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COMPONENTS OF CERTAIN SPECIES OF THE ELAEAGNACEAE FAMILY

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Data from the last 50 years for various classes of compounds from certain plant species of the oleaster (Elaeagnaceae) family are reviewed.

Key words: Elaeagnaceae, carbohydrates, amino acids, proteins, lipids, flavonoids, alkaloids, vitamins, microelements.

The oleaster family (Elaeagnaceae Lindl.) includes three plant genera, sea buckthorn (*Hippophae*), shepherdia (*Shepherdia*), and oleaster (*Elaeagnus*), that are represented by about 45 species [1-5].

This family is represented by two genera and three species in the flora of Uzbekistan. The exception is shepherdia, which grows in North America [6] according to the literature [7, 8]. The one species of sea buckthorn (*Hippophae rhamnoides* L.) and two oleaster species [wild narrow-leaf oleaster (*Elaeagnus angustifolia* L.), which is used in medicine, and Eastern oleaster (*Elaeagnus orientalis* L.), which is cultivated as a forage plant].

Sea buckthorn is the best known plant of this family. Its oil accumulates simultaneously in the seeds and fruit pulp [9-11]. Oil from the fruit acts as an antiinflammatory, antibacterial, and antiburn agent and is widely used in medical practice to cure various diseases [12-22]. The leaves, fruits, and seeds of sea buckthorn are also used in folk medicine [23, 24].

Oleaster is widely used for gastrointestinal-tract disorders and in certain medicinal preparations [1, 7, 25-28]. Fresh oleaster leaves are effective in curing festering and non-healing wounds [29] and rheumatic pain [30]. Cardiac functioning is improved by inhaling essential oil of the flowers [7]. Extract of fresh flowers is also used for this purpose. In France, it is used as an anti-insomniac [31].

Shepherdia is used analogously [32].

CARBOHYDRATES AND RELATED COMPOUNDS

Literature data on the carbohydrate content are summarized in Table 1.

Quantitative determination of the carbohydrate composition of sea buckthorn fruit [33] found that five monosaccharides in the water-soluble polysaccharide fraction, D-galactose, D-glucose, L-arabinose, D-xylose, and L-rhamnose, are present in ratio 3.0:5.3:6.1:trace:1.0. These data place the polysaccharides from sea buckthorn fruit of the Altai population in the pectin class.

Sea buckthorn fruit of Azerbaidzhan [37] contains 1.32% glucose, 0.71% fructose, and 0.7% saccharose.

With respect to the dynamics of carbohydrates in Elaeagnaceae species, it is known that the amount of sugars increases as the fruit ripens for the *Elaeagnus* genus [40].

Pectin in whole sea buckthorn fruit is present at 0.59-0.79% [35, 37]; in fruit pulp, 0.41% [35]; in juice from fruit, 0.21-3.7% [35, 37, 41]; in dry pulp, 0.36% [37]; in seeds, 0.14; flowers, 0.2; leaves, 0.42% [35].

The molecular weight of sea buckthorn fruit pectin is 47,000-50,000. Free and esterified carboxylates make up 4.5-5.4 and 13%, respectively; methoxys, 9-14.4; uronides, 70-80% of the pectin [42]. It was concluded that sea buckthorn pectin has a molecular weight similar to that of lemon pectin.

Pectinic substances of sea buckthorn fruit consist of galacturonic acid, xylose, arabinose, rhamnose, and galactose units [35].

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TABLE 1. Content of Total Sugars, Free Carbohydrates, and Water-Soluble Polysaccharides in Plants of the *Elaeagnaceae* Family

Plant	Content, %	Composition	Reference
H. rhamnoides, fruits	Total sugar 0.79-6.63	Glucose, fructose, saccharose, arabinose	[34-37]
	Free carbohydrates 2.69	Glucose, fructose, saccharose, arabinose	[34-37]
	Water-soluble polysaccharides 2.2-3.0	Xylose, D-galacturonic acid, D-galactose, D-glucose, L-arabinose, D-xylose, L-rhamnose	[34]
leaves	Free carbohydrates 2.6	Glucose, fructose, saccharose	[35]
flowers	Free carbohydrates 1.2	Glucose, fructose, saccharose	[35]
seeds	Free carbohydrates 0.38	Only saccharose	[35]
Sh. argentea, fruits	Total sugar 12.1-21.1	-	[38]
E. multiflora		Glucose, fructose, saccharose	[39]
E. umbellate	-		
E. orientalis, fruits			[40]

Pectinic substances of sea buckthorn seeds contain xylose, rhamnose, and galactose.

In general, it can be concluded that shepherdia fruit has the highest sugar content of all plants in this family. Carbohydrates of the family are represented mainly by glucose and fructose with a small amount of other compounds.

LIPIDS

The literature contains the broadest information on the content of neutral lipids of sea buckthorn fruit, which is due to the value of the oil isolated from them [Table 2].

A relationship was found between several quantitative indicators and the color of the fruit. Yellow fruit has more pulp mass and oil content than red fruit [75] although others [76] determined that the oil content of fruit is negatively correlated with their size.

Thus, a consensus has not been reached on the correlations between oil-content indicators and fruit mass. Many ecological factors affect the oil-formation process. Nevertheless, the oil content of fruit is determined mainly by physiological and genetic characteristics of the variety [77].

The principal indicators of oils from various plant organs of the Elaeagnaceae family are listed in Table 3.

FATTY ACIDS

The fatty-acid (FA) content of sea buckthorn was first determined by Obodovskaya and Devyatnin [82]. The total FA in sea buckthorn fruit oil is 77-86.6% [81, 83], >90% according to others [37]. Of these 47% are saturated; 53%, unsaturated [56].

The FA mass of commercial sea buckthorn oil, which is a concentrated extract of sea buckthorn berries with sunflower oil [83], consists of >47% palmitoleic 16:1(9) acid according to GLC. The structures of the 16:1(9) and 18:1(9) acids were confirmed by periodate—permanganate oxidation of the monoene fraction [65]. The number of plants that contains such a high content of palmitoleic acid is limited. Therefore, this indicator is rigorously included in the list of requirements in all published pharmacopeic articles on sea buckthorn oil.

The FA content of sea buckthorn fruit was determined using a combination of GLC and chromatography—mass spectrometry. The presence of 16:2 acid was confirmed [84]. GC—MS of the pyrrolidine derivatives of monoene acids [85] was used to identify for the first time in this sample *cis*-11-octadecenoic (vaccenic) acid.

