REVIEW ARTICLE

SABRAO Journal of Breeding and Genetics
56 (3) 1049-1059, 2024
http://doi.org/10.54910/sabrao2024.56.3.13
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

ASSESSMENT OF PHYTOCHEMICALS IN *ALLIUM* SPECIES: A SYSTEMATIC REVIEW

M.I. IVANOVA[1], A.A. BAIKOV[1*], E.M. GINS[2], V.K. GINS[1], A.I. KASHLEVA[1], M.S. GINS[1,3], S.M. MOTYLEVA[4*], V.F. PIVOVAROV[1], and N.V. SMUROVA[5]

[1]Federal State Budgetary Scientific Institution Federal Scientific Vegetable Center, Vniissok, Moscow Region, Russia
[2]Russian Potato Research Center, Kraskovo, Moscow Region, Russia
[3]Peoples' Friendship University of Russia, Moscow, Russia
[4]Strogoorganic Online Gardening School, Moscow, Russia
[5]All-Russian Scientific Research Institute of Medicinal and Aromatic Plants, Moscow, Russia
*Corresponding authors' emails: physiol@inbox.ru, motyleva_svetlana@mail.ru
Email addresses of co-authors: ivanova_170@mail.ru, katya.888888@yandex.ru, v.gins@inbox.ru, vniioh@yandex.ru, anirr@bk.ru, plant.physiol@yandex.ru, plant.physiol@ro.ru

SUMMARY

Phytochemicals are plant-based bioactive compounds produced by plants for their protection. In *Allium* species, the principal bioactive phytochemicals include organosulfur compounds, polyphenols, and saponins. Most of them have also displayed antioxidant activities aside from other biological properties. Selection for productivity, disease resistance, and long shelf life has brought the biologically active substances out of control of selection. However, at the same time, enhancement of their contents could result from hybridization with some wild species of *Allium*.

Keywords: *Allium* L., calorie content, biochemical composition, nutritional values, onions, chives, garlic, leeks

Key findings: Genus *Allium* L. species is a valuable source of biologically active compounds, such as vitamins, dietary fibers, antioxidants, and cholesterol-lowering compounds.

INTRODUCTION

In modern society, for a healthy lifestyle, the importance of diet escalates (Ivanova *et al*., 2021a). Vegetables play a considerable role in preventing free radical diseases associated with aging, obesity, cancer, and cardiovascular diseases (Gins *et al.,* 2021). In *Allium*, the bioactive compounds mainly include organosulfur compounds, polyphenols, dietary

Communicating Editor: Dr. Kamile Ulukapi

Manuscript received: October 9, 2023; Accepted: March 6, 2024.

Citation: Ivanova MI, Baikov AA, Gins EM, Gins VK, Kashleva AI, Gins MS, Motyleva SM, Pivovarov VF, Smurova NV (2024) Assessment of phytochemicals in *Allium* species: a systematic review. *SABRAO J. Breed. Genet.* 56(3): 1049-1059. http://doi.org/10.54910/sabrao2024.56.3.13.

fibers, and saponins (Poojary *et al*., 2017; Dabeek *et al*., 2019; Quecan *et al*., 2019; Putnik *et al*., 2019). Research has also demonstrated that flavonoids, especially onion flavonols, have antioxidant, antitumor, hypolipidemic, antidiabetic, cardioprotective, neuroprotective, and antimicrobial activities (Aleksandar *et al*., 2019; Kothari *et al*., 2020; Myint *et al*., 2020; Zhou *et al*., 2020).

Inclusion criteria

This review focused on analyzing the biochemical composition of onion crops, including biologically active compounds of pharmacological significance. The review included databases, viz., Web of Science, Scopus, PubMed, Science Direct, SciFinder, and Google Scholar. The online sources used were the Research Gate, National Center for Biotechnology Information (NCBI), Springer Nature Open Access, and Wiley Online Library.

Secondary metabolites

Secondary metabolites are tiny organic molecules from primary metabolites during the plant embolism. According to the classification adopted by the British Nutrition Foundation, plants secondary metabolites can have four main groups, i.e., phenolic and polyphenol compounds (about 8,000 compounds), terpenoids (about 25,000 compounds), alkaloids (about 12.000 compounds), and sulfur-containing compounds (Goldberg, 2003). In onion crops, the summarized information about the secondary metabolites and their content is available in Table 1.

Phenolic and polyphenolic compounds

Phenolic and polyphenolic compounds are often characteristic of an aromatic ring structure; they include flavonoids, phenolic acids, and lignans. Phenolic compounds are plants' secondary metabolites associated with protection mechanisms against pathogens and pests, defense against radiation, and attraction of pollinators signaling (Polivanova *et al*., 2021). These metabolites balance the system of the enzymatic antioxidants and have considerable potential to reduce and prevent tissue damage (Motyleva *et al*., 2021).

In *A. victorialis* L. leaves, the total phenolic compounds showed the highest level with methanol extraction (37.7 mg/L), followed by ethanol extract (31.9 mg/L) and hot water extract (25.4 mg/L). The total content of flavonoids was also the maximum during extraction with methanol (22.2 mg/L) (Cho *et al*., 2011). In garlic (*A. sativum* L.), chives (*A. schoenoprasum* L.), ramson (*A. ursinum* L.), and red, yellow, and white onions (*A. cepa* L.), the total polyphenols ranged at 0.444–1.591 mg/g, which declines in the order as chives > red onion > garlic > yellow onion > ramson > white onion (Lenková *et al*., 2016).

Flavonoids have the largest polyphenolic compound collections in fruits, vegetables, nuts, teas, wines, and other food ingredients. The bulb onion (*A. cepa* L.), garlic (*A. sativum* L.), and other onion types are wealthy sources of dietary flavonoids (Marefati *et al*., 2021; Recinella *et al*., 2022). Polyphenols with several health-regulating effects, contained in *Allium* species, particularly flavonols, which refer to their antioxidant

Table 1. Secondary metabolites and their content in onion crops.

