

Opportunities for Using of Eleutherococcus Fruits as a New Food Raw Material

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Abstract—The purpose of study is to identify possibilities of using fruits of eleutherococcus *Eleutherococcus senticosus* Rupr. & Maxim. and *Eleutherococcus sessiliflorus* Rupr. & Maxim., which are undergoing introduction tests in arboretum of N.V. Tsitsin Main Botanical Garden of Russian Academy of Science, as easily renewable biosafety drug and food resource. By standard methods, comparative morphology-anatomical and morphometric study of fruits was carried out; content of air-dry, absolutely-dry substance and ascorbic acid was determined in them; statistical processing of the results was performed.

The fleshy drupes that we studied vary in fruits shape, by number, shape and size of stones. Features and similarities of anatomical structure of exocarp, mesocarp and endocarp of fruits, typical for most members of the Araliaceae family, were revealed. Fresh fruits of *E. senticosus* are smaller and lighter than fruits of *E. sessiliflorus*, but surpass them in terms of volume of stones and amount of ascorbic acid; content of absolutely-dry matter in them is equally high. We propose to consider fruits of both types as a new promising raw material for the production of biologically active additives and functional foods, alternative to traditional raw materials from roots of eleutherococcus, traumatic to the plants.

Keywords—*eleutherococcus*, *morphology-anatomical structure*, *morphometric parameters*, *air-dry mass*, *absolutely-dry matter*, *vitamin C*

I. INTRODUCTION

Currently, the lack of various nutrients in diets is a global human problem. The relevance of search for new opportunities of food saturating with necessary vitamins and minerals is unquestionable. Manufacturing of food products using alternative plant materials, especially fruits, characterized by a high content of biologically active substances (BAS), is promising [1-6].

Eleutherococcus (*Eleutherococcus* spp.), which have a high bioresource potential, have been known for their medicinal properties since ancient times. Plant roots and rhizomes are a common, albeit difficult to renew, natural resource for modern nutritional supplements and multivitamin complexes. At the same time, *Eleutherococcus senticosus* Rupr. & Maxim. and *Eleutherococcus sessiliflorus* Rupr. & Maxim. annually and abundantly fructifies in the middle zone of Russia. Our

studies are aimed at identifying the possibilities of using their fruits as an easily renewable biosafe medicinal and food raw material. To determine the resource potential of the mature fruits of *E. senticosus* and *E. sessiliflorus*, their morphological and anatomical structure, size and weight indices, and the content of ascorbic acid in them were studied [7, 8].

Genus *Eleutherococcus* Maxim. belongs to the family Araliaceae (Araliaceae Juss). *E. senticosus* and *E. sessiliflorus* are shrubs, distributed in the temperate zone, and not in the tropics or subtropics, like most Araliaceae. These species are winter-hardy, able to grow and bear fruits in the Central regions of Russia, although their typical habitat is the Far East. It is known, that eleutherococcus are unpretentious and undemanding to soils, can tolerate short periods without watering, but they develop better on fertile and moderately moist soils [9].

Fruits of eleutherococcus - drupes, 7-10 mm in diameter, containing up to five stones flattened from the sides. In *E. sessiliflorus* they are ellipsoid-ovoid, black, with two stones, strongly compressed from the sides and flat on the ventral side. In representatives of Araliaceae family, pericarp is multilayer, consisting of three zones. Endocarp is narrow, distinctly differentiated, consists of lignified fiber-like cells; three zones with a different number of cell layers alternate in it: the outer and inner ones are made from oblique fibers, and the intermediate one is made from longitudinal ones. The basic part of pericarp is parenchymal. In mesocarp secretory channels and crystals in cells are often present. Seed coat is derivative of single, initially multilayer integument, while a single layer of large cells of exotesta is often preserved. The remaining cell layers of integument are obliterated to greater or lesser extent and they are a thin structureless pellicle. Endosperm is abundant, storing oil, protein and cellulose. Germ is located on top of the seed, small, poorly differentiated, with the rudiments of cotyledons [10, 11].

In the natural habitat conditions flowering of *E. sessiliflorus* is observed in August, from 3 years old; yearly fruiting in September from 4 years. In conditions of Moscow region *E. senticosus* begins to bloom at the age of 4 years; blooms in August-September for about a month; forms seeds in mid-September, *E. sessiliflorus* bears fruit from 4 years old, fruits ripen in late September [8, 12].