TABLE 2. Lipid Content of Various Organs of *Elaeagnaceae* Plants

Sample	Lipid yield, % of mass	Reference
H. rhamnoides:		
fresh fruits	1.9-14.9	[34, 35. 37, 43-60]
fresh fruits cald. for dry weight	1.89-41.5	[51, 52, 58-64]
fresh fruit pulp	4.8	[35]
dry fruit pulp	15.4-57.8	[52, 64, 58]
oil from juice	7.4	[65]
fresh fruit pulp, extracted with freon	17-19	[66]
seeds	5.3-15.7	[35, 50, 52, 65, 66]
fresh leaves	0.33	[35]
dry leaves	4.0-12.2	[64, 67]
flowers	0.9	[35]
dry pulp	18.0-22.6	[37, 68]
grist	5.2	[69]
E. angustifolia:		
seeds	3.5-26.0	[70, 71]
pericarp	0.8-1.2	[71]
leaves	1.4-9.5	[72, 73]
flowers	3.0	[74]

TABLE 3. Properties of Lipids from Various Organs of Plants of the *Elaeagnaceae* Family

Property	*H. rhamnoides*					*E. angustifolia*
	fruit oil	pulp oil	seed oil	leaves lipids [35, 71]*	pulp oil [68]	seed oil [70, 79]
Iodine number, % I_2	59-76.1 [35, 50, 78]	68.5[35]	121.2 [35]	69.4	112.5	113.3-155
Acid number, mg KOH/g	1.2-30.8 [34, 50-52, 56, 78, 80]	4.2-12.0 [35, 52, 81]	4.88-23.23 [35, 52, 65, 80]	4.8-94.9	9-12	6.86
n_D	1.4271-1.4689 [35, 80]	1.4236[35]	1.4631-1.4764 [35, 65, 80]	1.4273	1.4590-1.4660	1.4702-1.4760
d_4^{20}, g/cm^3	0.9015-0.9538 [35, 56]	0.91622[35]	0.9524 [35]	0.9417	0.9217-0.9231	0.9260
Saponification number, mg KOH/g	198-227 [35, 50]	164.86-186.2 [35, 81]	218.4 [31]	185.8	200	184-197.5
Phospholipids, %	1.8 [35]	0.93 [35]	1.1 [35]	1.4	0.89	-

*References are given in square brackets.

The list of acids identified in sea buckthorn oil at present contains 24 acids of the C_{10}—C_{20} series. Of these, 10:0, 12:0, 12:1, 14:1, 15:0, 16:1-iso, 17:0, 19:0, 20:0, and 20:1 are present in trace quantities [70, 85]. The contents of the remaining acids are given in Table 4. Thus, the principal acids of sea buckthorn fruit are 16:0, 16:1, 18:1, and 18:2. They make up 60-80% of the total mass.

The FA composition of seeds consists of only nine components. Unsaturated acids, which average 80% of the total mass, are dominant.

Lipids of sea buckthorn leaves yielded 11 FA, 8 of which were identified [67].

Seed oil of *E. angustifolia* consists of 1% saturated acids, 32% monoene, and 48 and 14% unconjugated dienoic and trienoic C_{18} acids [79]. The separate components were determined in this sample [70].

Lipids of oleaster leaves contain a larger variety of acids from 9:0 to 22:0 [72, 73].

TABLE 4. Fatty-Acid Content of Various Organs of *H. rhamnoides* (I) [56, 62, 65, 68, 70, 80, 81, 83-89] and *E. angustifolia* (II) [70, 72, 73]

Acid	Pericarp I	Seeds I	Leaves I	Seeds II	Leaves II*
14:0	0.1-1.6	0.1-1.5	0.4-1.2	-	2.4-4.4
15:0	-	0.2-1.1	0.4-1.0	-	1.2-1.6
16:0	17.6-47.0	7.2-13.2	7.2-13.2	4.4	18.9-19.8
16:1 (9)	10.4-60.2	0.3-5.9	0.3-5.9	1.9	2.2-2.3
16:2	0.02-3.3	-	-	-	-
18:0	0.1-4.2	1.5-7.6	1.5-7.6	0.9	3.6-6.2
18:1 (9)	5.8-44.9	14.1-26.6	14.1-26.6	28.4	9.1-10.1
18:2	0.1-39.2	30.0-39.6	30.0-39.6	52.2	10.8-10.9
18:3	0.1-6.1	21.2-36.3	21.2-36.3	12.2	30.0-44.9
20:0	Tr.	0.4	-	-	-
21:0	-	-	-	-	1.0-1.3
22:0	-	-	-	-	3.5-5.3

*9:0-12:0 - 0.6-1.3%; 15:1 - 0.7-1.1%; 17:0 - 1.8-3.2%; 21:1 - 1.0%.

The data show that the 16:1(9) acid, which is characteristic of sea buckthorn pericarp oil, is found in small quantities in other parts of the plant. It probably cannot serve as a marker for plants of the Oleaster family [90].

The FAs in sea buckthorn fruit are distributed by lipid class into principally triacylglycerines (TAG), free FA (FFA), and phospholipids (PL) of 16:0 and 16:1 acids and esters of 18:1 [62, 64, 68, 91-94]. The principal FA in seed lipids are as follows [92, 93]: 18:2 in TAG and natural methyl and ethyl FA esters found in sea buckthorn seeds; 16:0 in FFA, and 18:1 in esters consisting of higher fatty and cyclic alcohols.

The FA composition of lipids from separate parts of the fruit (pericarp and pulp) showed no substantial differences. The main part of 16:1(9) acid was concentrated in the fruit pericarp [95, 96].

Sea buckthorn leaves, like most photosynthesizing tissues, have mostly 18:3 acid in the TAG and FFA. Cyclic and aliphatic alcohols in esters are bound mainly to 16:0 acid; in waxy esters, to 22:0 [64, 97].

The principal acids in glycolipids (GL) and phospholipids (PL) of the leaves are distributed as follows, depending on compound class: 16:0, from 9.1% in monogalactosyldiglycerides (MGDG) to 55.4% in sulfoquinovosyldiglycerides (SQVDG); 18:2, from 21.5% in phosphatidylglycerines (PG) to 37.4% in phosphatidylinosites (PI); 18:3, 15.8% in SQVDG, 72.2% in MGDG, 27.5% in PI, and 48.6% in PG [98].

According to the literature [99], 16:1 acid (36.7%) predominates in the TAG of sea buckthorn branch bark; 16:0 (34.4%), in FFA.

FA are distributed by lipid class of various oleaster organs as follows. TAG, FFA, esters, epoxy-TAG, hydroxy-TAG of seeds, and TAG of pericarp contain principally 18:2 acid. The main ones are 16:0 and 18:2 in all remaining classes of oleaster fruit [78, 90, 100].

In the TAG of branch bark, 18:1 (39.1%) dominates; in esters, 18:2 (24.3%); in GL and PL, 16:0, 18:2, and 18:3 acids, depending on the particular class [101].

FFA of oleaster flowers contain mainly 16:0 (60.0% of acid mass); esters, 16:0 (30.2%) and 18:1 (29.6%); TAG, 18:3 (46.6%) acid [74].