Chemical compound	*Allium* species	Content	References
Flavonoids			
Quercetin	*A. cepa*	13.27 mg/100 g FW	USDA
Tocopherols and tocotrienols			
α-tocopherol	*A. cepa*	0,04 mg/100 g FW	Chun *et al*. (2006)
α-T3	*A. cepa*	0,12 mg/100 g FW	
Quinones			
Phylloquinone	*A. cepa*	0,2 µg /100 g FW	Damon *et al*. (2005)
Sterols			
Campesterol	*A. cepa*	0,82 mg/100 g FW	Normén *et al*. (1999)
Campestanol	*A. porrum*	0,09 mg/100 g FW	

activity, determine their functional properties, including anti-inflammatory, antimicrobial, antiglycemic, and anticancer effects (Han *et al*., 2013; Elberry *et al*., 2014; Lee *et al*., 2014; Jakaria *et al*. 2019; Polivanova *et al*., 2020; Recinella *et al*., 2022).

However, all these flavonoid properties are structurally dependent, making them one of the powerful antioxidants, free radical scavengers, and chelators of divalent cations that cause DNA damage associated with numerous diseases (Panche *et al*., 2016; Fredotovič *et al*., 2017). During the consumption of onions, absorption of flavonoids mainly occurs from the stomach and small intestines (Aziz *et al*., 1998). After ingestion of onion flour, the plasma flavonoid glucosides also appeared to have enhanced significantly. In addition, a strong association exists between higher plasma levels of flavonoids and increased DNA resistance to oxidative DNA damage, which is the supreme evidence of their antioxidant activity (Boyle *et al*., 2000).

Onions have mainly two classes of flavonoids, i.e., flavonols, responsible for the yellow and brown skins, and anthocyanins, which give the red and purple color to some onions (Rodrigues *et al*., 2017). Flavonol concentrations and types widely vary based on the species, cultivar, and plant parts. Moreover, reports revealed post-harvest practices and seasonality have also affected the concentrations of onion flavonol (Rodrigues *et al*., 2010, 2011). Flavones, flavanones, flavonols, isoflavones, flavanonols, chalcones, and anthocyanins are the subclasses of flavonoids, with the flavonols profusely found in *A. cepa* (Liguori *et al*. 2017). In onion cultivars, the chief flavonols found are quercetin derivatives, while the derivatives of kaempferol and isorhamnetin were recognizably smaller amounts (Slimestad *et al*., 2007; Bonaccorsi *et al*., 2008). Generally, flavonol levels are higher in yellow onions than in red onions (Soininen *et al*., 2014). The most abundant flavonols in onions are two quercetin conjugates, namely, quercetin-3,4'-diglucoside and quercetin-4'-monoglucoside (Fredotovič *et al*., 2017).

These compounds together made about 80% of the total flavonol content, with some variation among the different *Allium* crops. Glycosides of quercetin, myricetin, kaempferol, and isorhamnetin accounted for 15% of the total flavonols in onions. Compared to yellow and white onions, red onions showed a higher total flavonol content (Prakash *et al*., 2007). In addition, the bulb's total content of flavonols in its outer layers was higher than in its inner layers. In different types of *Allium* spp., the flavonol content ranges from seven to 1,917 mg/kg wet weight (Table 2). In addition to flavonols, onions are a rich source of anthocyanins, the natural pigments responsible for the color of fruits, vegetables, flowers, and grains. They impart a red or purple color to the onion bulb's outer layers. The most common anthocyanins in red onions are cyanidin derivatives (more than 50% of all anthocyanins), cyanidin-3-(6"-malonyl glucoside), cyanidin-3-(6"-malonyl-3" glucosyl-glucoside), and cyanidin-3-glucoside. There are also small derivatives of peonidin, petunidin, and delphinidin (Slimestad *et al*., 2007; Rodrigues *et al*., 2017).

Vanillic and cinnamic acids commonly exist in onions, parsley, and spinach and coumaric acid in tomatoes, carrots, and garlic (Crozier *et al*., 2006; Rashmi and Negi, 2020). In onion (*Allium cepa* L.), the main phenolic compounds are gallic acid (22.1−182.4 mg/kg FW), quercetin (2.9−15.8 mg/kg FW), isorhamnetin 4´-glucoside (11.9−34.3 mg/kg FW), kaempferol 3-oglucoside (2.3−6.6 mg/kg FW), quercetin 4-oglucoside (112.3−337.5 mg/kg FW), quercetin 3-oglucoside (2.7−5.1 mg/kg FW), isorhamnetin 3,4´-diglucoside (0.7−18.6 mg/kg FW), quercetin 3,4´-diglucoside (127.3−376.0 mg/kg FW), quercetin 7,4´-diglucoside (2.7−9.5 mg/kg FW), and quercetin 3,7,4´-triglucoside (2.1−6.3 mg/kg FW). For garlic (*Allium sativum* L.), the major phenolic composites are gallic acid (79.13–96.48 mg/kg FW), chlorogenic acid (76.99–93.95 mg/kg FW), caffeic acid (3.72–14.06 mg/kg FW), epicatechin (1.17 mg/kg FW), *p*-coumaric acid (0.55–4.42 mg/kg FW), rutin (43.43 mg/kg FW), luteolin (0.15–22.92 mg/kg FW),

Table 2. Flavonol content of some common edible *Allium* species.

Allium species	Plant Part	Total Flavonol Content	References
A. cepa	Red bulb	415-1917 mg/kg FW	Slimestad *et al*. (2007)
	Yellow bulb	270-1187 mg/kg FW	
	White bulb	7 mg/kg FW	Bonaccorsi *et al*. (2008)
A. ascalonicum	Bulb	1023 mg/kg FW	Bonaccorsi *et al*. (2008)
A. porrum	Bulb	246 mg/kg FW	Soininen *et al*. (2014)
A. sativum	Cloves	16.19 mg/kg DW	Kim *et al*. (2013)
A. ursinum	Green leaves	1856.31 mg/kg DW	Oszmianski *et al*. (2013)
	Stalks	206.07 mg/kg DW	
	Seeds	73.14 mg/kg DW	
A. tricoccum	Leaves	11.81 mg/kg DW	Dabeek *et al*. (2019)
	Stem	0.0382 mg/kg DW	
A. odorum	Leaves	160 mg/kg DW	Miean and Mohamed (2001)
A. fistulosum	Leaves	2329 mg/kg DW	Miean and Mohamed (2001)
A. flavum subsp. *Flavum*	Aerial parts	44-264 mg/kg DW	Simin *et al*. (2013)
	Bulb	0.77-832 mg/kg DW	
A. carinatum	Whole plant	11.14 mg/kg DW	Aleksandar *et al*. (2019)

hyperoside (0.37–20.24 mg/kg FW), ferulic acid (0.90–15.73 mg/kg FW), quercetin (6.55–10.09 mg/kg FW), apigenin (3.24 mg/kg FW), naringenin (11.75–56.71 mg/kg FW), and allyl isothiocyanate (184.57–340.45 mg/kg FW) (Li *et al*., 2023a).