Literature contains information about chemical composition of eleutherococcuses, rich in antioxidants, microelements and vitamins. Roots and rhizomes of *E. senticosus* contain starch, gum, galactide, essential oil, triterpenoids, steroids, alkaloids, phenols, phenolcarboxylic acids, lignans, chromones, flavonoids, coumarins and glycosides - eleutherosides, which determine the main pharmacological action of plant. Namely eleutherosides give high value to ginseng roots, less accessible than eleutherococcus roots. Carbohydrates and related compounds (17-20%), including pectin, essential oil, coumarins (0.19%), were found in the fruits. Roots of *E. senticosus* are widely used in Russia as stimulant of natural origin, adaptogen and ingredient for biologically active additives. Recently, interest in other parts of plant *E. senticosus*, including the leaves and fruits, is increasing. In 2012 Russian scientists proposed using leaves, containing a significant amount of Ca, K, Mn, Fe, Sr, Cu, Zn and other microelements along with glycosides, as medicinal and food raw materials (ash content of leaves by end of growing season reaches 13%). Foreign researchers identified some biochemical parameters of fruits of *E. senticosus* harvested in Korea in 2016: 197.9-334.3 mg / g of polyphenols, total phenolic content 41,2-203,7 mg / g [13-16].

E. sessiliflorus is somewhat different from *E. senticosus* in chemical composition. Starch, gum, essential oils, triterpenoids, steroids, cardenolides, alkaloids, lignans, coumarins were found in roots. Starch, gum, essential oils, triterpenoids, cardenolides, alkaloids were found in shoots. Coumarins (0.2%) exhibiting antitumor activity were found in fruits. Recently, more thorough study of *E. sessiliflorus* fruits biochemistry was begun by foreign researchers. In 2011 the content of Ca, Mg, Mn, and Zn in fruits growing in Korea was determined to be 465, 1433, 199, and 13 mg / kg dry weight, respectively. Fruits harvested in Poland in 2017 are also rich in mineral substances, their ash content is 4.89-5.53%. Fruits contain fiber (61.41%), proteins (16.70%), carbohydrates (25.7%), fats (3.26%) with a high content of monounsaturated (54.84-57.95%) and polyunsaturated (36.22-37.0%) fatty acids; protocatechuic (260-810 mcg / 100g), caffeic, p-coumarinic, salicylic acids; eleutherosides, anthocyanins, triterpenoids, phenols (52.3 mg / g) and flavonoids (18.4-23.0 mg / g) with a high concentration of hyperoside (120-780 mcg / 100g) [13, 17].

Eleutherococcus, recognized as a natural adaptogen, has been used in Chinese medicine since ancient times as valuable medicinal agent, that is not inferior in properties to ginseng. In Europe the plant became popular only after its introduction in medical practice in the USSR in the 70s of the twentieth century [18].

For medicinal purposes alcoholic extract of roots, tincture of roots (or bast), oil, decoction and cream are traditionally used. *E. senticosus* preparations have restorative, stimulating and tonic effect on the central nervous system, hypoglycemic and hypolipidemic effects, reducing content of cholesterol and β -lipoproteins in blood serum. Powder and infusion of fruits has tonic effect on the central nervous system in small doses, but in large ones - sedative. *E. sessiliflorus* differs somewhat from *E. senticosus* in pharmacological properties. It is used as an

immunostimulating, anti-tumor, anti-oxidant, anti-inflammatory, anti-stress, anti-viral agent; has a hypoglycemic, neuroprotective effect and direct stimulatory effect on bone formation. Recently it was found that *E. sessiliflorus* fruits can reduce the level of radicals and inhibit lipid peroxidation; they have ion-chelating ability, anti-teratogenic, anti-carcinogenic, anti-oxidant, anti-thrombotic, anti-microbial, anti-inflammatory and anti-allergic properties [16, 17, 19-22].

Leaves and vitamin preparations from eleutherococcuses are effective adaptogens, stimulants and immunomodulators not only for humans, but also for productive animals. Restoration of physiological functions of body occurs without depletion of energy resources due to high toxic threshold of eleutherococcuses and low probability of their overdose [19].

Eleutherococcuses are used in food industry: in manufacture of drink «Baikal» (roots), biologically active additives, including natural multivitamin complex «Elton», pectin extract, phyto-jam. It is proposed to use *E. senticosus* extract as functional ingredient for production of bakery products of therapeutic and preventive orientation [12], and *E. sessiliflorus* fruits - as ingredients in herbal teas and biologically active additives [12, 17, 23-25].

II. EXPERIMENTAL

We studied mature fruits of *E. senticosus* and *E. sessiliflorus*, undergoing introduction tests in arboretum of N.V. Tsytsin Main Botanical Garden, Russian Academy of Science.