Seeds of sea buckthorn and oleaster yielded oxygenated TAG, one or two acid moieties of which are hydroxy- or epoxyfatty acids (Table 5). The principal oxygenated acids of the two plant species are 9-hydroxy-10,12-, 13-hydroxy-9,11-, and 15,16-epoxy-9,12-octadecadienoic acids. Modern analytical methods such as high-resolution and metastable-defocusing mass spectrometry enabled several minor components to be identified. Furthermore, interpretation of the spectra considered trends in the decomposition of TMS derivatives of oxygenated FA upon electron impact and knowledge of the genesis of oxygenated components from unsaturated acids (Table 4).

TABLE 5. Oxygenated Acids from Seeds of *H. rhamnoides* [102, 103, 105] and *E. angustifolia* [104]

Structure	Short designation	Sample
	Hydroxyacids	
9-Hydroxytridecenoic	9-OH-13:1(X)*	Sea buckthorn
11-Hydroxytridec-9-enoic	11-OH-13:1 (9)	Sea buckthorn, oleaster
10-Hydroxytrideca-6,8-dienoic	10-OH-13:2(6,8)	Oleaster
10,11-Dihydroxytetradecenoic	10,11-diOH-14:1(X)	Sea buckthorn
7-Hydroxytetradec-8-enoic	7-OH-14:1(8)	Sea buckthorn
10,11-Dihydroxypentadecenoic	10,11-diOH-15:1 (X)	Sea buckthorn
9-Hydroxypentadeca-10,12-dienoic	9-OH-15:2 (10,12)	Sea buckthorn
7-Hydroxyhexadec-8-enoic	7-OH-16:1 (8)	Sea buckthorn
10-Hydroxyhexadec-8-enoic	10-OH-16:1 (8)	Sea buckthorn
9-Hydroxyhexadec-10-enoic	9-OH-16:1(10)	Sea buckthorn, oleaster
8-Hydroxyhexadecadienoic	8-OH-16:2(X,Y)*	Sea buckthorn
13-Hydroxyhexadeca-9,11-dienoic	13-OH-16:2(9,11)	Sea buckthorn
11,15-Dihydroxyheptadeca-9,13-dienoic	11,15-diOH-17:2(9, 13)	Sea buckthorn
10-Hydroxyoctadecanoic	10-OH-18:0	Sea buckthorn
12-Hydroxyoctadecanoic	12-OH-18:0	Sea buckthorn, oleaster
10-Hydroxyoctadecenoic	10-OH-18:1(X)	Sea buckthorn
8-Hydroxyoctadec-9-enoic	8-OH-18:1(9)	Sea buckthorn, oleaster
11-Hydroxyoctadec-9-enoic	11-OH-18:1(9)	Sea buckthorn
12-Hydroxyoctadec-9-enoic	12-OH-18:1(9)	Sea buckthorn
9-Hydroxyoctadec-12-enoic	9-OH-18:1(12)	Sea buckthorn
9-Hydroxyoctadecadienoic	9-OH-18:2(X,Y)	Sea buckthorn
10-Hydroxyoctadecadienoic	10-OH-18:2(X, Y)	Sea buckthorn
11-Hydroxyoctadecadienoic	11-OH-18:2(X, Y)	Sea buckthorn
14-Hydroxyoctadecadienoic	14-OH-18:2(X, Y)	Sea buckthorn
12-Hydroxyoctadeca-8,10-dienoic	12-OH-18:2(8, 10)	Oleaster
13-Hydroxyoctadeca-9,11-dienoic	13-OH-18:2(9, 11)	Sea buckthorn, oleaster
9-Hydroxyoctadeca-10,12-dienoic	9-OH-18:2(10, 12)	Sea buckthorn
9-16-Dihydroxyoctadeca-11,13-dienoic	9,16-diOH(11, 13)	Sea buckthorn
12-Hydroxyoctadeca-13,15-dienoic	12-OH-18:2(13, 15)	Sea buckthorn
7-Hydroxyoctadecatrienoic	7-OH-18:3(X, Y, Z)*	Sea buckthorn
9-Hydroxyoctadeca-9,11,13-trienoic	9-OH-18:3(9, 11, 13)	Sea buckthorn, oleaster
Trihydroxynonadecenoic	triOH-19:1(X)	Sea buckthorn
9,12-Dihydroxynonadec-15-enoic	9,12- di OH-19:1(15)	Sea buckthorn
9,15-Dihydroxy-12-eicosenoic	9,15- di OH-20:1(12)	Sea buckthorn
Dihydroxytricosenoic	di OH-23:1(X)	Sea buckthorn
	Epoxyacids	
9,10-Epoxyhexadecanoic	9,10-ep-16:0	Sea buckthorn
9,10-Epoxyheptadecanoic	9,10-ep-17:0	Sea buckthorn
9,10-Epoxyoctadecanoic	9,10-ep-18:0	Sea buckthorn
9,10,11,12-Diepoxyoctadecanoic	9,10,11,12-diep-18:0	Sea buckthorn
9,10,12,13-Diepoxyoctadecanoic	9,10,12,13-diep-18:0	Sea buckthorn
9,10,12,13,15,16-Triepoxyoctadecanoic	9,10,12,13,15,16-triep-18:0	Sea buckthorn
12,13-Epoxyoctadec-9-enoic	12,13-ep-18:1(9)	Sea buckthorn, oleaster
12,13,15,16-Diepoxyoctadec-9-enoic	12,13,15,16-diep-18:1(9)	Sea buckthorn
9,10-Epoxyoctadec-12-enoic	9,10-ep-18:1(12)	Sea buckthorn, oleaster
9,10,15,16-Diepoxyoctadec-12-enoic	9,10,15,16-diep-18:1(12)	Sea buckthorn
9,10,12,13-Diepoxyoctadec-15-enoic	9,10,12,13-diep-18:1(15)	Sea buckthorn
13,14-Epoxyoctadeca-9,11-dienoic	13,14-ep-18:2(9, 11)	Sea buckthorn
15,16-Epoxyoctadeca-9,12-dienoic	15,16-ep-18:2(9, 12)	Sea buckthorn
12,13-Epoxyoctadeca-9,15-dienoic	12,13-ep-18:2(9, 15)	Sea buckthorn
8,9-Epoxyoctadeca-10,12-dienoic	8,9-ep-18:2(10, 12)	Sea buckthorn
9,10-Epoxyoctadeca-12,15-dienoic	9,10-ep-18:2(12, 15)	Sea buckthorn

*X, Y, Z - the double-bond position is not known.

