edulis* and *A. aureus*, the content of tannins – *A. bouchjnii*, *A. edulis* and *A. mangostanus*, the content of carotenoids *A. bouchjnii*, *A. edulis* and *A. powellis*. Thus, a special attention should be paid to plant species *A. bouchjnii* and *A. edulis*, as potential sources of biologically active substances.

The collection also presents the plants of amaranth whose specific name is not defined, but they are of great interest due to a high crop capacity of green mass and seeds. This material exhibits a great potential as a possible source of biologically active substances. Noteworthy are the leaves of samples Nos. 11044, 11046, 11053, 11076 containing up to 2.4 % of flavonols, samples Nos. 11029, 11044, 11046 containing up to 0.31 % of catechins, samples Nos. 11029, 11044, 11054, 11076 containing up to 10.7 % tannins, samples Nos. 11029, 11053, 11054, 11076 containing up to 101.4 mg% of carotenoids therein. As a result, as far as all the groups of the mentioned substances are concerned, we indicate samples Nos. 11029, 11044 and 11076 (see Table 1).

The authors of [2] have created two novel cultivars of amaranth such as cultivar "Cherginsky" for fodder purpose and a versatile cultivar for food and fodder use "Yantar". The former was obtained by means of individual group selection from the collection sample VIR-40197 belonging to species *A. cruentus*, whereas cultivar "Yantar" was obtained *via* combining five inbred lines having a high combination value with respect to a number of characteristics (belongs to species *A. hypochondriacus*). In the course of the creation of the cultivar of "Yantar", the line material was selected for a high content of protein, oil and squalene [2]. For the content of biologically active substances, we studied 11 lines that appeared to be not equivalent (see Table 1). According to the content of flavonols in the leaves up to 2.7 % of these substances, one could indicate lines Nos. 800 and 802. The maximum content of catechins (0.24 %) is inherent in plant lines Nos. 788 and 801; the maximum of tannins (up 10.06 %) is inherent in plants belonging to lines Nos. 801, 800 and 798. A high content of carotenoids is observed in plants belonging to many lines (Nos. 787–806), the maximum amount reaching 78.9 mg%.

CONCLUSION

Experimental data are presented concerning the content of biologically active substances (flavonols, catechins, tannins, carotenoids) in 45 samples of amaranth (*Amaranthus* L.) of different geographical origin, grown at the experimental plot of the Institute of Cytology and Genetics of the SB RAS (Novosibirsk), *i. e.*, under the conditions of Siberia, where this genus was earlier represented by weed species only.

The leaves contain flavonols ranging within 0.5–3.2 %, catechins 0.03–0.33 %, tannins 2.6–10.7 %, carotenoids 7.6–101.4 mg%; the flowers contain these substances in the amounts of 0.2–3.1 %, 0.02–0.19 %, 2.1–11.3 % and 3.7–32.3 mg%, respectively. Studying a wide variety of amaranth revealed a significant variation in the characteristics under testing, which allows one to carry out the selection for increasing the content of either target substance, as well as to use existing forms as sources of feedstock. The results obtained in studying the secondary metabolites of amaranth represent a definite stage of the phytochemical and introduction studies concerning this remarkable plant in Siberia. Further research is required in the field of biology and biochemistry of amaranth as one of the most promising alien crops in our region.