Lignans are diphenolic compounds involved in synthesizing lignin, a hydrophobic component of the plant cell wall. Garlic and onions are usually prime sources of lignans in the Mediterranean diet (Rodríguez-García *et al*., 2019). One clove of garlic contains four micrograms of lignin (for a total of 117 micrograms of lignin per 100 g); one tablespoon of chopped chives contains five micrograms of lignin (158 micrograms of lignin per 100 g), and a medium-sized onion bulb contains 11 µg of lignin (Penalvo *et al*., 2008). In garlic (*A. sativum* L.), the main lignan compounds are lariciresinol (286 µg/100 g FW), pinoresinol (200 µg/100 g FW), and secoisolariciresinol (50 µg/100 g FW); in leek (*A. porrum* L.), the lignans are lariciresinol (37 µg/100 g FW), pinoresinol (3 µg/100 g FW), and secoisolariciresinol (38 µg/100 g FW); in onion (*A. cepa* L.), the lignans are lariciresinol (19 µg/100 g FW) and secoisolariciresinol (18 µg/100 g FW) (Milder *et al.*, 2005).

Lignans play a vital role in protecting plants from insects by acting as regulators of insect feeding and development (Harmatha and Dinan, 2003). Some plant lignans, such as secoisolariciresinol, matiresinol, lariciresinol, and pinoresinol, can convert to 'enterolignans' by the intestinal microflora and then be absorbed by the human body (Heinonen *et al*., 2001). In humans, lignans have several biological activities, such as antioxidant and anti-estrogenic properties, which may reduce the risk of particular cancers and cardiovascular diseases (Hu *et al*., 2021). Therefore, many have suggested that compared with the semi-vegetarian diet in many Asian countries, the Western diet may alter the production, metabolism, and hormone action at the cellular level, increasing the incidence of breast, colorectal, and prostate cancers. Observational studies enunciated that high lignan intake has an association with a significantly reduced risk of breast cancer, particularly in postmenopausal women (Mason and Thompson, 2014).

Saponins

Steroidal saponins from the genus *Allium* can comprise three groups based on the sapogenin structure: spirostanols, furostanols, and open-chain saponins (Sobolewska *et al*., 2016). They play a crucial role in protecting plants from pathogens, pests, and herbivores, and several studies have shown that these compounds can act as natural agents in the treatment of many diseases (Sobolewska *et al*., 2016). Reports have also indicated that steroidal saponins isolated from *A. porrum* have a strong antifeedant effect on Lepidoptera insects, such as *Peridroma saucia* and *Mamestra configurata* (Li *et al*., 2023b). In *Allium* species, the saponins have the highest cytotoxic activity, which makes them potential candidates for future development as anticancer agents (Lanzotti *et al*., 2014).

Records show around 45 species of the genus *Allium,* the steroid saponins, and their genins existed. However, about 50 spirostanol and furostanol glycosides as isolates came from onion species (Lai *et al*., 2010; Jabrane *et al*., 2011). In addition to glycosides, isolating 28 genins have come from different onion species, and the most common is diosgenin, found in 18 species. From a research point of view, the raw materials rich in diosgenin and the *A. fuscoviolaceum* Fomin and *A. nutans* L. are of more interest, containing 2.1% and 2.3% of this genin, respectively. Unbound diosgenin, spirostanol glycoside deltonin, and two glycosides of furostanol nature (deltoside and protodioscin) were prominent in the roots, bulbs, and buds of onions. The aglycone smilagenin was evident in the integumentary scales and leaves. The *A. ursinum* L. bulbs also contain diosgenin, the concentration of which chiefly depends upon the harvesting time (Sabha *et al*., 2012).

Mostafa *et al.* (2013) provided the following total saponin content values (per DW) for *A. nigrum* in the roots (19.38 mg/g), bulbs (15.65 mg/g), and leaves (10.48 mg/g). The total number of saponins was almost 40-fold higher in purple garlic than in white varieties (Diretto *et al.*, 2017). In garlic, the average content of total saponins in dry roots was 14.49 mg/g DW and varied from 3.36 mg/g DW to 32.18 mg/g DW (Abdelrahman *et al.*, 2021).

Sulfur compounds

High levels of sulfur compounds characterized *Allium* species, such as S-alk(en)ylcysteine sulfoxide (ACSO), sulfides, alkyl polysulfides, and amino acids. Therefore, it is noteworthy that different types of onions contain diverse profiles of organosulfur compounds (Block *et al*., 2010). The volatile sulfur compounds cause a pungent odor in the onion species. These disulfide compounds are mostly nonexistent in intact bulbs; however, they form from the enzymatic breakdown of precursors when the bulb tissue is destroyed. The alliinase enzyme belongs to the group of C–S lyases and plays a chief role in the formation of volatile compounds of the *Allium* genus (Hrbek *et al*., 2018; Aswani *et al.*, 2024). In *A. sativum*, the main thiosulfinate is diallyl disulfide derived from allicin, while in *A. cepa,* it is dipropyl disulfide derived from isoalliin (Rose *et al*., 2005). Thiosulfinates are chemically unstable and undergo dissociation and rearrangement into volatile sulfur compounds responsible for the specific smell of onions (Poojary *et al*., 2017).