UNSAPONIFIABLE LIPIDS OF ELAEAGNACEAE PLANTS

Fruit of *H. rhamnoides*. It is now quite certain that the biological activity of sea buckthorn oil stems mainly from several unsaponified lipids [106, 107], the content of which in fresh fruit is 94-102 mg/100 g [108, 109]; in oil, 5.4% [110]; in extracts of fruit pulp, 3.3-4.2% [68, 111]. Hexane extracts of sea buckthorn pericarp, pulp, and seeds contain 11, 0.3, and 0.7%, respectively, of unsaponified substances [95].

Thus, unsaponified components, which are responsible for the restorative activity, are concentrated in the pericarp. They contain C_{13}-C_{28} fatty alcohols, β-sitosterol, α- and β-amyrins, 24-methylenecycloartanol, citrostadienol, 24-ethylcholest-7-en-3β-ol, erythrodiol, uvaol [111], obtusifoliol, ursolic and oleanolic aldehydes [112], $C_{21:0}$-$C_{31:1}$ hydrocarbons, carotenoids, and tocopherols [95].

Analysis of the alcohol part of unsaponified substances (except carotenoids and tocopherols) gave the following composition: fatty alcohols, 35%; mixture of sterols and triterpenes, 65% [111]. The triterpenes contain mainly (40%) β-sitosterol and (29%) 24-methylenecycloartanol.

A relationship was found between the ability of plants to accumulate fatty oil and sterols. This was noted previously for animals [108].

The sterol content was about the same in sea buckthorn seed oil and pericarp (1.7-1.8% of the oil mass) [76]. The sterol fraction of pharmacopeic sea buckthorn oil consists of 62.3% β-sitosterol and 16.8% stigmasterol according to GLC [83].

The composition of unsaponified substances in the oil depends experimentally on the preparation method [112, 113]. Thus, oil isolated by hexane or freon extraction contains up to 16.7% fatty alcohols, which is 6-8 times greater than commercial oil obtained by extraction with sunflower oil.

Leaves of *H. rhamnoides*. Lipids of *H. rhamnoides* leaves contain significantly more unsaponified compounds than those of fruit, 44-47% in diethylether extract [114-116]. Extraction with freon reduces the content of unsaponified substances to 17% [116]. The content of unsaponified substances in the ether extract is as follows, mass %: hydrocarbons, carotenoids, tocopherols, phytol, 23.4; fatty alcohols, 19; dimethylsterols, 11.6; methylsterols, 0.8; sterols, 6.8; triterpene aldehydes, 1.1; diols, 9.1 [114]. In addition to these compounds, the leaves, in contrast with fruit, contain a significant fraction (up to 12%) of polyprenols in addition to phytol, cycloartenol, and nortriterpene alcohols [115].

All alcohol components of the unsaponified part of *H. rhamnoides* leaves extract are found in the free or bound form. The main alcohols were shown to appear in FA esters [97, 116]. Free polyprenols contain components with 9-13 isoprenoid units; bound, 9-18 [116]. Furthermore, lipids of the leaves and fruit differ in composition of fatty aliphatic alcohols. Whereas palmitates of C_{24} and C_{26} alcohols dominate in fruit, the principal ones in leaves are behenate alcohols C_{22} and C_{24} [97, 117].

Lipids of sea buckthorn branch bark are 5.7% (mass) free fatty alcohols with triterpenes and 4.8% sterols. The content of bound alcohols is 11.7% [99, 118].

***Elaeagnus*.** The unsaponified part of *E. angustifolia* fruit oil contains 9.8 mg% carotenoids and 36.5 mg% tocopherols [74]. About 50 unsaponified components including C_{16}-C_{34} alkanes, steroids, and tocopherols were detected by GC-MS [119].

Leaves of *E. angustifolia* have 57 mass % unsaponified components in the $CHCl_3$ extract [73]. The principal ones are polyprenols (deca-, undeca-, and dodecaisoprenols). Furthermore, C_{21}-C_{31} hydrocarbons (mainly C_{29}), carotenoids, C_{16}-C_{26} fatty alcohols, α- and β-amyrins, cycloartenol, 24-methylenecycloartanol, triterpene aldehydes, citrostadienol, and β-sitosterol were identified. The last was found in other *Elaeagnus* species (leaves and branches of *E. glabra* [120] and leaves of *E. pungens* [121]).

TRITERPENE ACIDS

Sea buckthorn fruit yielded terpenoid substances that were localized mainly in the epidermis and somewhat in the fruit cuticle. These substances were identified as a mixture of ursolic and oleanolic acids [122, 123]. Similar triterpene hydroxyacids were found in leaves [35, 97, 124], seeds [35], and bark [99] in addition to the leaves and roots of certain *Elaeagnus* species [120, 121]. In addition, roots of *E. oldhami* gave arjunolic and maslinic acids [125]; branches of *E. pungens*, arjunolic acid [120].

Triterpene dihydroxyacids (pomolic and etc.), the fraction of which is two times less than that of the monoacids, were found in the ether and freon extracts of sea buckthorn leaves, in addition to hydroxyacids [116].

Data have been reported for the content of triterpene acids (based on ursolic): in dry sea buckthorn fruit, 504.6-1712.0 mg/100 g [47, 48, 57]; in fresh fruit, 80.0-170.0 mg/100 g [45].

Opinions regarding their distribution in plant organs are contradictory. According to some, terpene acids are greater in leaves [35]; to others, in fruit [126].

Triterpene acids in sea buckthorn branch bark contain 4% by mass neutral lipids [99].

PHOSPHOLIPIDS

Oil from sea buckthorn pericarp contains from 0.2-0.5 [127] to 1% PL [37, 128]. Phosphatidylserines (PS), 5.8%; phosphatidylcholines (PC), 26.7%; phosphatidylethanolamines (PE), 13.1%; inosit-containing fractions (PI), 8.9%; and cephalins (PI+PS+PE), 27.8% were found among them [127].

Sea buckthorn seeds contain 0.3-0.6% PL [129, 130] including PC, PI, PE, PG, lyso-PI, lyso-PC, and phosphatidic acids (PA) [130].

Sea buckthorn leaves have PC, 32.8; PE, 29.7; PG, 21.5; and PI, 16.0 (mass %) [98].

Seeds of *E. angustifolia* yielded seven PL; pericarp, three [100]. These included PC, 52.1; PE, 16.4; PI, 19.2; PA, 3.5; N-acyl-PE, 1.7; lyso-N-acyl-PE, 3.2; unidentified, 3.9 (mass %). Pericarp had PC, 45.8; PE, 25.0; and PI, 29.2 (mass %).

Branch bark of *E. angustifolia* contains 64% PL, including PC, 45.6; PE, 32.4; PI, 9.2; PG, 11.5; and unidentified, 1.3% [101].

AMINO ACIDS AND PROTEINS

The immunochemical properties of the albumin—globulin fraction of proteins from seeds of representative oleaster species indicate that they are genetically related [131]. The immunochemical similarity of these proteins corresponds with results on the morphology of oleaster fruit and seeds.

