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FOOD POTENTIAL OF ALTERNATIVE POME FRUIT TREES CULTIVATED IN MOSCOW REGION

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Abstract: The research is aimed at finding new sources of food raw materials for the industrial use at the expense of alternative pome fruit trees (*Maleae* Small) cultivated in the middle zone of the Russian Federation. The mature fruits of medlar (*Mespilus germanica* L.), quince (*Cydonia oblonga* Mill.) and hawthorns (*Crataegus submollis* Sarg. and *C. punctata* Jacq.) were studied. A rapid analysis of the methods of classical botanical study of morphology, anatomy and morphometry, with the addition of biochemical samples for vitamin C and oil content, was performed.
The studied pome fruits are promising for the food use, as well as possibly competitive compared to imported analogues.

Keywords: *ascorbic acid, dietary fibers, fruit, non-native plants, nontraditional raw material, nutrients, oil content, pericarp, rapid analysis, seeds, vegetable*

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INTRODUCTION

The global problem of our time is lack of food resources. Due to the fact of significant global environmental deterioration over the past 100-150 years, vast biogeochemical provinces, where a steady decrease of the element content in drinking water, plant and animal products [1], are emerging. About 80 % of population is fiber-deficient [2]. The vitamin C deficiency is revealed in 60-80 % of Russians and in, some countries, people still die of scurvy [3, 4].

The lack of vitamins is massive and year-round due to the need to reduce the volume of incoming food in connection with the reduction of energy consumption of modern man at the increased norms of physiological consumption of many vitamins, use of highly refined products, inability of the body to accumulate many vitamins for the future, unbalanced diets, loss of vitamins in the culinary processing of products, bad habits, *etc.* [5].

A promising direction of the vitaminization of population is enriching food products with vitamins and microelements and the use of vitamin-mineral complexes for mass consumption [5 – 7].

It is possible to enrich foods to the optimum level with necessary nutrients by introducing safe and environmental-friendly alternative raw materials of plant origin, including those from wild plants [8 – 10] into economic and food circulations. The research on alternative pome plant fruits is currently underway [11 – 20].

Harvesting wild growing plants in natural habitats presents such technical difficulties as geographical distance of plants, lack of roads, unnecessary impurities, pollution, etc. and involves some problems with ecological and biological features of plants (dispersion of certain growing species, compliance with the rules of harvesting, etc.). An alternative could be making plantations of valuable plants in nurseries [21]. A variety of fruit plants cultivated from the world flora is presented in collections of botanical gardens. According to the results of a comprehensive assessment, the most promising species can become the basis for cultivation.

It is a well-known fact that both vegetative and generative parts of plants unevenly accumulate substances, including biologically active ones. The angiosperm fruits that are evolutionarily designed to protect, nourish and disperse seeds - future off springs - accumulate substances which are the most physiologically significant. The plant variety of morphological fruit types is large in the world. The endozoochoric propagation of seeds has led to the fleshy fruit pulp formation, attractive to disseminators. In different flowering plant taxa, a variety of flower structures can grow out during the formation of a fleshy pericarp, such as ovary wall, flower tube, seed outgrowth, etc. The biochemical specialization of the substance deposition in a fruit pulp is closely related to the dynamics of growth, structure, terms of isolation for a fruit pulp and seeds. The obvious connection of fruits functioning with their morphological and anatomical structure explains the need for their careful and scrupulous study by microscopy, measurements and weighing. Based on the botanical assessment, it is possible to draw conclusions about the nature, location and substance abundance accumulated in a pomiferous fruit and its components. Obtaining a model of developing a mellow fruit is necessary for optimizing the terms of raw material harvesting and identifying the possibilities of its most appropriate and complete use, as well as plant breeding, for example, to increase the size of most valuable parts of a fruit.

