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Original article

STRUCTURE AND SOME BIOCHEMICAL CHARACTERISTICS OF QUINCE FRUITS (*CYDONIA OBLONGA* MILL.) FOR BREEDING CULTIVATED IN THE CONDITIONS OF THE MOSCOW REGION

E.V. Solomonova, N.A. Trusov, V.N. Sorokopudov, O.A. Sorokopudova, T.D. Nozdrina

In accordance with the policy of the Russian Federation, which, on the one side, is aimed at maintaining health and increasing the life expectancy of the country's population, and, on the other side, at import substitution, the maximum use of the food potential of domestic plants is required. One such plant is the quince (Cydonia oblonga Mill.). The range of wild quince is concentrated only on the Western and Southern coasts of the Caspian Sea. The aim of this work is to study the fruits of quince, cultivated in the conditions of the Moscow region and establishing the possibility of using it in breeding. The structure, morphometric and biochemical characteristics of quinces fruits, growing in the Moscow region, have been studied. It is shown that quince fruit well in the conditions of the Moscow region. Quinces fruits, ripen in the conditions of the Moscow region, have a typical morphologo-anatomical structure, the content of absolutely dry matter comparable with cultural forms, as well as a high content of ascorbic acid. The increased content of ascorbic acid in the fruits of quince plants, resistant to the conditions of the Moscow region, allows us to recommend them for use in breeding, to obtain high-vitamin cultivars. Nutritional use of fruits of quince can be non-waste, because both pericarp and seeds are rich in biologically active substances; there is a possibility of additional extraction of oils from oilcake after using the fruit pulp. Under the conditions of import substitution, the competitiveness and economic benefits from the use in the food industry of significantly smaller fruits of the quince, introduced in the northern regions, compared to imported fruits have been presuppose.

Keywords: *selection; quince; fruit; morphologo-anatomical structure; content of ascorbic acid; Moscow region*

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Научная статья

СТРОЕНИЕ И НЕКОТОРЫЕ БИОХИМИЧЕСКИЕ ОСОБЕННОСТИ ПЛОДОВ АЙВЫ (*CYDONIA OBLONGA* MILL.), КУЛЬТИВИРУЕМОЙ В УСЛОВИЯХ МОСКОВСКОГО РЕГИОНА, И ВОЗМОЖНОСТИ ЕЁ ИСПОЛЬЗОВАНИЯ В СЕЛЕКЦИИ

Е.В. Соломонова, Н.А. Трусов, В.Н. Сорокопудов, О.А. Сорокопудова, Т.Д. Ноздрина

В соответствии с политикой РФ, с одной стороны направленной на сохранение здоровья и увеличение продолжительности жизни населения страны, а с другой - на импортозамещение, требуется максимальное использование пищевого потенциала отечественных растений. Одним из таких растений является айва обыкновенная (Cydonia oblonga Mill.). Ареал дикорастущей айвы сосредоточен лишь на западном и южном побережьях Каспийского моря. Цель работы - изучение плодов айвы обыкновенной, выращиваемой в условиях Московского региона, и установление возможности ее использования в селекционной работе. Изучены строение, морфометрические и биохимические характеристики плодов айвы, произрастающей в Московском регионе. Показано, что айва хорошо плодоносит в условиях Московского региона. Плоды айвы, созревающие в условиях Московского региона, имеют типичное морфолого-анатомическое строение, содержание абсолютно сухих веществ, сравнимое с культурными формами, а также высокое содержание аскорбиновой кислоты. Повышенное содержание аскорбиновой кислоты в плодах растений айвы, устойчивых к условиям Московского региона, позволяет рекомендовать их для использования в селекции для получения высоковитаминных сортов. Пищевое использование плодов айвы может быть безотходным, так как и околоплодник, и семена богаты биологически активными веществами; есть возможность дополнительного извлечения масла из жмыха после использования фруктовой мякоти.

В условиях импортозамещения предполагается конкурентоспособность и экономическая эффективность от использования в пищевой промышленности значительно более мелких плодов айвы, интродуцированных в северных регионах, по сравнению с импортными плодами.