The total N content in fresh pulp of sea buckthorn fruit reaches 0.26% [132]. Protein N depends on the sea buckthorn variety, from 38 to 60%; non-protein, from 40 to 62% of total N.

The quantity of raw protein (i.e., taking into account the non-protein N fraction) varies in sea buckthorn fruit from 0.79 [133] to 3.11% [34]; juice, from 0.58 to 3% [34, 37, 133]; seeds, 24.4% [133]; leaves, bark, and suckers, from 19.6 to 26.5% [134], grist from sea buckthorn production, 20.6% [69] per dry weight.

The principal non-protein N in the fruit comes from N of free amino acids. It is known that free amino acids contribute significantly to the food value of the plants owing to their more facile assimilation than proteins [132]. The total free amino acids in sea buckthorn juice is 94.5-188.3 mg/100 ml of juice [132]; in grist of sea buckthorn production, 15.05% [69, 135].

About 20% of amino acids in sea buckthorn juice are in the free state. All proteinaceous amino acids were observed, i.e., those that form protein.

Protein isolated from sea buckthorn seeds contained 13 amino acids [133, 136]; pulp of fruits, and juice, 18 [133]; leaves, 13 [137]; woody parts (leaves, bark, suckers), 17 [134].

Total essential amino acids in sea buckthorn juice is 22.6-49.5% of the total amino acids [132-134, 138, 139].

The amino-acid composition of proteins in juice, seeds, and woody parts of sea buckthorn was investigated [133, 134, 139, 140]. The biological value of proteins from woody parts of sea buckthorn exceeds that of such traditional crops as alfalfa and clover [134]. Such a high protein content as in sea buckthorn seeds is also characteristic of beans, especially soybeans. The amino-acid composition of the total protein of seeds is close to that of reserve proteins of barley, wheat, and corn.

Solonenko et al. [141] first performed electrophoretic analysis of sea buckthorn proteins and determined that reserve proteins of seeds and fruit pulp are highly heterogeneous. Prolamins (alcohol-soluble proteins of sea buckthorn seeds), which are called hippolins, consist of 18-21 components. The fast-migrating zone typical of albumins and globulins contains 30-32 components. The electrophoretic spectrum of pulp proteins is less heterogeneous and consists of 3-12 components, depending on the variety.

Sea buckthorn fruit contains 35 mg of S-methylcysteine per 1 g of fresh fruit; 1 g of seeds, 900 mg of S-methylcysteine and 8000 mg of γ-glutamyl-S-methylcysteine. The determination was carried out on an automated amino-acid analyzer.

Dipeptides were purified by chromatography. Glutamic acid and S-methylcysteine in a 1:1 molar ratio were found in the hydrolysate of pure peptides.

Seeds of *E. angustifolia* contain 42% protein [79].

Free amino acids of *E. multiflora hortensis* pericarp contained a rather large amount of aspartic acid, lysine, and proline; seeds, glutamic acid, arginine, asparagine, leucine, and lysine [143, 144].

The amino-acid composition of proteins in seeds of this plant showed a low content of leucine in albumins and of lysine in globulins. The principal acids were arginine and glutamine.

All three plant genera of this family exhibit analogous amino-acid components. *Shepherdia argentea* and five species of *Elaeagnus* have different levels of arginine and glutamic acid. *Hippophae* differs by a high content of arginine and proline compared with the other two genera. Furthermore, all studied species contained unidentified non-protein amino acids that, according to the literature, are characteristic for Elaeagnaceae [140].

FLAVONOIDS (CATECHOLS, LEUCOANTHOCYANS, FLAVONOLS, PHENOLCARBOXYLIC ACIDS) (Table 6)

Sea buckthorn fruit grown at various locations contains from 37 to 709 mg% flavonols [35, 44, 45, 48, 177, 178, 179], 54.6-563.27 mg% catechols [44, 45, 48], 16-497.5 mg% leucoanthocyans [44, 45, 48], and 130-172 mg% chlorogenic acids [35, 45].

Recent data indicate that geographic location affects not only the quantity of polyphenols in sea buckthorn fruit but also the quality [46, 180].

Leucoanthocyans dominate the flavonoids in sea buckthorn fruit; flavonols, in the leaves [138, 181].

The dynamics of flavonol composition in sea buckthorn have been studied [182]. In green fruits of 2 mm in length, one glycoside was observed. As the fruit ripens, the number of flavonols increases to six. In young leaves (when the fruit is green), five glycosides are found. Their number decreases as the plant grows. The composition of these compounds is the same in male and female plants.

Leaves and flowers of *Elaeagnus* plants give a strong reaction for flavonoids [183]. From four (flowers) to eight (leaves, fruit) flavonoids are detected in various parts.

The polyphenol content in oleaster fruit pulp decreases markedly during ripening [184].

P-vitamins are known to be very effective for increasing the activity of ascorbic acid. The presence of both these substances, which are synergistic in animals, increases the value of these plants as polyvitamin sources.

ALKALOIDS

Screenings for alkaloids in this plant family generated ambiguous results. Certain studies that used general precipitation did not detect alkaloids in the aerial part of *S. canadensis* [185], *E. angustifolia*, and *E. orientalis* and the aerial and subterranean parts of *H. rhamnoides* [186].

Alkaloids were observed by using TLC on the principal fractions from various organs of certain Elaeagnaceae species [187].

The widely distributed genus *Elaeagnus* (*E. angustifolia*, *E. hortensis*, *E. orientalis*, and *E. spinosa*) is the richest in these substances [188]. The alkaloids are concentrated mainly in the root bark and the aerial part [187, 189]. The alkaloid elaeagnin, the structure of which was shown to be tetrahydroharman, was isolated from bark of *E. angustifolia* [188, 190, 191]. Recently the bark of this plant yielded tetrahydroharmol, N-methyltetrahydroharmol [192], harman [193], dihydroharman and 2-methyl-1,2,3,4-tetrahydro-β-carboline [194], harmine and harmol [187].

A search for active compounds in aqueous and ethanol extracts of sea buckthorn bark discovered various experimental antitumor agents such as serotonin or 5-hydroxytryptamine (5-hydroxy-3-β-aminoethylindole). Its content was 0.3-0.4%, which is much greater than in other plants [195]. This alkaloid was also found in stems, leaves, sea buckthorn juice [196, 197] and in *E. umbellata* leaves [198].