The fruits of tribe *Maleae* are pentameric hemi-symphycarpous pomes [22, 23]. Gynaeceum and its overgrown hypanthium, becoming fleshy during their ripening, are involved in the process of apple formation. Hypanthium is a flower tube formed by lower parts of sepals, petals and stamens accreted together among themselves and with each other. In a mature pome, the carpel tissues are differentiated into a leather-like cartilaginous endocarp, lining the cavity of the ovary locules, and a fleshy exo-mesocarp merging with the hypanthia pulp. Its seeds (stones) are large, oval-oblong or pear-shaped, sometimes angular, dark brown, smooth and shiny. The seed skin, formed from the outer integument of a two-covering ovule, is multi-layered [22, 23].

The alternative representatives of pome fruit trees for the Moscow region - *Mespilus germanica* L. (medlar), *Cydonia oblonga* Mill. (Quince), *Crataegus submollis* Sarg. and *Crataegus punctata* Jacq. (Quebec hawthorn and dotted hawthorn), that underwent introduction tests in the arboretum of N.V. Tsitsin Main Botanical Garden of the Russian Academy of Sciences (MBG of RAS), became the materials of our research due to their general reliability under rough conditions and abundant fruiting compared with other types of pomes, in accordance with preliminary observations and the literature analysis.

The group of pome fruit trees (tribe *Maleae*) includes 25 genera and about 600 species growing mainly in the temperate zone of the Northern Hemisphere. The taxonomic revision of pome fruit trees, including molecular signatures, revealed an intensive evolution of some species and the possibility of their hybridization (*Pyrus* L. and *Chaenomeles* Linll., *Malus* Mill. and *Pyrus*, *Crataegus* L. and *Sorbus* L.), despite their significant genetic differences. Large traditional fruit plant genera are apple tree (*Malus*), pear tree (*Pyrus*), hawthorn (*Crataegus*) and rowan (*Sorbus*) [24]. The fruits of smaller genera of quince (*Cydonia* Mill.) and medlar (*Mespilus* L.) are also edible. There are insufficient data in the literature on the morphological and anatomical structure, fruit morphometry and the biochemical composition for their widespread use as a plant material.

MATERIALS AND METHODS

Most of the wild growing forms of medlar are concentrated in the forest vegetation of foothills in the south and south-east of Asia Minor, Northern Iran and also in the Caucasus. This plant can grow not only in natural conditions, but also in those of cultivation. Medlar is not cultivated in large quantities in Russia. It can be found only in botanical and private gardens. In the area of the MBG RAS arboretum, medlar is represented by 5 plant species (19 specimens) planted in 1949. At the time of fruit gathering, the average height of the plants was 3.8 m. The crown diameter was 3.5-4 m.

Quince grows well and bears fruits in the cultivation of Moscow region. Since 1939, 12 plant samples (78 specimens) with a height up to 3 m and with a crown diameter up to 2 m have been growing in the MBG RAS.

Concerning hawthorns on a production scale, they have never been grown on Russian plantations, although, in some countries, they are used as cultivated fruit plants. In the Moscow region, hawthorn can be found in amateur gardens, and some species - only in botanical gardens. On the *C. submollis* side, it has been cultivated in the arboretum of

the MBG RAS since 1939 and is represented by 4 samples (11 specimens) reaching 9 m in height; *C. punctata* - since 1958, 4 samples (6 specimens) up to 8 m high [25].
The mature fruits of *M. germanica, C. oblonga, C. submollis and C. punctata* cultivated in the arboretum of the MBG RAS are the objects of our research. The *C. oblonga* fruits imported from the free sale have been studied for comparison.
It is known that the biochemical composition of seeds and pericarps in the plant mature fruits used as vitaminized plant materials is not the same [13]. In our studies, the stones (seeds) and fruit pulp were considered independently of each other; their sizes, weight, locules in the fruit and the possibilities of shared or distributed use were determined.
The material for morphological and anatomical studies was fixed in a 70 % ethanol solution. The skin peeling, longitudinal and transverse sections of fruit and seeds (stones) were performed manually using a Gillet razor blade. The water and glycerin unpainted preparations made from them were studied with the use of a Biolam LOMO light microscope with camera attachments as light modifiers. The observation results were documented by the pictures taken using a Canon EOS 650D camera with a Sigma 150 mm 1: 2.8 APO Micro DG HSM macro lens.
The morphometric parameters of the objects (the fruit length and diameter, length and width of seeds or stones) were measured using calipers at the most prominent points on their surface.
The content of air-dry and absolutely dry matter in fruits and their parts was investigated on the standard methodology [26]. The samples were weighed on an electronic Pocket scales ML-A03, ground in an electric grinder (ECMO model IPZO) and dried in a SUPRA DFS-211 drying oven.
The content of ascorbic acid in air-dry fruits was determined by the iodometric method in accordance with GOST 7047-55 by the titrating with a potassium iodide solution (KIO_3) of the samples of plant raw material hydrochloric extracts (2 % HCl) mixed with the 1 % potassium iodide solution and 0.5 % starch solution [3].
The determination of oil content in the samples was performed with the dry skin residue method. Crude fat was being extracted with chloroform from the ground air-dried material for two weeks.
The number of counting repeats was not less than 4 in the experiments. All the obtained material was processed by the methods of variation statistics [27]. The chemicals were commercially available as pure chemicals.