Ключевые слова: *селекция; айва; плоды; морфолого-анатомическое строение; содержание аскорбиновой кислоты; Московский регион*

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In accordance with the policy of the Russian Federation, which, on the one side, is aimed at maintaining health and increasing the life expectancy of the country's population [8], and, on the other side, at import substitution, the maximum use of the food potential of domestic plants is required [23]. There are numerous reports that ascorbic acid and fiber deficiency is found in more than half of Russians [12, 13, 15]. It is possible to qualitatively and quantitatively enrich the diet of the population of Russia by introducing new or used, but little-spread plants, especially woody ones, into industrial plantations. In replenishing the assortment of food plants, a significant role is played by the introduction of wild species in botanical gardens. Species with a wide ecological adaptation in cultural conditions are of particular value, because yield, size of fruits and the accumulation of useful nutrients in them depend on climatic conditions. It has been established that many introduced plants, including valuable food plants, grow well in the conditions of the Moscow region [23]. One such plant is the common quince (*Cydonia oblonga* Mill.).

Quince belongs to the Rosaceae Juss., tribe *Maleae* Small, the monotypic genus *Cydonia* Mill., represented by one species. *C. oblonga* is a shrub or tree 1.5-7 m tall, with a spherical crown and numerous root shoots. Quince is characterized by ecological plasticity and rather high resistance to abiotic stressors. The life expectancy of a quince is 35-60 years. The productive period of plantations lasts up to 20-30 years. [2, 3, 6, 11].

The origin of quince is connected with Eastern and Southern Transcaucasia and nearby regions of Western Asia and Iran. The range of wild quince is concentrated only on the Western and Southern coasts of the Caspian Sea. In culture, quince is common in the southern republics of the Caucasus and Central Asia, in the countries of Western and Southeastern Europe, Moldova and southern Ukraine, in Western Asia, Iran and Afghanistan, in the Balkans and throughout the Mediterranean, India, Pakistan, China, Australia, New Zealand, Africa, North and South America. Over the past 100-150 years, about 700 cultivars and forms of quince have been created in the world, and there are more than 200 ones in the Russian Federation [11].

For a long time it was believed that the area of quince growth is limited by the average annual air temperature - 8-9°C and the absolute minimum temperature -15°C [7]. In Russia, quince is traditionally cultivated in private gardens, rarely in industrial plantations, mainly in regions with a relatively warm climate - in the Volga region, Krasnodar Territory, Chechnya and Ingushetia. An analysis of the literature showed that quince is steadily moving north. It has been established that quince has no genetic restrictions for breeding winter-hardy varieties with large fruits: the genes responsible for fruit size traits are not linked to winter-hardiness genes. In St. Petersburg, the cultivation of common quince in open ground has been observed since 1908 [11]. In the Moscow region, winter-hardy forms of quince are also found, including those growing in urban conditions [5]. In 2002, at the Russian State Agrarian University - Moscow Timiryazev Agricultural Academy (MTAA), the first quince variety (Moskovskaya Susova) was bred and included in the State Register of Varieties of Russia, suitable for growing in the middle lane, with high winter hardiness and disease resistance [11]. Since 1939, quince has been undergoing introduction tests in the arboretum of the Tsytsin Main Botanical Garden of Russian Academy of Science (MBG RAS) [9]. In 2003, at the fruit station of the MTAA, more than 20 quince seedlings were planted, grown from seeds provided by A. I. Rilishkis from the Vilnius University Botanical Garden, Lithuania.

Information about the morphologo-anatomical structure of various parts of quince, especially its fruits, is relatively scarce and disordered. The fruits are citron or dark yellow apples. The pulp of the fruit is tart, but sweet and fragrant, tough due to numerous stony cells, it becomes juicy only after a long maturation. The length of the fruit of cultural forms is 5-15 cm. The mass reaches 1-2 and even 3 kg. In wild-growing plants, the fruits are much smaller: their length is 2.5-3.5 cm and their weight is about 200 g. In a mature apple, a large number of seeds are formed in each of the five loculs of quince fruits [4, 14]. About 50% of quince cultivares have fruits above average size (250-350 g), 32% are large (350-600 g). Large-fruitedness depends on the weather conditions of the growing season, especially on the availability of moisture, as well as on the age of the plants, which give smaller fruits over time [3].