TABLE 6. Polyphenols of Plants of the *Elaeagnaceae* Family

Compound	Plant	Plant part	Reference
Catechols:			
(-)-epicatechol	*H. rhamnoides*	Fruits	[44, 145]
		Leaves	[146]
	E. glabra	Bark	[147]
	E. angustifolia	Bark	[148]
(+)-catechol	*E. angustifolia*	Bark	[148]
(+)-gallocatechol	*H. rhamnoides*	Leaves	[146]
(-)-epigallocatechol	*H. rhamnoides*	Fruits	[44]
		Leaves	[146]
	E. glabra	Bark	[147, 149, 150]
(+)-gallocatecholgallate	*H. rhamnoides*	Leaves	[146]
(-)-epicatecholgallate	*H. rhamnoides*	Leaves	[146]
(-)-gallocatechol	*H. rhamnoides*	Fruits	[44]
Phenolcarboxylic acids:			
caffeic acid	*E. angustifolia*	Leaves	[148]
		Fruits	[151]
	E. argentea	Leaves	[152, 135]
	E. montana	Leaves	[152, 135]
	E. multiflora	Leaves	[152, 135]
	E. umbellata	Leaves	[152, 135]
	S. argentea	Leaves	[152, 135]
	H. rhamnoides	Leaves	[152, 135]
chlorogenic acid	*H. rhamnoides*	Pulp, juice, seeds, leaves, flowers	[35]
		Fruits	[145]
	E. argentea	Leaves	[152]
	E. montana	Leaves	[152]
	E. multiflora	Leaves	[152]
	E. umbellata	Leaves	[152]
	S. argentea	Leaves	[152]
neochlorogenic acid	*E. angustifolia*	Leaves	[152]
gallic acid	*E. angustifolia*	Leaves	[152]
	H. rhamnoides	Roots	[153]
		Leaves	[154]
p-coumaric acid	*E. argentea*	Leaves	[152]
	E. montana	Leaves	[152]
	E. multiflora	Leaves	[152]
	E. umbellata	Leaves	[152]
	S. argentea	Leaves	[152]
	H. rhamnoides	Leaves	[152]
sinapic acid	*E. montana*	Leaves	[152]
	E. multiflora	Leaves	[152]
	E. umbellata	Leaves	[152]
	S. argentea	Leaves	[152]
	H. rhamnoides	Leaves	[152]
	E. orientalis	Leaves	[155]
	E. argentea	Leaves	[152]
ferulic acid	*E. montana*	Leaves	[152]
	E. multiflora	Leaves	[152]
	E. umbellata	Leaves	[152]
	S. argentea	Leaves	[152]
	H. rhamnoides	Leaves	[152]
	E. argentea	Leaves	[152]

TABLE 6. (continued)

Compound	Plant	Plant part	Reference
	E. orientalis	Leaves	[155]
ellagic acid	*E. argentea*	Leaves	[152]
	E. montana	Leaves	[152]
	E. multiflora	Leaves	[152]
	E. umbellata	Leaves	[152]
	S. argentea	Leaves	[152]
	H. rhamnoides	Leaves	[152]
protocatechoic acid	*E. argentea*	Leaves	[152]
	E. montana	Leaves	[152]
	E. multiflora	Leaves	[152]
	E. umbellata	Leaves	[152]
	S. argentea	Leaves	[152]
	H. rhamnoides	Leaves	[152]
gentisinic acid	*E. argentea*	Leaves	[152]
	E. montana	Leaves	[152]
	E. multiflora	Leaves	[152]
	E. umbellata	Leaves	[152]
	S. argentea	Leaves	[152]
	H. rhamnoides	Leaves	[152]
p-hydroxybenzoic acid	*E. argentea*	Leaves	[152]
	E. montana	Leaves	[152]
	E. multiflora	Leaves	[152]
	E. umbellata	Leaves	[152]
	S. argentea	Leaves	[152]
	H. rhamnoides	Roots	[153]
syringic acid	*E. argentea*	Leaves	[152]
	E. montana	Leaves	[152]
	E. multiflora	Leaves	[152]
	E. umbellata	Leaves	[152]
	S. argentea	Leaves	[152]
	H. rhamnoides	Leaves	[152]
Flavonoids:			
isorhamnetin(3,5,7,4-tetrahydroxy-3-methoxyflavone)	*H. rhamnoides*	Leaves	[154-156]
		Fruits	[148, 155, 157, 158, 159, 161]
		Flowers	[158-160]
		Pulp	[161-163]
		Juice	[164]
	E. angustifolia	Fruits	[151]
isorhamnetin-3-O-β-D-galactopyranoside	*E. angustifolia*	Fruits	[151]
isorhamnetin-3-D-gluco-D-galactoside	*E. angustifolia*	Leaves	[165]
isorhamnetin-3-D-gluco-D-galactoferuloyl	*E. angustifolia*	Leaves	[165]
isorhamnetin-3-rhamnoglucorhamnoside	*E. angustifolia*	Leaves	[165]
isorhamnetin-3-gluco-7-rhamnoglucoside	*E. argentea*	Leaves	[166]
isorhamnetin-3-glucoferuyl-7-rhamnoglucoside	*E. argentea*	Leaves	[166]
isorhamnetin-3-diglucoside	*E. argentea*	Leaves	[166]
isorhamnetin-3-β-rutinoside	*H. rhamnoides*	Juice	[167]
isorhamnetin-3-rutinoside	*H. rhamnoides*	Fruits	[44, 145, 147, 168]
isorhamnetin-3-O-rutinoside	*H. rhamnoides*	Fruits	[148]
isorhamnetin-3-β-sophoroside-7-α-L-rhamnoside	*H. rhamnoides*	Fruits	[169]
isorhamnetin-3-O-β-glucopyranosyl(6$\rightarrow$1)-O-α-Z-rhamnopyranoside (narcissin)	*H. rhamnoides*	Fruits	[158, 168]

TABLE 6. (continued)