RESULTS AND DISCUSSION

We found that the fruits of the studied unconventional pome fruit plants correspond to the literary descriptions [19, 28], and they are morphologically (Table 1) and anatomically (Table 2) similar. They have a rounded or slightly elongated shape; fruits have the remains of sepals. The same histological zones are distinguished in fruits: small cell monolayer epiderm with a cuticle, small layer hypoderm, multilayered parenchyma of the mesocarp (the main zone of the fruit fleshy part) and sclerenchymatized meso-endocarp. In the parenchymal zone, there are derivatives of vascular bundle, sclereides (exception of *C. punctata*) and a few cells with druses.
Numerous oil inclusions were found in the endosperm cells of quince, and the hyphae of fungi (ascomycetes) were found in the locules of the quince fruit from free sale.

The very hard medlar stones are completely immersed in the pulp. In fresh fruits, it is difficult to separate them from parenchyma. In dried medlar and hawthorn fruits, the stones, practically, do not separate from the fleshy part of the pericarp, which must be taken into account in the industrial use of raw materials.

Table 1. *Morphological structure of fruits and their parts*

Indicator	*M. germanica*	*C. oblonga*	*C. submollis*	*C. punctata*
Fruit shape	Varies from obovate to oblong-elliptical. Apple-shaped, cubic and compressed-spherical shapes, mentioned in the literature, not found	Rounded in the fruits of MBG RAS; spherical in fruits from free sale	Elongated; fruits are firm, smooth	More rounded compared to the shape of the fruits of *C. submollis*; fruits are dense, smooth
Fruit surface	Red-ginger color, covered with thin and hard hairs	Green or yellowish, pubescent (MBG RAS); yellow, no pubescence (free sale)	Reddish, slightly fleecy	Red-ginger color, covered with small dark dots
Sepals on fruits	Large, well-preserved, constantly deployed	Small, poorly preserved	Medium size, partially preserved	Medium size, partially preserved
Characteristics of stones (seeds)	The number of stones in all samples studied was 5, never 4. The stones have the shape of an irregular trihedron; wrongly striated; light brown	A large number of brown seeds of elongated-pointed shape in each locule of the ovary	The number of stones varies, reaching a maximum of 5. They are small, ovate-pointed, beige, with a dense, porous, sclerenchymatized cover	Usually fruits contain 4 stones. The stones are larger than those of *C. submollis*, ovoid, grayish, with a harder cover

Table 2. *Anatomical structure of fruits and their parts*

Indicator	*M. germanica* (Fig. 1, A)	*C. oblonga* (Fig. 1, B)	*C. submollis* (Fig. 1, C)	*C. punctata* (Fig. 1, D)
Fruit epiderm	Single layer; cells are small, tabular; with a cuticle	Single layer; cells are small, slightly radially elongated; with a cuticle	Single layer; cells are small, tabular; with a cuticle	Single layer; cells are small, tabular; with a cuticle
Fruit hypoderm	Consists of 2 layers of tabular cells, similar to the epidermis. In the literature, the epidermis and the underlying hypoderm stand out as a periderm [27]	Consists of 5-6 layers of rounded, small, densely located cells with thickened cell membranes	Consists of 2 layers of small tabular cells with colored contents	Consists of 2 layers of small tabular cells with thickened cell membranes