Material for morphological and anatomical studies was fixed in 70% ethanol solution. Using razor blade of Gilletbrand, sections of peel, longitudinal and transverse sections of fruits and seeds were manually performed. Water and glycerin unpainted preparations prepared from them were studied using light microscope Biolam LOMO. Observation results were documented by photographing with camera Canon EOS 650D with nozzle for macro photography Sigma 150 mm 1:2.8 APO Micro DG HSM.

Morphometric indicators of objects (length and diameter of fruits, length and width of stones) were measured with caliper by the most protruding points on surface.

The content of air-dry and absolutely-dry matter in air-dried fruits and their parts was studied according to standard methods. Samples were weighed on electronic scales Pocket scale ML-A03, were ground in electric coffee grinder ZMM and were dried in drying cabinet SUPRA DFS-211 [26].

The content of ascorbic acid in air-dried fruits was determined by iodometric method by titration with 0.001N solution of potassium iodate (KIO₃).

Morphometric studies of 20 fruits of each species were performed. Repetition of weight and biochemical analyzes is 5-fold. All received material is processed by methods of variation statistics [27].

III. RESULTS AND DISCUSSION

The fruits we studied are fleshy drups, with stones that differ in number, size and shape (Fig. 1).

The rounded *E. senticosus* fruits contain up to 5 stones, located close to each other, having the form of a crescent moon. The oblong *E. sessiliflorus* fruits have 2 elongated in length stones, which are larger in size than at *E. senticosus*. Mature eleutherococcus fruits are black; and stone color varies from light brown to brown, surface of stones is tuberous.

The studied fruits and stones of both species of eleutherococcus are similar in anatomical structure. Epidermis of fruits consists of polygonal cells, tightly adjacent to each other (Fig. 2). Cells of mesocarp are parenchymal, large, friable, with transparent contents. Closer to endocarp, the mesocarp cells become shallower and stretch radially. In mesocarp there are secretory channels and derivatives of conducting bundles. In the cells of mesocarp, especially in those located closer to the endocarp, druses were found. Cells of the layer adjacent to stone grooves are large, with a slightly thickened cell wall. Endocarp is multi-layered. Inner 2 layers of endocarp cells are represented by fibers, oriented askew to stone axis. Closer to mesocarp, there are 2 layers of fibers, elongated along axis of stone. At *E. senticosus* in tuber, the number of fiber layers, oriented along stone, increases to 4, and sizes of cells themselves is larger. In *E. sessiliflorus* tubers are formed only by mesocarp. Radially elongated cells of mesocarp with thickened cell walls are located by multilayer groups on endocarp and separate from it only at washing stones.

Seed coat is single-layered, from large, tabular on transverse section, cells. Contents of cells are brown. Endosperm is plentiful; cells are rounded, large, tightly adjacent together.

Anatomical structure of fruits of *E. senticosus* and *E. sessiliflorus* described by us is similar to that characteristic of most representatives of Araliaceae family [11].

Fruits and stones of *E. sessiliflorus* are larger than those of *E. senticosus* (table I); these differences are statistically significant by Student's criterion. Shape of *E. senticosus* fruits is more rounded, and of *E. sessiliflorus* fruits is more oblong. Variation of parameters of *E. senticosus* and *E. sessiliflorus* was noted in following limits: fruits length 6.0-8.0 mm opposite 9.0-13.0 mm; fruits diameter 3.0-6.5 mm opposite 4.0-7.0 mm; stones length 4.0-6.0 mm opposite 6.0-8.0 mm and stones diameter 1.0-3.0 mm opposite 3.0-4.0 mm, respectively.

Stones cumulative volumerelative to fruit volume in *E. senticosus* (27.7%) is less than in *E. sessiliflorus* (37.5%).

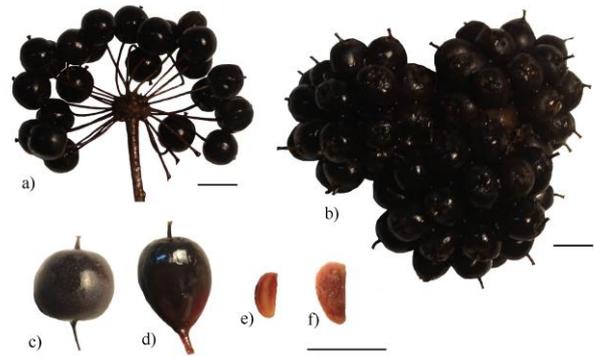


Fig. 1. Fruits and stones of *Eleutherococcus senticosus* and *E. sessiliflorus*: a – *E. senticosus* infructescence; b – *E. sessiliflorus* infructescence; c – *E. senticosus* fruit; d – *E. sessiliflorus* fruit; e – *E. senticosus* stone; f – *E. sessiliflorus* stone. Scale – 1 cm.