REFERENCES

1 Gusev V. D., *Botan. Zh.*, 57, 5 (1972) 457.
2 Zheleznov A. V., Zheleznova N. B., Burmakina N. V., Yudina R. S., Amarant: Nauchnye Osnovy Introduktsii, GEO, Novosibirsk, 2009.
3 Gamel T. H., Linssen J. P., *Recent Progress in Med. Plants*, 15 (2006) 347.
4 Zheleznova N. B., Yudina R. S., Zheleznov A. V., Morozov S. V., VIII Mezhdunar. Nauch.-Prakt. Konf. (Proceedings), Michurinsk, 2008, vol. 2, p. 215.
5 Belonozhkina T. G., Kuretskaya V. A., II Ros. Nauch.-Prakt. Konf. (Proceedings), Moscow, 2003, p. 33.
6 Zeashan H., Amresh G., Singh S., Rao Ch. V., *Food Chem. Toxicol.*, 46, 11 (2008) 3417.
7 Verma R. K., Sisodia R., Bhatia A. L., *J. Med. Food*, 5, 4 (2002) 189.
8 Kamal R., *Himalayan J. Environ. Zool.*, 21, 2 (2007) 315.
9 El Hossary G. A., El Sofany R. H., Farag M. A., *Bull. Fac. Pharm.*, 38, 2 (2000) 129
10 Mishra M., Tarunkumar S., Venkatesan B., Suriaprabha K., Mullaicharam A. R., Muthuprasanna P., *Nat. Products*, 3, 3 (2007) 190.
11 Kim H. K., Kim M. J., Cho H. Y., Kim E.-K., Shin D. H., *Cell Biochem. Function*, 24, 3 (2006) 195.
12 Sangameswaran B., Jayakar B., *J. Nat. Med.*, 62, 1 (2008) 79.
13 Kaur N., Dhuna V., Kamboj S. S., Agrewala J. N., Singh J., *Protein & Peptide Lett.*, 13, 9 (2006) 897.
14 Rivillas-Acevedo L., Soriano-Garcia M., *J. Mexican Chem. Soc.*, 51, 3 (2007) 136.
15 Kononkov P. F., Gins V. K., Gins M. S., Amarant – Perspektivnaya Kultura XXI Veka, Moscow, 1997.
16 Ofitserov E. N., Kostin V. I., Uglevody Amaranta i Ikh Prakticheskoye Ispolzovaniye, UlGU, Ulyanovsk, 2001.
17 Skyarov O. Y., Kovalyk N. B., *Med. Khim.*, 8, 3 (2006) 63.
18 Barba de la Rosa A. P., Silva-Sanchez C., Gonzalez de Mejia E., *Hispanic Foods: ACS Symp. Ser.*, 946 (2007) 103.
19 Martirosyan D. M., Miroshnichenko L. A., Kulakova S. N., Pogojeva A. V., and Zoloedov V. I., *Lipids in Health and Disease*, 6, 1 (2007) 1.
20 RU Pat.No. 2170096, 2001.
21 Shubin A. A., Krylova L. V., 6 Mezhdunar. Konf. "Bioantioksidant" (Proceedings), Moscow, 2002, p. 635.
22 Vasanthamani G., Rema, N., *Ind. J. Nutrition and Dietetics*, 43, 9 (2006) 372.
23 Pasko P., Bednarczyk M., *Bromatol. Chem. Toksykol.*, 40, 2 (2007) 217.
24 Potkin N. A., III Vseros. Konf. "Novye Dostizheniya v Khimii i Khimicheskoy Tekhnologii Rastitelnogo Syrya" (Proceedings), Barnaul, 2007, book 3, p. 249.
25 Belikov V. V., Shrayber M. S., *Farmatsiya*, 1 (1970) 66.
26 Kukushkina T. A., Zykov A. A., Obukhova L. A., in: Aktualnye Problemy Sozdaniya Novykh Lekarstvennykh Preparatov Prirodnogo Proiskhozhdeniya, St. Peterburg, 2003, p. 64.
27 Gosudarstvennaya Farmakopeya SSSR, 11 Ed., Moscow, 1987, issue 1, pp. 286–287.
28 Kriventsov V. I., Metodicheskiye Rekomendatsii po Analizu Plodov na Biokhimicheskiy Sostav, Yalta, 1982.
29 Chernenko T. V., Glushenkova A. I., Gusakova S. D., *Chem. Nat. Compd.*, 34, 5 (1999) 571.
30 Rastrelli L., Aquino R., Abdo S., Proto M., De Simone F., De Tommansi N., *J. Agric. Food Chem.*, 46, 5 (1998) 1797.
31 Tekelova D., Mrlianova M., *Farm. Obzor*, 71, 1 (2002) 3.
32 Srivastava B. K., Reddy M. V. R. K., *Orient. J. Chem.*, 10, 3 (1994) 293.
33 Gins M. S., Kononkov P. F., Gins V. K., Lysenko G. G., Desalen T. L., Bravova G. B., *Prikl. Biokhim. Mikrobiol.*, 34, 4 (1998) 450.
34 Klimczak I., Malecka M., Pacholek B., *Nahrung*, 46, 3 (2002) 184.
35 Tereshkina L. B., Gulshina V. A., Lyashchenko G. A., Kadyrov S. V., Lapin A. A., Zelenkov V. N., Obshcheros. Konf. Molodykh Uchenykh "Pishchevye Tekhnologii" (Proceedings), Moscow, 2006, p. 165.
36 Repo de Carrasco R., Zelada, Ch. R. E., *Revista de la Sociedad Quimica del Peru*, 74, 2 (2008) 85.
37 Karaseva A. N., Karlin V. V., Mironov V. F., Konovalov A. I., *Chem. Nat. Comp.*, 37, 1 (2001) 88.
38 Bratoeff E., Perez-Amador M. C., Ramirez E., Flores G., Valencia N., *Phyton.*, 60, 1/2 (1997) 103.
39 Junkuszew M., Oleszek W., Jurzysta M., Piancente S., Pizza C., *Phytochem.*, 49, 1 (1998) 195.
40 Cai Y., Corke H. J., *Food Sci.*, 64, 5 (1999) 869.
41 Sala M., Berardi S., Bondioli P., *Riv. Ital. Sostanze Grasse*, 75, 11 (1998) 503.
42 Yadav R. K., Bhatia A. L., Sisodia R., *Asian J. Exp. Sci.*, 18, 1 (2004) 63.
43 Samarth R. M., Panwar M., Kumar M., Soni A., Kumar M., Kumar A., *Food Chem.*, 106, 2 (2008) 868.
44 Akubugwo I. E., Obasi N. A., Chinyere G. C., Ugbogu A. E., *African J. Biotechnol.*, 6, 24 (2007) 2833.
45 Chitindingu K., Ndhlala A. R., Chapano C., Benhura M. A., Muchuweti M., *J. Food Biochem.*, 31, 2 (2007) 206.
46 Yadav Sh. K., Sehgal S., *Int. J. Trop. Agric.*, 17, 1–4 (1999) 37.
47 Khandaker L., Ali M. B., Oba Sh., *J. Japan. Soc. Hort. Sci.*, 77, 4 (2008) 395.