***Table 2.** Anatomical structure of fruits and their parts (continued)*

Indicator	*M. germanica* (Fig. 1, A)	*C. oblonga* (Fig. 1, B)	*C. submollis* (Fig. 1, C)	*C. punctata* (Fig. 1, D)
Mesocarp parenchyma	Multi-layered. Cells are large, their size increases from the fruit periphery to the center. Over the greater part of the parenchymal zone, the cells are slightly flattened aderdermally; closer to the stone, they are extended radially	Multi-layered. The cells are thin-walled, large, increasing in size and extending radially from the fruit periphery to the center within this zone. Radially more elongated cells of the parenchyma in the middle part of the pericarp	Multi-layered. Cells larger than the cells of the epidermis and hypoderm, rounded, of relatively equal size, densely arranged; their radial elongation is observed only in several layers of cells adjacent to the stone	Multi-layered. Cells are large, as well as in *C. submollis*, but their shape is more oval (in cross-section), the arrangement is more intercellular ductes, there are large intercellular spaces, especially in the peripheral part. Radial elongation of cells is observed not only in the layers adjacent to the stone, but also in the middle part of the fleshy mesocarp
The presence of derivatives of vascular bundle and sclereids in the mesocarp	The derivatives of the vascular bundle, as well as the sclereids, are arranged in small groups or singly	In the pericarp thickness, closer to the periphery, there are small groups of sclereids, surrounded by radially elongated parenchymal cells of the size smaller than the main part of parenchyma cells, and derivatives of vascular bundle. In the middle part of the pericarp slice, there are derivatives of larger vascular bundle surrounded by sclereides	In the parenchyma, there are derivatives of vascular bundle and single sclereides	There are derivatives of vascular bundle. Sclereides not found
The presence of druses and plastids in the fruit parenchyma	Sometimes, there are small druses in the cells	Sometimes, there are small druses in the cells	Druses are larger than in the cells of medlar and quince. Chromoplasts are also found in cells	

Table 2. *Anatomical structure of fruits and their parts (continued)*

Indicator	*M. germanica* (Fig. 1, A)	*C. oblonga* (Fig. 1, B)	*C. submollis* (Fig. 1, C)
Fruit meso-endocarp	Presented by the sclereides, which form the hard part of the stone	Relatively soft, "cartilaginous". It is represented by thick-walled sclereides and less thick-walled fibers, elongated along the fetus axis, as well as the areas formed by relatively small parenchymal cells. In this pericarp zone, there are derivatives of large vascular bundles (ventral carpel vascular bundles) that are not reinforced with a sclerenchymal tissue	The stone tissue is sclereides
Comparative characteristics of the fleshy part of the fruit	The least powerful of all the studied plant fruits	The most powerful of all the studied plant fruits	According to the thickness of the fleshy part of the pericarp, the studied hawthorn fruits occupy the intermediate position between medlar and quince

Dimensional, weight and biochemical characteristics of fruits and their parts are presented in Tables 3 and 4.

Table 3. *Morphometric indicators of fruits and their parts*

Indicator	*M. germanica*	*C. oblonga*	*C. submollis*	*C. punctata*
Fruit length [mm]	27.00±4.50*	41.40±4.85	18.50±4.40	16.21±2.80
Fruit diameter [mm]	21.00±9.70	46.80±3.45	17,21±4,11	17.01±2.89
Stones length (seed) [mm]	8.30±0.64	7.02±0.30	7.01±0.23	9.02±0.17
Stones width (seed) [mm]	5.80±0.16	3.76±0.24	5.20±0.27	6.02±0.19
Air-dry fruit mass [g]	54.00	97.33	86.62	89.41