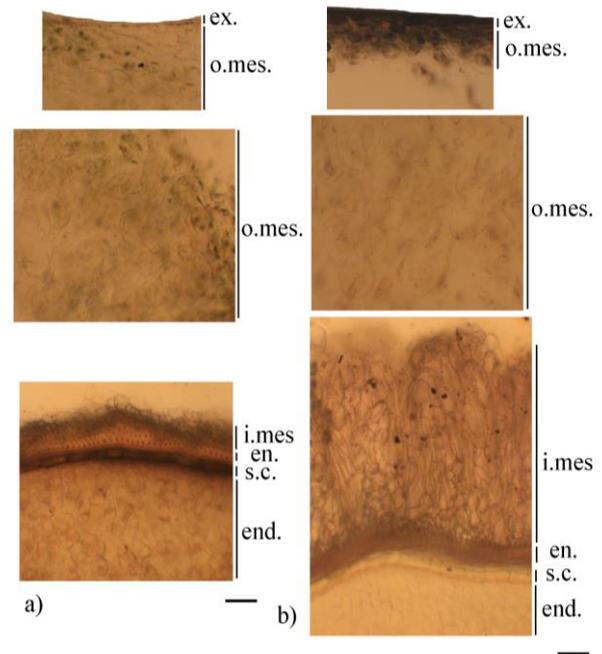


Fig. 2. Anatomical structure of *Eleutherococcus senticosus* (a) and *E. sessiliflorus* (b) fruits: en. – endocarp; end. – endosperm; ex – exocarp; i.mes. – inner zone of mesocarp; o.mes. – outer zone of mesocarp; s.c. – seed coat. Scale – 0.1 mm.

TABLE I. MORPHOMETRIC INDICATORS OF *ELEUTHEROCOCCUS SENTICOSUS* AND *E. SESSILIFLORUS* FRUITS

Parameters	<i>E. senticosus</i>				<i>E. sessiliflorus</i>			
	$M \pm m_M$	tm_M	V, %	P, %	$M \pm m_M$	tm_M	V, %	P, %
Fruit length, mm	6,95 ± 0,25	0,51	15,80	3,53	10,80 ± 0,29	0,60	11,86	2,65
Fruit diameter, mm	4,65 ± 0,22	0,46	20,96	4,68	5,25 ± 0,22	0,45	18,41	4,11
Stone length, mm	5,25 ± 0,26	0,55	16,40	4,76	7,35 ± 0,20	0,41	11,90	2,66
Stone width, mm	1,98 ± 0,09	0,18	20,24	4,52	3,55 ± 0,11	0,23	14,37	3,21

Note: $M \pm m_M$ – arithmetic mean and its error, tm_M – confidence interval, V – coefficient of variation, P – experience accuracy indicator for standard confidence level of 95% (accuracy of experiment is considered satisfactory with indicator values not exceeding 5%).

TABLE II. WEIGHT INDICATORS OF *ELEUTHEROCOCCUS SENTICOSUS* AND *E. SESSILIFLORUS* FRUITS

Parameters	<i>E. senticosus</i>				<i>E. sessiliflorus</i>			
	$M \pm m_M$	tm_M	V, %	P, %	$M \pm m_M$	tm_M	V, %	P, %
Mass of air-dried fruit, g	0,227 ± 0,01	0,02	14,83	4,69	0,405 ± 0,01	0,03	9,18	2,90
Content of absolutely dry matter in air-dried fruits, %	97,25 ± 0,49	1,52	0,98	0,49	98,25 ± 0,48	1,52	0,97	0,48

Note: $M \pm m_M$ —arithmetic mean and its error, tm_M – confidence interval, V – coefficient of variation, P – experience accuracy indicator for standard confidence level of 95% (accuracy of experiment is considered satisfactory with indicator values not exceeding 5%).

Studied morphometric indices of *E. senticosus* are more variable than corresponding parameters of *E. sessiliflorus*.

In each species of eleutherococcuses, longitudinal dimensions of objects are more stable than transverse ones.