Volatile sulfur compounds have sturdy antioxidant properties and antimicrobial, anti-inflammatory, and anti-cancer effects (Salehi *et al*., 2019). In *A. sativum* essential oil, the main components were diallyl trisulfide (41.62%), diallyl disulfide (19.74%), allyl methyl trisulfide (12.95%), diallyl sulfide (7.1%), and diallyl tetrasulfide (4.22%). In the *A. cepa,* the essential oil contains the diallyl trisulfide (22.17%), dipropyl trisulfide (11.11%), 2-methyl-3,4-dithiaheptane (9.88%), methyl propyl trisulfide (8.14%), dipropyl tetrasulfide (8.07%), and 2-propenyl propyl disulfide (5.15%) (Ndoye-Foe *et al*., 2016). The organosulfur compounds (OSCs) of onion include diallyl monosulfide (DMS), diallyl disulfide (DADS), diallyl trisulfide (DATS), and diallyl tetrasulfide (DTTS) (Sagar *et al*., 2022).

Loredana *et al*. (2019) obtained the following OSCs values (per DW) for Alife onion (963.90 ± 69.88 mg/kg), Montoro onion (1322.79 ± 253.22 mg/kg), tapered shape Vatolla onion (1368.63 ± 127.60 mg/kg), and spinning top Vatolla onion (1393.15 ± 156.48 mg/kg) from the Italian Mediterranean. Similarly, Zhou *et al*. (2020) reported the highest amount of OSCs (per FW) was in 'Storey onion' (962.20 µg/g), followed by 'onion' (634.65 µg/g) and 'Welsh onion' (606.48 µg/g). Past findings also reported that the amount of cysteine sulfoxides and precursors of volatile sulfur compounds rose upon hybridization of onion with some wild species of *Allium* (Fredotovič *et al*., 2020). The content of volatile sulfur compounds in freshly cut *Allium* species is available in Table 3.

CONCLUSIONS

Numerous onion types of the wild-growing species have been effective in traditional medicine, but further clinical trials with human volunteers are necessary to validate any putative health benefit claims. Knowledge of the chemical composition is also crucial. In the Moscow Region, Russia, the onion crop studies revealed that dry matter content (DMC) varied from 8.6 (*A. leucocephalum* Turcz. ex Vved.) to 19.3 (*A. narcissiflorum* Vill.), on average (23.6% ± 2.9%); nitrates ranged from 110 (*A. ramosum* L.) to 256 (*A. tuberosum* Rottler ex Spreng), on average (175.3 ± 37.5 mg/kg FW); monosaccharides ranged from 2.6 (*A. oschaninii* O. Fedtsch., *A. altyncolicum* N. Friesen, *A. ledebourianum* Schult. & Schult. F.) to 4.2 (*A. ascalonicum* L., *A. ramosum* L., *A. cyrilli* Ten.), on average (3.3% ± 0.6% FW); ascorbic acid ranged from 119.2 (*A. pskemense* B. Fedtsch.) to 133.5 (*A. suworowii* Regel), on average (126.0 ± 4.1 mg/100 g FW); chlorophyll from 138 (*A. pskemense* B. Fedtsch.) to 289 (*A. gultschense* O. Fedtsch., *A. ascalonicum* L.), on average (219.1±46.8 mg/100 g DW); carotene - from 14.5 (*A. pskemense* B. Fedtsch.) to 33.1 (*A. barsczewskii* Lipsky), on average (24.2 ± 4.9 mg/kg FW); hydroxycinnamic acids - from 169.8 × 10^{-3} (*A. oliganthum* Kar. & Kir.) to 185.0 × 10^{-3} (*A. sewerzowii* Regel), on average (174.4 × 10^{-3}% ± 3.9 × 10^{-3}% DW; also the same values as lettuce (*Lactuca sativa* L.) (Ivanova *et al*., 2021b); flavonoids - from 289.8 × 10^{-3} (*A. oliganthum* Kar. & Kir.) to 311.3 × 10^{-3} (*A. sewerzowii* Regel), on average

Table 3. Volatile compounds in freshly cut *Allium* species (%) (Fredotovič, 2020).

Chemical compound	*A. cornutum*	*A. cepa*
Sulfur dioxide	0.3 ± 0.01	0.4 ± 0.02
Methanethiol	0.9 ± 0.04	0.8 ± 0.03
Propanal	0.2 ± 0.01	0.2 ± 0.01
Carbon disulfide	0.5 ± 0.02	0.2 ± 0.01
Prop-2-en-1-thiol	0.3 ± 0.02	0.3 ± 0.03
1-Propanethiol	14.1 ± 0.20	13.1 ± 0.31
Dimethyl disulfide	0.1 ± 0.01	0.0 ± 0.00
2-Methylpentanal	0.1 ± 0.01	0.1 ± 0.01
(E)-Hex-2-enal	0.3 ± 0.02	0.2 ± 0.01
(Z)-Hex-3-en-1-ol	0.2 ± 0.01	0.2 ± 0.01
Propyl hydrosulfide	0.3 ± 0.02	0.4 ± 0.03
(E)-Hex-3-en-1-ol	0.9 ± 0.04	0.5 ± 0.02
S-Propyl ethanetihoate	1.5 ± 0.10	1.3 ± 0.15
2,5-Dimethylthiophene	0.1 ± 0.01	0.2 ± 0.01
Methyl propyl disulfide	0.8 ± 0.01	0.9 ± 0.01
Methyl (E)-prop-1-enyl disulfide	0.0 ± 0.00	0.1 ± 0.01
Ally propyl disulfide	0.6 ± 0.01	0.9 ± 0.01
Dipropyl disulfide	45.5 ± 0.01	31.9 ± 0.01
(E)-prop-1-enyl propyl disulfide	0.1 ± 0.01	3.8 ± 0.20
Methyl methylthiomethyl disulfide	2.8 ± 0.10	0.5 ± 0.04
Methyl propyl trisulfide	0.2 ± 0.01	0.2 ± 0.01
Diisopropyl trisulfide	18.3 ± 0.21	24.6 ± 0.41
(Z)-Prop-1-enyl propyl trisulfide	3.1 ± 0.11	2.8 ± 0.10
(E)-Prop-1-enyl propyl trisulfide	0.7 ± 0.05	1.7 ± 0.10
Dipropyl tetrasulfide	0.7 ± 0.02	0.0 ± 0.00
cis-3,6-Diethyl-1,2,4,5-tetrathiane	0.4 ± 0.01	1.7 ± 0.12
trans-3,6-Diethyl-1,2,4,5-tetrathiane	1.8 ± 0.10	4.8 ± 0.21

Table 4. Biochemical parameters of some *Allium* species from the collection of the Federal Scientific Vegetable Center (Ivanova *et al*., 2019).