* - $M \pm tm_M$

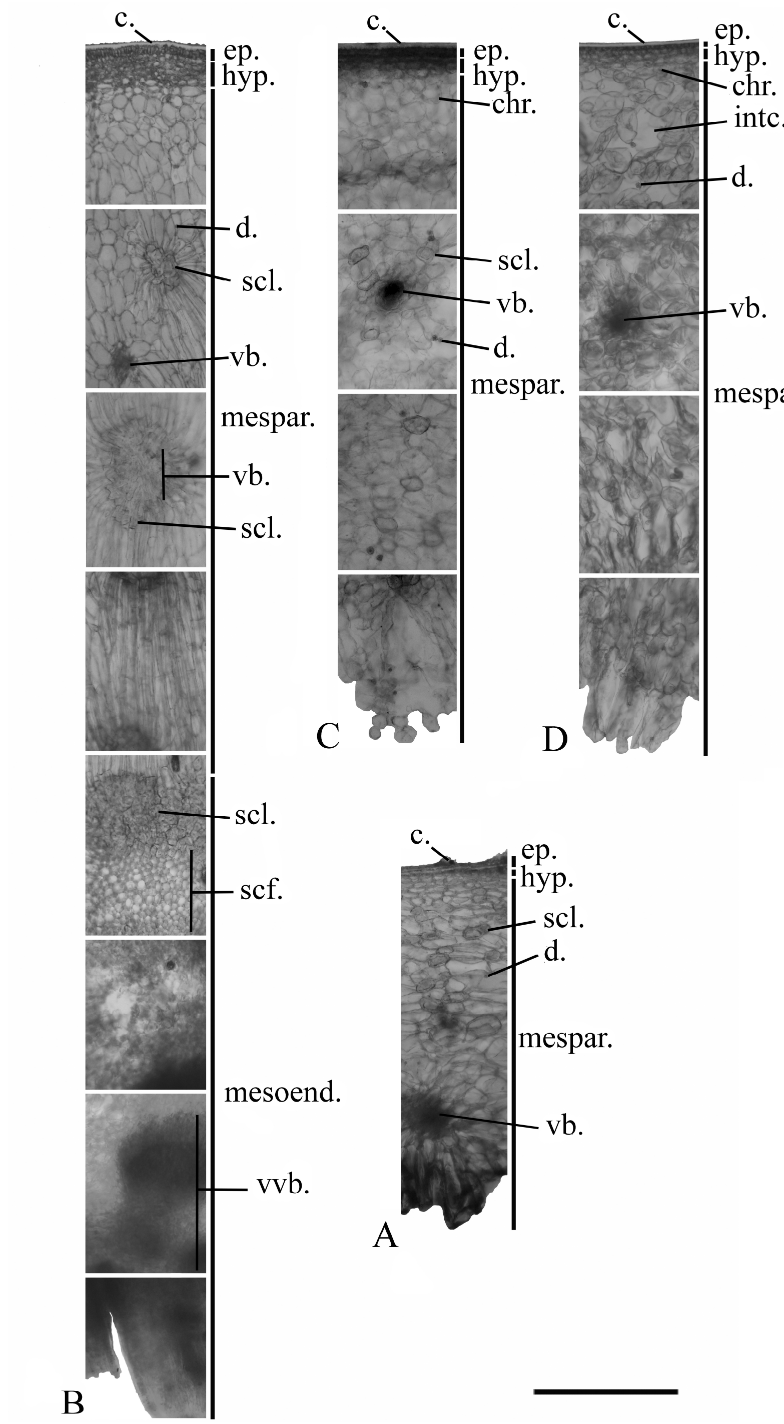

Figure 1. *Anatomical structure of the fruit of alternative pome plants collected in the MBG RAS arboretum (cross-sections)*

In Figure 1, A is the fleshy part of the pericarp of *Mespilus germanica*; B is pericarp *Cydonia oblonga*; C is the fleshy part of the pericarp of *Crataegus submollis*; D is the fleshy part of the pericarp of *Crataegus punctata*. c. – cuticle; chr. – chromoplasts; d. – druses; ep.– epiderm; hyp. – hypoderm; intc. – intercellular duct; mesoend. – “cartilaginous” mesoendocarp; mespar. – mesocarp parenchyma; scf. – sclerenchyma fibers; scl. - sclereides; vb. – derivatives of vascular bundle; vvb. – ventral vascular bundle of carpel. scale bar - 1 mm.