The anatomical structure of the pericarp in the literature is described as follows. The cells of the epidermis are elongated radially, sometimes divided across into 2. Under the epidermis, 4 subzones are distinguished. Hypodermis (subzone I) of several layers of larger, round or oval cells. The tissue has large intercellular spaces. Below the hypodermis is subzone II of 14 layers of even larger cells. The widest subzone (subzone III) is observed below, occupying 2/3 of the mesocarp thickness. Its cells are radially elongated, even larger. The cells of subzones II and III contain druzes, numerous starch grains, and rare plastids. In the same subzones, there are groups of stony cells (they are absent in cultivated varieties). The number and size of stony cells increase towards the center of the fruit. Between subzones III and IV, sclereids form a discontinuous layer. Subzone IV forms the walls of fetal locules and is represented by loose thin hypha-shaped cells. The intercellular spaces of subzone IV are very large. The inner epidermis is composed of narrow long cells of various orientations. It is noted that large-fruitedness depends on the width of the subzones of parenchymal cells [16].

Pears and apple trees are of great industrial importance. However, unlike quince, their fruits are well suited for fresh consumption. European authors have recommendations that quince fruits, due to hardness, acidity and astringency, should not be eaten without pre-treatment, it is advisable to preserve them in the form of jam, jam, jelly, liqueurs and marmalade. [24, 25]. In the southern zone of Russia (in Kabardino-Balkaria, in the Krasnodar Territory, in the Crimea), quince fruits are also a very valuable raw material for the canning industry, because they are well stored for 2 to 3 months after harvest in late September - early October, when there is a shortage of traditional processed products - apples and pears at canning factories [1].

Quince fruits contain significant amounts of carbohydrates, organic acids, amino acids, vitamins, tannins, minerals, as well as ascorbic acid (the content of ascorbic acid increases when quince is grown in the northern regions) and pectin substances. In account to pectin substances, ascorbic acid and catechins are well preserved in fresh fruits [11]. Quince fruits are rich in polyphenols. In ripe quince fruits, flavonols, catechins, and leucoanthocyanins are localized mainly in the peel (2–3 times more than in the pulp), while chlorogenic acid is localized in the pulp [21, 22]. The biochemical composition of quince determines its antioxidant, antimicrobial, and antiulcer effects [18–20]. It is noteworthy that during the industrial production of jam, the antioxidant properties of quince fruits do not decrease, although the phenolic profile changes qualitatively and quantitatively [17].

Currently, quince, unfortunately, is not given due attention. There are practically no industrial plantations in Russia. The areas occupied by this crop are insignificant and consist mainly of small scattered plantations, which have almost no commercial value. In the production of juices, nectars, jams, imported fruits are often used, although domestic quince can compete with them. It is possible that the fruits of quince, widely involved in food production as a raw material, will be able to satisfy the need of Russians for valuable nutrients, especially for the most deficient pectin and ascorbic acid.

The aim of this work is to study the fruits of common quince, cultivated in the conditions of the Moscow region. For a comprehensive analysis of mature fruits and seeds of *C. oblonga*, the following tasks were set:

- analysis of their morphologo-anatomical structure (fruits from the arboretum of the MBG RAS and fruits from free sale taken for comparison);
- determination of their morphometric parameters (fruits from the arboretum of the MBG RAS and from the fruit station of the TMAA);
- determination of the content of air-dry and absolutely dry matter in fruits (fruits from the arboretum of the MBG RAS and fruits from free sale taken for comparison);
- determination of the content of ascorbic acid in fruits (fruits from the arboretum of the MBG RAS and fruits from free sale taken for comparison);
- determination of the content of crude fat in seeds (fruits from the arboretum of the MBG RAS).

In the conditions of the Moscow region, data on the introduction of *C. oblonga* were obtained. The phenospectrum of the culture is shown, morphologo-anatomical features of plant fruits are revealed, the characters of fruiting, weight and size of quince fruits are studied. The data obtained make it possible to carry out breeding work with this culture in the Moscow Region in order to create horticultural cultivars with a complex of economically valuable traits for gardeners and farms.

Materials and methods

Objects of study: mature fruits of *C. oblonga* collected in the arboretum of the MBG RAS. Experimental quince plants represent their own reproduction of the MBG RAS, obtained as a result of free crossing of collection plants from various botanical gardens and experimental stations of the former USSR. For comparison, imported fruits of *C. oblonga* from free sale were used. Seedlings growing in the Schroeder arboretum (TMAA), obtaining from seeds from free crossing of various cultivars of quince in the Moscow.

Fresh fruits and seeds were measured using a caliper II-250-0.05 (measurement error 0,05 mm). The morphometric parameters of the objects (the length and diameter of the fruit, the length and width of the seeds) were measured using calipers at the most prominent points on their surface. Seeds and pericarp were weighed separately on a Pocket Scale ML-A03 after drying at a temperature of 20-25ºC to an air-dry state.