Compound	Plant	Plant part	Reference
isorhamnetin-3-O-β-D-glucopyranoside	*H. rhamnoides*	Fruits	[158, 168]
		Pulp	[148]
isorhamnetin-3-(O-β-D-glucopyranosyl)-7-O-α-L-rhamnopyranoside	*H. rhamnoides*	Fruits	[158, 168]
isorhamnetin-3[O-β-D-glucopyranosyl-(7)-O-α-L]-rhamnopyranoside diglycoside	*H. rhamnoides*	Leaves	[170]
isorhamnetin-3-glucoside	*E. argentea*	Leaves	[166]
	H. rhamnoides	Fruits	[150]
		Juice	[167]
3-β-D-isorhamnetin glucoside	*H. rhamnoides*	Fruits	[44, 145, 147, 148]
		Pulp	[168]
isorhamnetin 7-rhamnosido-3-glucoside	*H. rhamnoides*	Fruits	[145]
isorhamnetin 3-β-D-glucoside-7-α-L-rhamnoside	*H. rhamnoides*	Fruits	[169]
isorhamnetin-3-β-D-glucofuranosido-6-β-D-glucopyranoside	*H. rhamnoides*	Leaves	[162]
isorhamnetin-3-O-β-D-glucopyranosido[2→1]-β-D-glucopyranoside	*H. rhamnoides*	Production wastes	[168]
isorhamnetin-7-rhamnoside-4-glucoside	*H. rhamnoides*	Fruits	[44]
isorhamnetin-3-rhamnoglucoside	*H. rhamnoides*	Fruits	[150]
kaempferol	*H. rhamnoides*	Leaves, fruits	[148, 154]
kaempferol 7-*p*-coumaroyl-3-β-D-glucoside	*E. angustifolia*	Leaves	[165]
	E. argentea	Leaves	[166]
kaempferol 3-glucoside	*E. argentea*	Leaves	[166]
kaempferol-3-β-D-glucopyranoside (astragalin)	*H. rhamnoides*	Leaves	[156]
	E. angustifolia	Leaves	[165]
kaempferol 3-O-β-D-glucosido-4′-*p*-coumaroyl-7-O-β-D-acylgalactoside	*E. angustifolia*	Leaves, flowers	[171]
kaempferol oligoside	*H. rhamnoides*	Juice	[167]
quercetin	*H. rhamnoides*	Leaves	[154]
		Fruits	[148, 157, 172, 173]
		Production wastes	[148]
quercetin-3-β-D-glucopyranoside (isoquercetrin)	*H. rhamnoides*	Leaves	[162]
		Production wastes	[148]
quercetin-3-galactoglucoside	*H. rhamnoides*	Leaves	[162]
quercetin-7-O-rhamnoside	*H. rhamnoides*	Fruits	[148]
		Wastes	[168]
quercetin 3-O-methyl ester	*H. rhamnoides*	Fruits	[148]
		Wastes	[168]
quercetin oligoside	*H. rhamnoides*	Juice	[167]
myricetin	*H. rhamnoides*	Leaves	[154, 158]
		Fruits	[173]
		Wastes	[168]
rutin (5,7,3′,4′-tetrahydroxyflavon-3-β-D-rutinoside)	*H. rhamnoides*	Fruits Grist	[147, 148, 168, 157, 158, 163]
eleagnoside	*E. angustifolia*	Leaves	[168]
		Flowers	[174, 175]
Leucoanthocyans:			
leucocyanidin	*H. rhamnoides*	Leaves	[176]
leucodelfinidin	*H. rhamnoides*	Leaves	[176]
peonin	*H. rhamnoides*	Juice	[161]

Other β-carboline alkaloids were found in *E. commutata* root bark: 1-isobutyl-1,2,3,4-tetrahydro-β-carboline [199] and 6-hydroxy-2′-(2-methylpropyl)-3,3′-spirotetrahydropyrrolidinohydroxyindole, the structure of which was confirmed by x-ray diffraction analysis [193].

Use of labeled compounds established that 1-methyl-1,2,3,4-tetrahydro-β-carboline-1-carboxylic acid is the precursor to β-carboline alkaloids in *E. angustifolia* [200].

In 1967, a report on the isolation from sea buckthorn of an alkaloid belonging to the 1-methyl-β-carboline group appeared [201]. Harmaline and harman were present in all studied organs (bark, leaves, fruit).

Root bark of *S. argentea* and *S. canadensis* yielded N,O-diacetyltetrahydroharmol, its isomer called shepherdine, and tetrahydroharmol [32].

Thus, plants of the Elaeagnaceae family are distinguished by the presence of β-carboline alkaloids concentrated mainly in the root bark and aerial part. Therefore, it seems promising to search further for indole and β-carboline alkaloids, which can be synthesized by condensation of tryptophane (tryptamine) and a C_5-terpene.

VITAMINS

The vitamin content of sea buckthorn has been studied most. The speciation of this plant is slightly varied. Nevertheless, it has many forms owing to environmental factors and inherited features.

Vitamin C. Sea buckthorn surpasses many other fruit and berry crops in ascorbic acid content and is recognized as one of the most valuable natural sources of vitamin C. However, this property of sea buckthorn is highly variable. The vitamin content of various forms in natural groves varies significantly.

The vitamin C content is known to vary significantly with the seasons. Therefore, the determined amount varies significantly for various collection times. A study of the seasonal dynamics [202] indicated that the vitamin C content increases before August and then decreases. The situation is the same in fruit from plants of the *Elaeagnus* genus. Thus, the ascorbic acid content in fruit of *E. multiflora var. gigantea* and *E. umbellata* decreases from the beginning to the end of ripening from 5 to 2 and from 10 to 3 mg%, respectively [39]. A drop in the vitamin C level with ripening is unusual for the majority of known fruits.

Vitamin C is well preserved in processed sea buckthorn products because the fruit lacks ascorbinoxidase [6]. Ascorbic acid is found in the free form in this plant.

Oleaster fruit contains L-ascorbic acid and dehydroascorbic acid at a maximum of 22 mg%, which also decreases with ripening.

Freshly pressed sea buckthorn juice contains from 120 to 544 mg% [35, 41, 70, 203-209] vitamin C; leaves, from 127 [35] to 503 mg% [202] (maximum occurs at the beginning of August and then decreases, as in the fruit); seeds and flowers [35], 92 and 86 mg%, respectively.

Furthermore, the vitamin C content in sea buckthorn bark was determined [210]. It was found that it varies with the elevation: 500, 375, 916, and 904 mg% at 500, 800, 1000, and 1300 m above sea level.

Fruit of *S. argentea Nutt* [38] contains up to 250 mg% of ascorbic acid.

Carotenoids (provitamin A). Fruit pulp of all known forms and varieties of sea buckthorn contains carotenoids, the content of which varies widely depending on the climate during the vegetative period. Warm sunny weather with moderate precipitation favors the accumulation of carotenoids. The carotenoid content in fruit varies from 0.16 to 20.79 mg% in fresh fruit [34, 37, 44, 45, 47, 49, 53, 61, 63, 211-214], from 8.0 to 425 mg% in dry fruit [48, 50, 51, 54, 55, 215, 216]. Fresh fruit contains 1.7-14.7 mg% carotenes, especially β-carotene [43, 48, 57, 172, 211, 216]; dry fruit, 26.5-137.5 mg% carotenes, which is 19.3-36.9% of the total carotenoids [50].

Carotenoids are fat-soluble and concentrate in the fruit oil. Only traces occur in the juice [34, 41]. Oil of fruit pulp contains 168-1089 mg%. Storage for three months decreases the amount of carotenoids by about three times [35, 37, 51, 52, 62, 63, 65, 73, 76]. Seed oil contains 5.0-38.1 mg% [52, 76]; leaves, 368-900 mg% [35, 67, 97, 217]. Grist from sea buckthorn production contains 10.2-40 mg% carotenoids [36, 192].