Table 4. *Weight and biochemical indicators of fruits and their parts*

Indicator	*M. germanica*	*C. oblonga*	*C. submollis*	*C. punctata*
Share of pericarp in fruit (air-dry mass) [%]	1.25±0.11*	8.011±0.61	0.83±0.07	1.05±0.07
Content of absolutely dry matter in pericarp [%]	0.135±0.012	0.023±0.001	0.080±0.011	0.142±0.010
Content of absolutely dry matter in seed [%]	46.32	85.93	61.45	59.05
Content of ascorbic acid in fruit air-dry matter [mg %]	90.30±0.73**	87.87±1.43	92.47 ± 2.92	86.53 ± 7.73
Share of pericarp in fruit (air-dry mass) [%]		78.18±7.17	85.41 ± 4.66	89.93 ± 3.72
Content of absolutely dry matter in pericarp [%]	32.00	57.00	24.40	24.00

* - $M \pm tm_M$, ** - the whole fruit

As shown in Tables 3 and 4, the significance level for all experiments (P) does not exceed 5 %, indicating the reliability of the data. The studied characters vary to different extents. The most stable indicators are the content of absolutely dry matter in fruits, pericarps and stones (seed), as well as the mass of air-dry stones (seed) (coefficient of variation, V, not more than 7.39 % and 8.48 %, respectively, *i.e.* the variation of the character is small, within the interval of 0-10 %). The most variable character is the air-dried fruit mass; the variation coefficient of this indicator in medlar and hawthorns is within 11-20 % (average variation), reaching 32.11 % in quince (V> 20 % is a large variation of the character). This indicates a different degree of water content or juiciness of fresh fruit of the studied plant species. The longitudinal dimensions of fruit and stones (seeds) vary less than the transverse ones: their length varies slightly or moderately (V <20 %), and the fruit diameter and the width of stones (seeds) are very unstable (V = 5.93-24.40 %).

CONCLUSIONS

1. The morphological and anatomical structure of the studied species fruits is similar and does not contradict the literary descriptions. Four zones were distinguished in the pericarp: the epidermis, hypoderm, the parenchyma of the mesocarp and the sclerenchyma of the meso-endocarp. The main fleshy part of the fruit occupies the parenchymal mesocarp. The meso-endocarp in *C. oblonga* is relatively soft; but in three remaining studied species, the seeds are surrounded by hard and stony stones, which are poorly separated from the fleshy part of the pericarp in a dry form.
2. Fruits of the largest sizes and masses are typical of *C. oblonga* (41 × 47 mm; 8.0 g), hawthorn has the lightest fruit of the smallest size (16-18.5 × 17 mm; 0.8-1.0 g); the dimensional and weight indexes of *M. germanica* fruit have average values (27 × 21 mm; 1.3 g). At the same time, *C. oblonga* and *M. germanica*, under the conditions of the Moscow region, are smaller in size than in areas of natural vegetation, while the dimensions of hawthorn are comparable.
3. The fleshy part of the pericarp, rich in nutrients, occupies the largest volume and has a large relative air-dry mass in the *C. oblonga* fruit (97 and 86 %); average values are

typical of hawthorn (86-89 and 59-61 %), and the smallest are for *M. germanica* (54 and 46 %).
4. The highest ascorbic acid content of *C. oblonga* fruits is 57 mg %, the average number is in the *M. germanica* fruits - 32 mg %, the smallest one is in the hawthorns fruit - 24-24.4 mg %. At the same time, the vitamin C content in the cultivated *C. oblonga* fruit is more than 2 times higher than that in the studied imported sample, in terms of the fruit air-dry matter.
5. The dimensions of the studied species stones (seeds) are comparable (7.01-9.02 × 3.76-6.02 mm), and their mass (0.023-0.140 g) and shares (14-54 %) in the air-dry fruit vary greatly.
6. It has been revealed that, for the industrial use of medlar and hawthorn fruits, it is advisable to separate the seeds and fruit pulp when fruits are raw, since the fruit pre-drying complicates the separation greatly, making it time-consuming, incomplete or impossible. The stones of hawthorn are stony. They need to be removed because they reduce the quality of raw materials.

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