Allium species	DMC(%)	Nitrates (mg/kg FW)	Monosacc-harides (% FW)	Ascorbic acid (mg /100 g FW)	Chlorophyll (mg /100 g DW)	Carotene (mg/kg FW)	Hydroxycinnamic acids (10^{-3} % DW)	Flavonoid (10^{-3} % DW)
A. ascalonicum L.	15.3	194	4.2	129.1	289	30.1	170.0	290.4
A. barsczewskii Lipsky	11.9	245	4.1	129.7	236	33.1	173.6	294.2
A. leucocephalum Turcz. ex Vved.	8.6	234	3.5	129.5	212	19.2	177.7	300.8
A. lineare L.	9.01	190	2.9	127.5	212	29.5	177.3	298.7
A. suaveolens Jacq.	18.9	167	3.9	127.5	267	32.7	176.9	301.7
A. hymenorrhizum Ledeb.	14.4	220	3.1	127.9	235	28.3	178.8	300.4
A. obliquum L.	15.7	117	3.8	128.4	198	23.4	180.9	306.2
A. altaicum Pall.	11.6	111	3.8	122.6	139	19.9	172.5	293.6
A. fistulosum L.	17.3	111	2.8	127.9	197	24.4	172.4	293.2
A. galanthum Kar. & Kir.	12.8	215	3.4	124.8	283	29.1	172.3	294.1
A. oschaninii O. Fedtsch.	13.9	178	2.6	122.9	146	16.8	172.6	302.5
A. pskemense B. Fedtsch.	11.7	170	2.7	119.2	138	14.5	172.2	292.9
A. altyncolicum N. Friesen	17.9	169	2.6	128.8	252	23.7	174.0	295.2
A. ledebourianum Schult. & Schult. F.	9.3	237	2.6	121.1	233	21.2	170.6	293.8
A. oliganthum Kar. & Kir.	11.9	187	2.7	122.4	218	19.6	169.8	289.8
A. schoenoprasum L.	13.6	200	2.8	123.6	204	18.4	173.0	294.6
A. ramosum L.	14.5	110	4.2	119.4	157	18.6	180.1	304.5
A. tuberosum Rottler ex Spreng	12.4	256	2.9	133.4	254	31.7	176.7	294.2
A. narcissiflorum Vill.	19.3	139	2.9	128.7	167	19.4	171.8	292.9
A. chyatophorum Bureau & Franch	17.8	227	3.2	125.5	250	26.5	171.4	291.2
A. gultschense O. Fedtsch.	10.1	158	2.9	130.4	289	19.4	172.2	293.8
A. sewerzowii Regel	14.1	170	3.9	122.8	213	23.8	185.0	311.3
A. aflatunense B. Fedtsch.	12.9	187	3.1	130.8	287	24.2	181.6	298.5
A. libani Boiss.	8.6	145	2.7	119.4	159	20.1	170.8	291.2
A. cyrilli Ten.	10.9	189	4.2	127.9	147	24.5	172.8	294.1
A. altissimum Regel	12.6	162	2.8	126.5	248	27.6	174.9	296.9
A. komarowii Lipsky	12.9	175	2.9	129.8	256	25.8	171.4	291.2
A. suworowii Regel	13.7	151	3.8	133.5	261	28.9	181.3	298.6
A. chamaemoly L.	12.8	146	3.8	123.7	258	22.4	173.3	294.6
A. angulosum L.	12.0	158	3.7	122.4	187	23.1	172.2	293.5
A. montanum F.W. Schmidt	11.8	156	3.9	125.6	198	29.0	172.4	293.5
A. nutans L.	13.9	163	3.7	128.7	195	25.3	173.2	294.9
A. senescens L.	14.0	167	3.0	120.0	200	26.9	171.5	292.1
A. victorialis L.	18.6	154	3.8	131.8	254	27.4	179.9	304.0
Mean (M)	13.6	175.3	3.3	126.0	219.1	24.2	174.4	296.0
Standard deviation (σ)	2.9	37.5	0.6	4.1	46.8	4.9	3.9	5.0

($296.0 \times 10^{-3}\% \pm 5.0 \times 10^{-3}\%$ DW). Therefore, the studied representatives of the genus *Allium* L. (Table 4) can be supreme potential sources of biologically active compounds (Ivanova *et al*., 2019).

Funding

This work proceeded within the topic of the state task of the All-Russian Scientific Research Institute of Medicinal and Aromatic Plants № FGUU-2022-0014.

REFERENCES

Abdelrahman M, Hirata S, Mukae T, Yamada T, Sawada Y, El-Syaed M, Yamada Y, Sato M, Hirai MY, Shigyo M (2021). Comprehensive metabolite profiling in genetic resources of garlic (*Allium sativum* L.) collected from different geographical regions. *Molecules* 26: 1415.

Aleksandar P, Dragana M-Ć, Nebojša J, Biljana N, Nataša S, Branka V, Jelena K-V (2019). Wild edible onions - *Allium flavum* and *Allium carinatum* - successfully prevent adverse effects of chemotherapeutic drug doxorubicin. *Biomed. Pharmacother.* 109: 2482-2491.

Aswani N, Terryana RT, Lestari P, Sudarmonowati E, Satyawan D, Nugroho K, Murtiningsih RRR, Mulya K, Prihaningsih A, Karjadi AK, Saidah, Basuki RS, Harmanto (2024). Genetic variability studies of Indonesian garlic (*Allium sativum* L.) accessions based on morphological traits. *SABRAO J. Breed. Genet*. 56(2): 557-571.

Aziz AA, Edwards CA, Lean MEJ, Crozier A (1998). Absorption and excretion of conjugated flavonols, including quercetin-4'-O-beta-glucoside and isorhamnetin-4'-O-beta-glucoside by human volunteers after the consumption of onions. *Free Radic. Res.* 29: 257-269.