The level of carotenoids increases as the fruit ripens. The widespread belief that red fruit contains more carotenoids than yellow fruit has been disproved [71]. The array of carotenoids cannot be determined from the color of the fruit. Sea buckthorn fruit pulp, like the leaves, is the genetic material of the plant. At the cellular level, chloroplasts of the leaves and pulp have a common origin. Therefore, a genetically derived relationship between the content of pigments in the fruit and leaves is assumed. This was confirmed [218]. The greater the carotenoids in the leaves, the more in the fruit.

Carotenoids with the α- and β-ionone structures are found in the leaves, flowers, and green fruit. β-Ionone carotenoids predominate in ripe fruit [212]. According to the literature [213], 48% of the total carotenoids are those exhibiting A-provitamin activity (β-carotene, β-zeacarotene, γ-carotene, cryptoxanthin, sintaxanthin). Of these, greater than 50% are the biologically active β-carotene and cryptoxanthin.

Savinov and Protsenko [219] first determined the qualitative composition of carotenoids in sea buckthorn pericarp. They found α- and β-carotenes, zeaxanthin, and lycopin. Subsequent investigations lengthened the list of identified carotenes to 41: α-carotene, β-carotene, neo-β-carotene, δ-carotene, α-cryptoxanthin, γ-carotene, isocryptoxanthin, β-cryptoxanthin, lutein, zeaxanthin, lycopin, flavoxanthin, eloxanthin, violaxanthin, β-zeacarotene, prolycopin, mutatochrome, taraxanthin, sintaxanthin, lycophyll, escholtzxanthin, luteoxanthin, *cis*-luteoxanthin, capsanthin, auroxanthin, trollichrome, poly-*cis*-lycopin-3, hydroxy-α-carotene, neurosporin, lutein-epoxide, anteraxanthin, *cis*-violaxanthin, *cis*-trollixanthin, trollixanthin, pro-γ-carotene, gazaniaxanthin, rubixanthin, citranoxanthin, tangeraxanthin, lycoxanthin, and cantaxanthin [35, 37, 65, 211-213, 216, 220, 221].

With respect to the other two representatives of the family, fruit of *S. argentea* is known to contain 1.3 mg% carotene [38]. Compared with several varieties of sea buckthorn fruit, shepherdia was enriched in β-carotene [220]. The unsaponified lipid fraction of oleaster fruit contained 9.8 mg% carotenoids [70].

The principal carotenoids in *S. canadensis* according to PMR, mass spectrometry, and physicochemical properties in addition to directed synthesis are lycopin and methyl-apo-6′-lycopinoate.

Tocopherols (vitamin E). Total tocopherols in sea buckthorn fruit is 1.42-50 mg% [37, 49, 63, 222], fruit pulp, 2.9-18.4 mg/100 g [35, 223], leaves, 0.79 mg% (7.9 μg/100 g) [35], flowers, 1.4 mg% (14 μg/100 g) [35], seeds, 4.7 mg% (47 μg/100 g) [35]. Wastes from sea buckthorn oil production have the following contents: dry pulp, 28 mg% tocopherols [37], CO_2-extract of this pulp, 455 mg% [224, 225], grist, 17.5 mg/kg [69].

Sea buckthorn fruit oil contains from 60 to 330.4 mg% tocopherols [35, 63, 80, 127, 142]; pulp oil, from 103.0 to 154 mg% [35, 37, 52]; seed oil, from 113.3 to 260 mg% [35, 52, 80]; juice oil, 300 mg% [65]; leaves lipids, 96.3 mg% [35].

Total tocopherols in oil produced at the Biisk vitamin plant by extraction of sea buckthorn fruit with sunflower oil is 200 mg%. According to GLC on QF-1, the composition is 51% of the physiologically most active α-tocopherol, 37% of δ-, and 12% of γ-tocopherols, which are antioxidants [83, 226]. Oil isolated by extraction with solvents has a higher content of tocopherols and contains only trace quantities of γ-tocopherol according to TLC [65].

In addition to the above vitamins, sea buckthorn oil also contains 0.2% of vitamin K [142].

Thus, plants of the Elaeagnaceae family typically have significant contents of vitamins C and E in addition to provitamin A (carotenoids) and are valuable natural sources of these compounds.

MICROELEMENTS

The microelement composition of sea buckthorn has been studied in detail. Juice obtained by pressing fruit contains (mg%) Fe, 2.4; Co, 2.7; Cu, 200.2; and Zn, 813.4 [204] in addition to Mg, Ca, Ti, Al, and Na [196].

The Co content is significantly greater than in other fruit juices; Cu, two times greater than in apricots, strawberries, and red currants. These microelements together with vitamin C are among the necessary components of a healthy diet.

The microelement content in fruit oil and leaves after dry-ashing with conc. H_2SO_4 was determined by x-ray fluorescence analysis. The results were (10^{-4}%) 0.32-0.56, 5.8-9.7, 12-19, and 41-73 for Fe, Co, Cu, and Zn, respectively, in sea buckthorn oil and 0.001-0.004, 10-58, 45-60, and 69-187 in leaves.

Leaves of the sea buckthorn subspecies *maritima* [228] contain Ca (1.2%), K (0.7%), Mg (0.15%), and a trace of Na.

Therefore, the undisputed leader in microelement content is juice and then leaves of sea buckthorn.

We think that these microelements play a definite role in tissue regeneration and restoration of normal substance exchange in the organism.

ESSENTIAL OIL

Fresh sea buckthorn fruit contains about 36 mg of essential oil per kg [229]. We found 60 components by GC-MS. They included several aliphatic esters (ethylhexanoate, 3-methylbutyl-3-methylbutanoate, 3-methylbutylhexanoate, 3-methylbutylbenzoate, 3-methylbutyloctanoate) and 3-methylbutanoic acid.

Essential oil of fruit of the sea buckthorn subspecies *sinensis Rousi* [230] contains >80 components including alkanes, alkenes, aldehydes, acetals, ketones, esters, terpenoids, and the new natural component 1,1-diethoxy-*n*-tetradecane. The principal components are *n*-tetradecanal and *n*-hexadecanal.

Essential oil in flowers of *E. angustifolia* makes up 0.1 mass % of the raw material [231]. Capillary GC-MS revealed 85 components, 47 of which (totaling 96.5%) were identified. The principal component is *trans*-ethylcinnamate, the content of which is 78.88 mass % [232].

CONCLUSION

The literature and our research on the chemical composition of plants of the Elaeagnaceae family suggest the conclusion that plants of this family are rich in water- and fat-soluble vitamins, flavonoids, carbohydrates, valuable proteins that contain all proteinaceous amino acids, alkaloids, and biologically active lipids.

Continuing research on the chemical composition and pharmacological activity of various classes of compounds in addition to regularly scheduled international conferences and symposia devoted to these areas confirm that interest in these plants remains high [233-236].

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