Material for morphological and anatomical studies was fixed in a 70 % ethanol solution. Peeling of skin, longitudinal and transverse sections of fruit and seeds were performed manually using a Gillet razor blade. The water and glycerin unpainted preparations prepared from them were studied with the use of a Biolam LOMO light microscope with camera attachments as light modifiers. Observation results were documented by pictures taken using a Canon EOS 650D camera with a Sigma 150 mm 1: 2.8 APO Micro DG HSM macro lens.

The content of air-dry and absolutely dry matter in fruit and their parts was investigated on the standard methodology [10]. Samples were weighed on an electronic Pocket scales ML-A03, ground them in an electric grinder (ZMM), and dried in a SUPRA DFS-211 drying oven.

The content of ascorbic acid in the air-dried fruit was determined by the iodometric method in accordance with GOST 7047-55 by the way of titration with a solution of iodine potassium (KIO_3) the samples for the hydrochloric acid extracts of plant raw materials (2 % HCl), which were mixed with 1 % solution of potassium iodide and 0.5 % solution of starch [15].

The determination of the oil content in the samples was performed with the dry skim residue method. Crude fat had been extracted with chloroform from the ground air-dried material for two weeks.

The repeat count in the experiments is 5. All the obtained material was processed by the methods of variation statistics. The chemicals were commercially available as pure chemicals.

Additionally, the volume of the seeds occupied in relation to the fruit and the ratio of the mass of the pericarp and seeds in relation to the fruit were determined.

We also studied mature fruits of *C. oblonga* collected at the fruit station of the TMAA. We studied the size and weight of fruits and seeds. The mass of fruits and seeds, the length and diameter of fruits and the thickness of the pericarp were determined. The number of seeds in the fruit was counted, and their share in the weight of the fruit was determined.

The coldest month of 2020 (year of research) is December, the average monthly temperature is -4.4°C. The warmest month is June, with an average monthly temperature of 18.9°C and a monthly rainfall of 159 mm. The maximum amount of rainfall in 2020 fell in July - 175 mm. And the minimum amount of rainfall fell on April - 29 mm. The average annual temperature was 8.0°C and the annual rainfall was 901 mm. The growing degree days in 2020 (more than 10°C) is 2630°C (table 2).

Table 1.

Average monthly and annual air temperatures and rainfall in Moscow

	January	February	March	April	May	June	July	August	September	October	November	December	Year
t_{air}, °C	0.1	-0.3	3.8	4.8	11.7	18.9	18.7	17.6	13.9	9.2	2.2	-4.4	8.0
rainfall, mm	55	40	49	29	160	159	175	34	65	55	50	31	901

Table 2.

Growing degree days in 2020

> 0°C	> 5°C	> 10°C	> 15°C
3132	3084	2630	1891

Results and discussion

Morphologo-anatomical features of mature fruits and seeds of *C. oblonga* from MBG RAS and free sale, corresponding to the previously given literature data, are shown in the fig. 1.

The fruits are spherical apples. Domestic and imported fruits differ in color (green or yellowish versus yellow, respectively), surface pubescence (present only in fruits from the MBG RAS) and size (much smaller in the Moscow region).

The epidermis of the fruit is formed by a single layer of small radially elongated cells. The outer walls of the epidermal cells are covered with a rather thick cuticle layer extending into the anticlinal intercellular spaces. Fruit hypodermis consists of 5-6 layers of rounded, small, densely located collenchymal cells with thickened cell membranes. Mesocarp is multilayered. The parenchymal cells are thin-walled, large, increasing in size and extending radially from the periphery of the fruit to the center within this zone. Radially more elongated cells of the parenchyma are located in the middle part of the pericarp. In the thickness of the pericarp, closer to the periphery, there are small groups of sclereids, surrounded by radially elongated parenchymal cells of smaller size than the main part of parenchymal cells, and derivatives of vascular bundles. In the middle part of the pericarp, there are derivatives of larger vascular bundles, surrounded by sclereides. Small druses are sometimes presence in the parenchymal cells. Meso-endocarp is unlignified, relatively soft, «cartilaginous». It is represented by thick-walled sclereides and less thick-walled fibers, elongated along the axis of the fruit, as well as areas formed by relatively small parenchymal cells. In this zone of the pericarp, there are derivatives of large vascular bundles (ventral carpel vascular bundles) that are reinforced with sclerenchymal tissue.