Coefficients of variation of lengths are lower than of diameters for fruits: 15,80 % ≤ 20,96 % – *E. senticosus*, 11,86 % ≤ 18,41 % – *E. sessiliflorus*; as well as for stones: 6,40 % ≤ 20,24 % and 11,90 % ≤ 14,37 %, respectively. Diameters of fruits and stones of *E. senticosus* vary greatly ($V \geq 20$ %); other parameters are characterized by medium variability ($10\% \leq V \leq 20\%$).

The received data are reliable, because indicators of accuracy of experiments do not exceed 5%.

Air-dried *E. sessiliflorus* fruits are heavier than *E. senticosus* fruits. Content of absolutely-dry matter in air-dried *E. sessiliflorus* fruits is 98.25%, and in *E. senticosus* fruits – 97.25% (table II). Mass of individual air-dried *E. senticosus* fruits varies from 0.19 g to 0.29 g; *E. sessiliflorus* – from 0.38 g to 0.47 g. Differences in corresponding arithmetic means are statistically significant, according to Student's criterion. Coefficients of variation of air-dry weight of fruits are not above average.

Slight differences in content of absolutely dry matter in air-dried fruits of *E. sessiliflorus* and *E. senticosus* are not statistically significant, according to Student's criterion. This feature is different by constancy, judging by low values of variation coefficient (0,98 % – *E. senticosus*, 0,97 % – *E. sessiliflorus*). It is possible to trust experimental results because indicators of their accuracy are less than 5%.

It was determined that in *E. senticosus* fruits contains 30 mg% of vitamin C, and in *E. sessiliflorus* fruits – 27 mg%. In literary sources information about amount of ascorbic acid in fruits of various species of eleutherococcuses was not found.

IV. CONCLUSION

In connection with problem of lack of beneficial substances in rations of food, as well as increase in population's interest in biologically active additives of plant nature, representatives of eleutherococcuses, *E. senticosus* and *E. sessiliflorus*, are promising species for further study.

Despite the fact that homeland of eleutherococcuses of these species is Far East, they are able to grow and abundantly fructify in the middle zone of Russia.

In Russian Federation many pharmaceutical companies produce preparations from roots of Eleutherococcus.

We proposed to use fruits of eleutherococcuses simultaneously with roots; fruits can be harvested on plants, from which roots are extracted, but without need to destroy plants.

We have revealed advantages in terms of size and weight indices of fruits of *E. sessiliflorus* in comparison with fruits of *E. senticosus*. At the same time, in *E. senticosus* stones occupy smaller volume in fruit, mesocarp is less differentiated, and vitamin C content is higher. Therefore, we propose to consider fruits of both species as promising new raw material for production of BAS and functional food products.

1. Differences in shape of fruits and stones of *E. senticosus* and *E. sessiliflorus* were established. Fruits of *E. senticosus* are more rounded, in contrast to elongated fruits of *E. sessiliflorus*. Stones are furrowed, in *E. senticosus* they have shape of a crescent, and in *E. sessiliflorus* they are oblong.

2. Fruits of *E. senticosus* and *E. sessiliflorus* have a similar plan of anatomical structure. Exocarp is represented by single-layered epidermis. Mesocarp consists of parenchymal large cells, which in area adjacent to endocarp are more (*E. sessiliflorus*) or lesser (*E. senticosus*) degree differentiated: elongated radially and have thickened walls. In mesocarp there are secretory channels, derivatives of conducting bundles, and in cells – there are druses. Endocarp is from 2 zones: 2 layers (at *E. senticosus* in the tubers - 4) of fibers elongated along axis of stone and 2 layers of obliquely arranged fibers. Seed coat is single-layered, is from large tabular cells. Plentiful endosperm is from rounded densely located cells.

3. Morphometric parameters for fruits and stones were determined: fruits of *E. senticosus* 6.95 × 4.65 mm; fruits of *E. sessiliflorus* 10.80 × 5.25 mm; stones – 5.25 × 1.98 mm and 7.35 × 3.55 mm, respectively. In fruits of *E. senticosus*, stones occupy 27.7%, and in fruits of *E. sessiliflorus* – 37.5%.

4. The content of absolutely-dry matter in air-dry parts of fruits of *E. senticosus* and *E. sessiliflorus* was determined: 97.25% and 98.25%, respectively. Air-dry mass at *E. senticosus* is, on the average, 0.227 g, and that at *E. sessiliflorus* is 0.405 g.

5. *E. senticosus* contains 0.30 g of vitamin C per 100 g of raw material, and *E. sessiliflorus* is slightly less – 0.27 g per 100 g of raw material.

6. All of above data indicate that eleutherococcus studied by us have significant resource potential, and their fruits are of interest to food industry as raw materials.

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