Block E, Dane AJ, Thomas S, Cody RB (2010). Applications of direct analysis in real time mass spectrometry (DART-MS) in Allium chemistry. 2-propenesulfenic and 2-propenesulfinic acids, diallyl trisulfane S-oxide, and other reactive sulfur compounds from crushed garlic and other Alliums. *J. Agric. Food Chem.* 58(8): 4617-4625.

Bonaccorsi P, Caristi C, Gargiulli C, Leuzzi U (2008). Flavonol glucosides in *Allium* species: A comparative study by means of HPLC–DAD–ESI-MS–MS. *Food Chem*. 107(4): 1668-1673.

Boyle SP, Dobson VL, Duthie SJ, Kyle JA, Collins AR (2000). Absorption and DNA protective effects of flavonoid glycosides from an onion meal. *Eur. J. Nutr.* 39(5): 213-223.

Cho J-Y, Park Y-J, Oh D-M, Rhyu D-Y, Kim Y-S, Chon S-U, Kang S-S, Heo B-G (2011). Amino acid contents and various physiological activities of *Allium victorialis*. *Korean J. Plant Resour*. 24(2): 150-159.

Chun J, Lee J, Ye L, Exler J, Eitenmiller RR (2006). Tocopherol and tocotrienol contents of raw and processed fruits and vegetables in the United States diet. *J. Food. Comp. Anal.* 19: 196-204.

Crozier A, Clifford M, Ashihara H (2006). Plant Secondary Metabolites: Occurrence Structure and Role in the Human Diet. Blackwell Publishing Ltd., Oxford, UK.

Dabeek WM, Kovinich N, Walsh C, Ventura Marra M (2019). Characterization and quantification of major flavonol glycosides in ramps (*Allium tricoccum*). *Molecules* 24(18): 3281.

Damon M, Zhang NZ, Haytowitz DB, Booth SL (2005). Phylloquinone (vitamin K1) content of vegetables. *J. Food Comp. Anal.* 18(8): 751-758.

Diretto G, Rubio-Moraga A, Argandoña J, Castillo P, Gómez-Gómez L, Ahrazem O (2017). Tissue-specific accumulation of sulfur compounds and saponins in different parts of garlic cloves from purple and white ecotypes. *Molecules* 22: 1359.

Elberry AA, Mufti S, Al-Maghrabi J, Abdel Sattar E, Ghareib SA, Mosli HA, Gabr SA (2014). Immunomodulatory effect of red onion (*Allium cepa* Linn) scale extract on experimentally induced atypical prostatic hyperplasia in Wistar rats. *Mediat. Inflamm*. 2014: 640746.

Fredotovič Ž, Soldo B, Šprung M, Marijanovič Z, Jerkovič I, Puizina J (2020). Comparison of organosulfur and amino acid composition between triploid onion *Allium cornutum* Clementi ex Visiani 1842, and common onion *Allium cepa* L., and evidences for antiproliferative activity of their extracts. *Plants* 9(1): 98.

Fredotovič Ž, Šprung M, Soldo B, Ljubenkov I, Budič-Leto I, Bilušič T, Čikeš-Čulič V, Puizina J (2017). Chemical composition and biological activity of *Allium cepa* L. and *Allium cornutum* (Clementi ex Visiani 1842) methanolic extracts. *Molecules* 22(3): 448.

Gins VK, Motyleva SM, Kulikov IM, Tumanyan AF, Romanova EV, Baikov AA, Gins EM, Terekhin AA, Gins MS (2021). Antioxidant profile of *Amaranthus paniculatus* L. of the Pamyat of Kovas variety. *IOP Conf. Ser. Earth Environ. Sci.* 624: 012152.

Goldberg G (2003). Plants: Diet and Health. The report of a British Nutrition Foundation Task Force. Blackwell Publishing Ltd., Oxford, UK.

Han MH, Lee WS, Jung JH, Jeong J-H, Park C, Kim HJ, Kim G, Jung J-M, Kwon TK, Kim G-Y, Ryu CH, Shin SC, Hong SC, Choi YH (2013). Polyphenols isolated from *Allium cepa* L. induces apoptosis by suppressing IAP-1 through inhibiting PI3K/Akt signaling pathways in human leukemic cells. *Food Chem. Toxicol.* 62: 382-389.

Harmatha J, Dinan L (2003). Biological activities of lignans and stilbenoids associated with plant-insect chemical interactions. *Phytochem. Rev.* 2: 321-330.

Heinonen S, Nurmi T, Liukkonen K, Poutanen K, Wähälä K, Deyama T, Nishibe S, Adlercreutz H (2001). In vitro metabolism of plant lignans: New precursors of mammalian lignans enterolactone and enterodiol. *J. Agric. Food Chem.* 49(7): 3178-3186.

Hrbek V, Rektorisova M, Chmelarova H, Ovesna J, Hajslova J (2018). Authenticity assessment of garlic using a metabolomic approach based on high-resolution mass spectrometry. *J. Food Compos. Anal.* 67: 19-28.

Hu Y, Li Y, Sampson L, Wang M, Manson JE, Rimm E (2021). Lignan intake and risk of coronary heart disease. *J. Am. Coll. Cardiol*. 78(7): 666-678.

Ivanova M, Gins E, Baikov A, Demyanova Roy G, Gins V, Mizrukhina Y, Zagirov N, Choloquinga M, Dembele L, Litnetskiy A, Kashleva A (2021b). Influence of different types of AGROTEX™ mulching material on the yield of perennial wall-rocket (*Diplotaxis tenuifolia*) introduced in Moscow region. *Res. on Crops*. 22(1): 134-140.

Ivanova M, Gins E, Fedosov A, Baikov A, Demyanova-Roy G, Gins V, Mizrukhina Y, Choloquinga M, Dembele L (2021a). Influence of different types of AGROTEX™ mulching material on the yield of lettuce (*Lactuca sativa*) introduced in Moscow region. *Res. on Crops*. 22(3): 596-601.