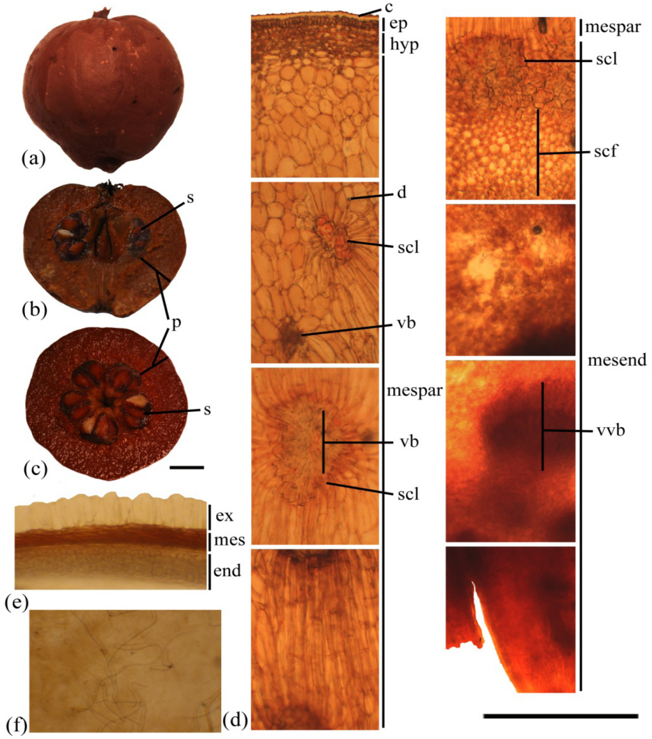

Figure 1. Morphologo-anatomical structure of fruits *Cydonia oblonga* collected in MBG RAS arboretum (a-e) and from sale (f). (a) – side view of fruit; (b) – longitudinal section of fruit; (c) – cross section of fruit; (d) – anatomical structure of pericarp (cross section); (e) – anatomical structure of seed coat (cross section); (f) – fragment of pericarp with hypha-shaped cells. c – cuticle; d – druses; ep – epidermis; hyp – hypodermis; mesoend – «cartilaginous» mesoendocarp; mespar – mesocarp parenchyma; p – pericarp; s – seed; scf – sclerenchyma fibers; scl – sclereides; vb – derivatives of vascular bundle; vvb – ventral vascular bundle of carpel. Scale bar: (a-c) - 1 cm, (d-f) – 1 mm.

In tissues of the pericarp of quince from a free sale (cultivars), long narrow cells similar to fungal hyphae were found. According to the literature, such cells are characteristic of the pericarp zone adjacent to the inner epidermis. Such cells were not found in the quince pericarp from the arboretum of the MBG RAS.

The seed coat is made up of several layers of cells. Exostesta cells are radially elongated, thin-walled, with transparent contents. Below it there are several layers of thick-walled elongated cells. The endosperm is well- developed, represented by several layers of isodiametric polygonal cells without intercellular spaces. The embryo is differentiated and occupies a large volume. It is represented by both rounded and radially elongated cells. A large number of vascular bundles are observed in the embryo.

The results of the study of the size and weight characteristics of fruits and seeds of *C. oblonga* from the MBG RAS and from the fruit station of the TMAA are presented in tables 3 and 4.

The weight of fresh fruits from the TMAA fruit station is 35.53 ± 2.42 g. The sizes of quince fruits from the MBG RAS arboretum and from the TMAA fruit station are comparable: fruit length is 41.40 ± 1.75 and 40.15 ± 1.41 mm, respectively; fruit diameter - 46.80±1.24 and 37.43±0.79 mm, respectively. The thickness of the quince pericarp from the fruit station of the TMAA is 10.37 ± 0.48 mm. In the quince fruit from the fruit station TMAA, there are from 17 to 59 seeds (32.25 ± 2.03 on average), which is 4.81 ± 0.31% of the fruit weight. The mass of seeds from an air-dry fruit in the arboretum of the MBG RAS is about 14.07%, while the volume of seeds in relation to a fresh fruit is about 2.7%. The mass of the pericarp in an air-dry fruit is about 85.93%, respectively. The estimated weight of 1000 seeds from the fruit station of the TMAA is 51.61 ± 2.33 g. The size of the seeds from the arboretum of the MBG RAS is 7.02 ± 0.10 × 3.76 ± 0.09 mm.