Ivanova MI, Bukharov AF, Baleev DN, Bukharova AR, Kashleva AI, Seredin TM, Razin OA (2019). Biochemical composition of leaves of *Allium* L. species in the conditions of the Moscow region. *Achiev. Sci. Technol.* 33(5): 47-50.

Jabrane A, Jannet HB, Miyamoto T, Mirjolet J-F, Duchamp O, Harzallah-Skhiri F, Lacaille-Dubois M-A (2011). Spirostane and cholestane glycosides from the bulbs of *Allium nigrum* L. *Food Chem.* 125(2): 447-455.

Jakaria M, Azam S, Cho D-Y, Haque M, Kim I-S, Choi D-K (2019). The methanol extract of *Allium cepa* L. protects inflammatory markers in LPS-induced BV-2 microglial cells and upregulates the antiapoptotic gene and antioxidant enzymes in N27-A cells. *Antioxidants* 8(9): 348-396.

Kim J-S, Kang O-J, Gweon O-C (2013). Comparison of phenolic acids and flavonoids in black garlic at different thermal processing steps. *J. Funct. Foods* 5(1): 80-86.

Kothari D, Lee W-D, Jung ES, Niu K-M, Lee CH, Kim S-K (2020). Controlled fermentation using autochthonous *Lactobacillus plantarum* improves antimicrobial potential of Chinese chives against poultry pathogens. *Antibiotics* 9(7): 386.

Lai W, Wu Z, Lin H, Li T, Sun L, Chai Y, Chen W (2010). Anti-ischemia steroidal saponins from the seeds of *Allium fistulosum*. *J. Nat. Prod.* 73(6): 1053-1057.

Lanzotti V, Scala F, Bonanomi G (2014). Compounds from *Allium* species with cytotoxic and antimicrobial activity. *Phytochem. Rev.* 13(4): 769-791.

Lee H-A, Han S-J, Hong S, Kim D-W, Oh G-W, Kim O (2014). Onion peel water extracts enhance immune status in forced swimming rat model. *Lab. Anim. Res.* 30(4): 161-168.

Lenková M, Bystrická J, Tóth T, Hrstková M (2016). Evaluation and comparison of the content of total polyphenols and antioxidant activity of selected species of the genus *Allium*. *J. Cent. Eur. Agric*. 17(4): 1119-1133.

Li W, Chen H, Xu B, Wang Y, Zhang C, Cao Y, Xing X (2023a). Research progress on classification, sources and functions of dietary polyphenols for prevention and treatment of chronic diseases. *J. Future Foods* 3(4): 289-305.

Li Y, Yang H, Li Z, Li S, Li J (2023b). Advances in the biosynthesis and molecular evolution of steroidal saponins in plants. *Int. J. Mol. Sci.* 24(3): 2620.

Liguori L, Califano R, Albanese D, Raimo F, Crescitelli A, Di Matteo M (2017). Chemical composition and antioxidant properties of five white onion (*Allium cepa* L.) landraces. *J. Food Qual.* 2017: 6873651.

Loredana L, Giuseppina A, Filomena N, Florinda F, Donatella A (2019). Biochemical, antioxidant properties and antimicrobial activity of different onion varieties in the Mediterranean area. *J. Food Meas. Charact*. 13: 1232-1241.

Marefati N, Ghorani V, Shakeri F, Boskabady M, Kianian F, Rezaee R, Boskabady MH (2021). A review of anti-inflammatory, antioxidant, and immunomodulatory effects of *Allium cepa* and its main constituents. *Pharm. Biol.* 59(1): 287-302.

Mason JK, Thompson LU (2014). Flaxseed and its lignan and oil components: Can they play a role in reducing the risk of and improving the treatment of breast cancer? *Appl. Physiol. Nutr. Metab*. 39(6): 663-678.

Miean KH, Mohamed S (2001). Flavonoid (myricetin, quercetin, kaempferol, luteolin, and apigenin) content of edible tropical plants. *J. Agric. Food Chem.* 49(6): 3106-3112.

Milder IEJ, Arts ICW, van de Putte B, Venema DP, Hollman PCH (2005). Lignan contents of Dutch plant foods: A database including lariciresinol, pinoresinol, secoisolariciresinol and matairesinol. *Br. J. Nutr.* 93(3): 393-402.

Mostafa A, Sudisha J, El-Sayed M, Ito S, Ikeda T, Yamauchi N, Shigyo M (2013). Aginoside saponin, a potent antifungal compound, and secondary metabolite analyses from *Allium nigrum* L. *Phytochem Lett* 6(2): 274-280.

Motyleva SM, Gins MS, Kabashnikova LF, Kozak NV, Tetyannikov NV, Panischeva DV, Mertvischeva ME, Domanskaya IN, Pilipovich TS (2021). Drought effects on the physiological and biochemical parameters of Amaranth (C-4) and Actinidia (C-3) plants. *SABRAO J. Breed. Genet.* 53(2): 248-262.

Myint AA, Aregay MG, Kang M, Kim B-S, Lee Y-W, Kim J (2020). Comprehensive study on the formation mechanism of highly bioactive compounds from *Allium hookeri* root using subcritical water and their antioxidant and anticancer effects. *J. Supercrit. Fluids. 157*: 104709.

Ndoye-Foe FM, Tchinang TFK, Nyegue AM, Abdou JP, Yaya AJG, Tchinda AT, Essame JO, Etoa FX (2016). Chemical composition, in vitro antioxidant and anti-inflammatory properties of essential oils of four dietary and medicinal plants from Cameroon. *BMC Complement. Altern. Med.* 16: 117.

Normén L, Jonson M, Andersson H, van Gameren Y, Dutta P (1999). Plant sterols in vegetables and fruits commonly consumed in Sweden. *Eur. J. Nutr.* 38: 84-89.

Oszmianski J, Kolniak-Ostek J, Wojdyło A (2013). Characterization and content of flavonol derivatives of *Allium ursinum* L. plant. *J. Agric. Food Chem.* 61: 176-184.

Panche AN, Diwan AD, Chandra SR (2016). Flavonoids: An overview. *J. Nutr. Sci.* 5: e47.