According to S. V. Klimenko [11], the ratio of pericarp and seeds in quince depends on the variety, fruit size, degree of maturity, and environmental conditions. Usually, the pericarp accounts for 86.9-91.6% (of which 1.5-2.9% for the peel), and the seeds - 0.32-2.46% of the fruit. The data obtained by us fit well into the ratios of fruit parts characteristic of quince.

Water content of *C.oblonga* fruit parts is characterized by the data from table 3. In addition, table 3 contains information about the content of raw fat in the seeds. Table 5 shows that the water content of the air-dry pericarp of quince from free sale significantly (according to the t-criterion) exceeds this indicator for quince from the MBG RAS arboretum. The content of absolutely dry matter is 62.65±1.03% versus 87.87±0.19%. The difference between the content of absolutely dry matter in dry seeds is insignificant.

Table 3.

Morphometric characteristics of fruit of *C. oblonga* and their parts (MBG RAS)

Characteristic	Max	Min	$M \pm m_M$	tm_M	V, %	P, %
Fruit length, mm	46,00	37,00	41,40±1,75	4,86	9,45	4,26
Diameter of fruit, mm	51,00	44,00	46,80±1,24	3,45	5,93	2,65
Seed length, mm	9,00	5,00	7,02±0,10	0,30	14,97	2,14
Seed width, mm	5,00	2,00	3,76±0,09	0,24	22,10	3,16
Mass of air-dry single fruit, g	15,58	4,34	8,01±0,22	0,61	3,78	32,11
Mass of air-dry single seed, g	0,028	0,022	0,02±0,0003	0,001	1,90	8,48

Note: Max – the maximum value; Min – the minimum value; M±mM – the arithmetic mean and its error; tmM – the confidence interval; V – the coefficient of variation; P – the experimental accuracy index for the standard 95% confidence level (experimental accuracy is considered satisfactory at values of indicator not exceeding 5%).

Table 4.

Morphometric characteristics of fruit of *C. oblonga* and their parts (TMAA)

Characteristic	$M \pm m_M$	tm_M	V, %	P, %
Fruit weight, g	35,53 ± 2,42	5,07	30,51	6,82
Fruit length, mm	40,15 ± 1,41	2,96	15,74	3,52
Diameter of fruit, mm	37,43 ± 0,79	1,61	13,43	2,12
Thickness of the pericarp, mm	10,37 ± 0,48	1,00	20,58	4,60
Number of seeds per fruit, pcs.	32,25 ± 2,03	4,24	28,09	6,28
Share of seeds in fruit weight, %	4,81 ± 0,31	0,65	28,88	6,46
Weight of 1000 seeds, g	51,61 ± 2,33	4,87	20,16	4,51

Note: see table 1.

Quince seeds from the MBG RAS arboretum accumulate about 16% of crude fat, which indicates the prospects for their use as a source of fatty oils.

Table 5.

Biochemical characteristics of fruit and their parts for *C. oblonga* (MBG RAS)

Characteristic	Max, %	Min, %	$M \pm m_M$, %	tm_M	V, %	P, %
Content of absolutely dry matter in pericarps, %	89,47 (64,89*)	86,36 (59,15*)	87,87±0,19 (62,65±1,03*)	1,43 (2,85*)	1,313 (3,67*)	0,59 (1,64*)
Content of absolutely dry matter in seeds, %	84,50 (83,63*)	69,53 (75,00*)	78,18±2,58 (79,06±0,93*)	7,17 (5,10*)	7,39 (5,20*)	3,30 (2,32*)
Content of crude fat in seeds, %	20,20	13,95	15,78±1,50	4,16	14,89	7,44

Note: see table 1; * – comparative data for *C. oblonga* from free sale.

In fruits from the arboretum of the MBG RAS, the content of ascorbic acid is 57 mg%. For comparison, according to S. V. Klimenko [11], the content of ascorbic acid in quince fruits depends on the amount of precipitation during the growing season, during fruit ripening and immediately before harvesting. In different regions, the content of ascorbic acid in quince fruits is different, for example, in Armenia on average – 13.9 mg%, in Moldova – 17.0 mg%, in the Lower Volga region – 21.7 mg%, and in Ukraine it can reach up to 458.7 mg%. These data indicate that the fruits of quince growing in the Moscow region have a rather high content of ascorbic acid.