Penalvo JL, Adlercreutz H, Uehara M, Ristimaki A, Watanabe S (2008). Lignan content of selected foods from Japan. *J. Agric. Food Chem.* 56(2): 401-409.

Polivanova OB, Gins EM, Moskalev EA, Simakov EA, Goryunova SV, Zhevora SV (2020). Evaluation of reproducibility methods for total phenolic and flavonoid content in skin and flesh of potato (*Solanum tuberosum*). *Res. on Crops.* 21(3): 520-528.

Polivanova OB, Gins EM, Moskalev EA, Voinova MS, Koroleva AK, Semenov AZ, Sivolapova AB, Ivanova AS, Kazakov OG, Simakov EA, Chalaya NA, Rogozina EV, Goryunova SV (2021). Quality evaluation, phytochemical characteristics and estimation of beta-carotene hydroxylase 2 (*Chy2*) alleles of interspecific potato hybrids. *Agronomy* 11(8): 1619.

Poojary MM, Putnik P, Kovačevič DB, Barba FJ, Lorenzo JM, Dias DA, Shpigelman A (2017). Stability and extraction of bioactive sulfur compounds from *Allium* genus processed by traditional and innovative technologies. *J. Food Compos. Anal.* 61: 28-39.

Prakash D, Singh BN, Upadhyay G (2007). Antioxidant and free radical scavenging activities of phenols from onion (*Allium cepa*). *Food Chem*. 102(4): 1389-1393.

Putnik P, Gabrič D, Roohinejad S, Barba FJ, Granato D, Mallikarjunan K, Lorenzo JM, Kovačevič DB (2019). An overview of organosulfur compounds from *Allium* spp.: From processing and preservation to evaluation of their bioavailability, antimicrobial, and anti-inflammatory properties. *Food Chem.* 276: 680-691.

Quecan BXV, Santos JT, Rivera ML, Hassimotto NM, Almeida FA, Pinto UM (2019). Effect of quercetin rich onion extracts on bacterial quorum sensing. *Front. Microbiol.* 10:867.

Rashmi HB, Negi PS (2020). Phenolic acids from vegetables: A review on processing stability and health benefits. *Food Res. Int.* 136: 109298.

Recinella, Gorica E, Chiavaroli A, Fraschetti C, Filippi A, Cesa S, Cairone F, Martelli A, Calderone V, Veschi S, Lanuti P, Cama A, Orlando G, Ferrante C, Menghini L, Di Simone SC, Acquaviva A, Libero ML, Nilofar, Brunetti L, Leone S (2022). Anti-inflammatory and antioxidant effects induced by *Allium sativum* L. extracts on an ex vivo experimental model of ulcerative colitis. *Foods* 11(22): 3559.

Rodrigues AS, Almeida DPF, Simal-Gándara J, Pérez-Gregorio MR (2017). Onions: A source of flavonoids. In: G.C. Justino (ed.), Flavonoids - From Biosynthesis to Human Health. InTech.

Rodrigues AS, Pérez-Gregorio MR, García-Falcón MS, Simal-Gándara J, Almeida DP (2010). Effect of post-harvest practices on flavonoid content of red and white onion cultivars. *Food Control.* 21(6): 878-884.

Rodrigues AS, Pérez-Gregorio MR, García-Falcón MS, Simal-Gándara J, Almeida DPF (2011). Effect of meteorological conditions on antioxidant flavonoids in Portuguese cultivars of white and red onions. *Food Chem*. 124(1): 303-308.

Rodríguez-García C, Sánchez-Quesada C, Toledo E, Delgado-Rodríguez M, Gaforio JJ (2019). Naturally lignan-rich foods: A dietary tool for health promotion? *Molecules* 24(5): 917.

Rose P, Whiteman M, Moore PK, Zhu YZ (2005). Bioactive S-alk(en)yl cysteine sulfoxide metabolites in the genus *Allium*: the chemistry of potential therapeutic agents. *Nat. Prod. Rep.* 22(3): 351-368.

Sabha D, Hiyasat B, Grötzinger K, Henning L, Schlegel F, Mohr F-W, Rauwald HW, Dhein S (2012). *Allium ursinum* L.: Bioassay-guided isolation and identification of a galactolipid and a phytosterol exerting antiaggregatory effects. *Pharmacology* 89(5-6): 260-269.

Sagar NA, Pareek S, Benkeblia N, Xiao J (2022). Onion (*Allium cepa* L.) bioactives: Chemistry, pharmacotherapeutic functions, and industrial applications. *Food Front.* 3(3): 380-412.

Salehi B, Zucca P, Orhan IE, Azzini E, Adetunji CO, Mohammed SA, Banerjee SK, Sharopov F, Rigano D, Sharifi-Rad J, Armstrong L, Martorell M, Sureda A, Martins N, Selamoğlu Z, Ahmad Z (2019). Allicin and health: A comprehensive review. *Trends Food Sci. Technol.* 86: 502-516.

Simin N, Orcic D, Cetojevic-Simin D, Mimica-Dukic N, Anackov G, Beara I, Mitic-Culafic D, Bozin B (2013). Phenolic profile, antioxidant, anti-inflammatory and cytotoxic activities of small yellow onion (*Allium flavum* L. subsp. *flavum*, Alliaceae). *LWT-Food Sci. Technol.* 54(1): 139-146.

Slimestad R, Fossen T, Vågen IM (2007). Onions: A source of unique dietary flavonoids. *J. Agric. Food Chem.* 55: 10067-10080.

Sobolewska D, Michalska K, Podolak I, Grabowska K (2016). Steroidal saponins from the genus *Allium*. *Phytochem. Rev*. 15(1): 1-35.

Soininen TH, Jukarainen N, Auriola SO, Julkunen-Tiitto R, Karjalainen R, Vepsäläinen JJ (2014). Quantitative metabolite profiling of edible onion species by NMR and HPLC–MS. *Food Chem*. 165: 499-505.

Zhou Y, Li C, Feng B, Chen B, Jin L, Shen Y (2020). UPLC-ESI-MS/MS based identification and antioxidant, antibacterial, cytotoxic activities of aqueous extracts from storey onion (*Allium cepa* L. var. *proliferum* Regel). *Food Res. Int.* 130: 108969.