Conclusion

Quince fruit well in the conditions of the Moscow region. The fruits ripen, have a typical morphologo-anatomical structure, the content of absolutely dry matter comparable with cultural forms, as well as a high content of ascorbic acid.

Nutritional use of fruits *of C. oblonga* can be non-waste, because both pericarp and seeds are rich in biologically active substances; there is a possibility of additional extraction of oils from oilcake after using the fruit pulp.

Thus, the competitiveness and economic benefits of using in the food industry significantly smaller fruits of introduced *C. oblonga* in comparison with imported fruits are presuppose.

Conflict of interests. The authors declare no conflict of interest.

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AUTHOR CONTRIBUTIONS

The authors contributed equally to this article.

ВКЛАД АВТОРОВ

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DATA ABOUT THE AUTHORS

Ekaterina V. Solomonova, Cand. Sc. (Biology), Assistant professor, Associate Professor of the Department of Botany, Breeding and Seed Production of Garden Plants
Russian State Agrarian University - Moscow Timiryazev Agricultural Academy
49, Timiryazevskaya Str., Moscow, 127550, Russian Federation
solomonova_k@mail.ru
SPIN-code: 3324-7723
ORCID: https://orcid.org/0000-0003-0061-4080
ResearcherID: ABF-2570-2021
Scopus Author ID: 57193072963

Nikolay A. Trusov, Cand. Sc. (Biology), Senior Researcher, Laboratory of Dendrology

Tsytsin Main Botanical Garden of Russian Academy of Sciences
4, Botanicheskaya Str., Moscow, 127276, Russian Federation
n-trusov@mail.ru
SPIN-code: 2193-2203
ORCID: https://orcid.org/0000-0002-5147-6602
ResearcherID: J-2180-2018
Scopus Author ID: 55883940800

Vladimir N. Sorokopudov, Doctor of Agricultural Sciences, Professor, Leading Researcher, Laboratory of Chemistry of Natural Compounds
All-Russian Scientific Research Institute of Medicinal and Aromatic Plants
7, Grin Str., Moscow, 117216, Russian Federation
sorokopud2301@mail.ru

Olga A. Sorokopudova, Doctor of Biological Sciences, Professor, Head of the Department of Plant Resources
All-Russian Scientific Research Institute of Medicinal and Aromatic Plants
7, Grin Str., Moscow, 117216, Russian Federation
osorokopudova@yandex.ru

Tatiana D. Nozdrina, Cand. Sc. (Biology), Assistant professor, Associate Professor of the Department of Botany, Breeding and Seed Production of Garden Plants
Moscow State University of Food Production
11, Volokolamskoe Highway, 125080, Moscow, Russian Federation
biomgupp@yandex.ru
SPIN-code: 6348-7597
ORCID: https://orcid.org/0000-0003-2589-4787
ResearcherID: G-2333-2018
Scopus Author ID: 57193079250

ДАННЫЕ ОБ АВТОРАХ

Соломонова Екатерина Владимировна, канд. биол. наук, доцент, доцент кафедры ботаники, селекции и семеноводства садовых растений
Российский государственный аграрный университет – МСХА имени К.А. Тимирязева

ул. Тимирязевская, 5, г. Москва, 127550, Российская Федерация
solomonova_k@mail.ru

Трусов Николай Александрович, канд. биол. наук, старший научный сотрудник Лаборатории дендрологии
Главный ботанический сад им. Н.В. Цицина Российской академии наук
ул. Ботаническая, 4, г. Москва, 127276, Российская Федерация
n-trusov@mail.ru

Сорокопудов Владимир Николаевич, д-р с.-х. наук, профессор, ведущий научный сотрудник Лаборатории химии природных соединений
ФГБНУ ВИЛАР
ул. Грина, 7, г. Москва, 117216, Российская Федерация
sorokopud2301@mail.ru

Сорокопудова Ольга Анатольевна, д-р биол. наук, профессор, заведующая отделом растительных ресурсов
ФГБНУ ВИЛАР
ул. Грина, 7, г. Москва, 117216, Российская Федерация
osorokopudova@yandex.ru

Ноздрина Татьяна Дмитриевна, канд. биол. наук, доцент, доцент кафедры биологии и биологической безопасности
Московский государственный университет пищевых производств
11, Волоколамское шоссе, 125080, г. Москва, Российская Федерация
biomgupp@yandex.ru

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